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Detection Technology for IVHS

Volume I: Final Report

Research and Development
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
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FOREWORD

This report presents the results of a comprehensive study to measure the laboratory and field performance of commercial vehicle detectors under different traffic conditions on freeways and surface-street arterial sites. The detectors were installed in three states having diverse climates ranging from cold winter and snow in Minneapolis, Minnesota; humidity, rain, lightning, and heat in Orlando, Florida; warm, dry weather in Phoenix and Tucson, Arizona; and hot summer temperatures with thunderstorms in Phoenix. IVHS traffic parameter specification were developed for interconnected intersection control, isolated intersection control, freeway incident detection, traffic data collection, real time adaptive control and vehicle-roadway communications. This report assesses the best performing detector technologies by application.

Sufficient copies of the report are being distributed to provide a minimum of two copies to each FHWA regional and division office, and five copies to each State highway agency. Direct distribution is being made to division offices.

A. George Ostensen

A. George Ostensen, Director
Office of Safety and Traffic Operations
Research and Development

NOTICE

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16. Abstract

This project identified traffic parameters and their required accuracies for characterizing traffic flow in conventional and newer intelligent transportation systems (ITS), obtained state-of-the-art detectors and installed and evaluated them in three states having diverse climates, and studied the need and feasibility of establishing a national detector evaluation facility. Task A was devoted to identifying traffic parameters and accuracies. Task B dealt with locating surface-street and freeway test and evaluation sites in Minnesota, Florida, and Arizona. Task C developed the test plans used to evaluate the detectors at Hughes and in Los Angeles before they were evaluated in the other states. Task D explained how the detectors to be evaluated were selected and then compiled specifications about detectors currently on the market. In Task E, detector setup and operation were studied as tests were performed according to the plans of Task C. Task F developed the plans and specifications for evaluating the detectors at the surface-street and freeway sites in each of the three states. Detector mounting, power availability, data recording, ground truthing, and security were addressed. Task G consisted of setting up the test sites and collecting detector performance data. The collected data were reduced as part of Task H. In Task I, the performance of the detectors was compared to the specifications developed in Task A. Task J discussed the need and feasibility of establishing permanent detector test facilities. A consensus appears to be developing for such a facility, with several universities and agencies vying for its operation. The preparation of the final report was contained in Tasks K and L. The addendum to this final report (FHWA-RD-96-109) contains additional field test results.

This project also used pooled funds from HPR-2(157) titled "Testing and Evaluating Traffic Detectors." The states which participated are Colorado, Florida, Iowa, Maryland, Minnesota, Missouri, Nebraska, New York, Oklahoma, Oregon, Virginia, and Wisconsin.

17. Key Words
Detection Technology, Detectors, Sensors, ITS, Microwave, Infrared, Video Image Processing, Ultrasound, Inductive Loops, Magnetometers, Presence, Speed, Occupancy

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Many people and organizations contributed to the success of this project. We feel fortunate to have had the generous support and expertise from several city and state departments of transportation. The Minnesota Department of Transportation (DOT) was instrumental in getting the project started correctly by supplying not only cables, equipment mounting racks, and power supplies, but indispensable knowledge of how to label, wire, and keep track of the hundreds of wires required to send power to the detectors and transmit information from them to the data logger. We followed the plans they developed at all of the test locations. The City of Minneapolis was a warm host to us as well during the Winter of 1993. They cut loops in their streets, cored holes for our magnetometers, and provided us with a test site not far from the best rib joint we found during the project. Our contacts and support in Minnesota were through Jim Wright, Ping Yi, Dave Long, and Tim Bangsund.

The Florida DOT helped us set up a unique test site along the I-4 corridor into Orlando where the same data acquisition trailer location was used for freeway and surface arterial detector evaluation. We simply moved the detectors from the freeway below to the overpass above when we were ready to switch highway types. In addition to the usual cutting of loops and coring for magnetometers, they designed a chain-link fence protective screen to shield our detectors from inquisitive onlookers. They also provided an out-of-the-ordinary technique for mounting the self-powered magnetometers under the overpass so that the vehicles above could be counted. Our Florida coordination was through George Gilhooley and Jon Cheney, with support from Steve Hull, Don Carmer, Mark Candella, and Larry Gross.

With the aid of the Arizona DOT, we selected a test site on the west side of the I-10 freeway in downtown Phoenix. We didn't use the pipe tree to support the overhead detectors at this site, but instead mounted them directly on the sign-bridge structure that spanned the westbound lanes. The cat-like ability and the fearlessness of the DOT personnel were greatly appreciated during this adventure. The Arizona DOT personnel who supported the project were Dan Powell, Sarath Joshua, Jim Shea, Larry Cummings, Andy Murray, and Sam Stubbs.

Not to be out done, the City of Tucson Department of Transportation provided a test location across the street from the largest shopping mall in the area. Only at this site did we bury our cable run from the signal mast arm and pole to the data acquisition trailer. After warding off prairie dogs and water from a spring storm, we got the detectors operating. Once more, the technicians made available to the project by the city were outstanding in their willingness and ability to aid us in mounting and diagnosing any problems with the detectors. Our appreciation is extended to Dennis Sheppard, Ray Svec, John Swanson, and Edwin Daugherty for arranging for the support of the city and assisting us in connecting and aiming the detectors.

The research division at FHWA provided an ideal technical representative. The project would not have been as successful without his many thought-provoking comments and suggestions and his general support. The efforts of the contracting officer to keep the proverbial checks in the mail were certainly appreciated. We are also indebted to the FHWA Program Manager for establishing the need for a project of this type and for his continued support throughout its many phases.

Don Savitt of Hughes Aircraft Company had the foresight to develop the strategy that led to the winning of this contract. With the assistance of JHK and Associates, we were able to develop a team that understood the need for acquiring accurate traffic parameter data and could develop methods for acquiring them. Many people at JHK helped develop one of the major outputs of the project, the Task A Report *Development of IVHS Traffic Parameter Specifications*. In particular, Scott MacCalden, Jr. and Craig Gardner provided the insights that are incorporated in the document.

Rick Anderson of Hughes and Steven Birch of Iron Mountain Systems designed the hardware and software used in the data logger to acquire and convert the detector output data into a user-friendly database format. Their expertise was instrumental in being able to simultaneously record and time-tag data from the approximately 20 detectors that represented the technologies under evaluation.

There is one more person to whom the project owes a great debt, Michael Kelley. As a key participant in the installation, data acquisition, and data analysis tasks, his contributions are priceless. He displayed his enthusiasm by spending long weeks and days in the field, getting up before sunrise and retiring after dark to make sure that the necessary data were recorded. With the encouragement of the Principal Investigator, he helped seek out the best ribs in each city we visited.

Lawrence A. Klein
Principal Investigator

PREFACE

The *Detection Technology for IVHS* project, under Federal Highway Administration Contract DTFH61-91-C-00076, began in September 1991 and continued through April 1995. In the first part of the project, parameters used in characterizing traffic flow for conventional traffic control systems and for newer Intelligent Vehicle-Highway Systems (IVHS) applications were identified. IVHS applications may place higher accuracy requirements on traffic parameters measured by detectors and may also require the acquisition of traffic data not normally output by the more conventional detectors. The traffic parameter data accuracies developed for IVHS applications are based on available operational test data, traffic control algorithms, and performance prediction analyses. Even though an extensive effort was made to acquire traffic data accuracy requirements, there was not a great deal of this information available. We expect that the accuracies given in this report will be updated as new control algorithms and information continue to be developed.

Detector manufacturers were contacted to determine if they would make their devices available to the program. A cross section of detectors that represented different technologies were obtained, including inductive loop with conventional and high sampling rate detector amplifiers, magnetometers with relatively small detection zones, magnetometer arrays with large multilane detection zones, microwave radar, laser radar, ultrasound, acoustic microphone arrays, passive infrared, imaging infrared, and video image processing.

In the next part of the project, laboratory test plans were developed and tests were conducted for detectors that would eventually be exposed to diverse environmental and traffic conditions during the field tests. The laboratory tests demonstrated the operation and capabilities of the detectors and their limitations. These tests were performed at Hughes Aircraft Company facilities in Fullerton, CA and by the City of Los Angeles Department of Transportation on Exposition Boulevard in Los Angeles.

Once the laboratory tests were completed, the detectors were installed in three states having diverse climates that ranged from cold winter and snow in Minneapolis; humidity, rain, lightning, and heat in Orlando; warm, dry weather in Phoenix and Tucson; and hot summer temperatures with thunderstorms in Phoenix. A freeway and a surface-street arterial site were used sequentially in each state. The tests were conducted according to a test plan that described the mounting of the detectors, their power requirements, test patterns, data acquisition and reduction, ground truth procedures, and security at the test sites.

The recorded data were processed using application-specific software designed for each detector. This resulted in a database being created that contained the normal outputs from the detector when a vehicle passed through its field of view, the time of the event, videotape index number, and air temperature and wind speed and direction. By using the video index number, a specific event can be accessed and reviewed on a computer-controlled video recorder.

The feasibility of establishing a national detector evaluation facility was also studied. Letters were sent to the detector manufacturers and several universities soliciting their inputs and thoughts about such a center.

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

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1. SCOPE OF THE PROGRAM

1.1 INTRODUCTION

Maximizing the efficiency and capacity of the existing transportation network is made necessary by the continued increase in traffic volume and the limited construction of new highway facilities in urban, intercity, and rural areas. Smart street systems that contain traffic monitoring detectors, real-time adaptive signal control systems, and motorist communications media are being combined with freeway and highway surveillance and control systems to create smart corridors that increase the effectiveness of the ground transportation network. The infrastructure improvements and new technologies are, in turn, being married to smart cars to form Intelligent Vehicle-Highway Systems (IVHS). Since the inception of this contract, Intelligent Transportation Systems (ITS) has replaced IVHS to represent the marriage of smart vehicles with smart infrastructure systems. As IVHS is included in the contract title, it is retained in this report.

Vehicle detectors are an integral part of nearly every modern traffic control system. Moreover, detectors and communications media will be major elements in future traffic monitoring systems. The types of traffic flow data, their reliability, consistency, accuracy, and precision and detector response time are some of the critical parameters to be evaluated when choosing a vehicle detector. These attributes become even more important as the number of detectors proliferate and the real-time control aspects of IVHS put a premium on both the quantity and quality of traffic flow data used in traffic surveillance and control algorithms.

Current vehicle detection is based predominantly on inductive loop detectors installed in the roadway subsurface. When properly installed and maintained, they can provide real-time data and a historical database against which to compare and evaluate more advanced detector systems. Alternative detector technologies being developed provide direct measurement of a wider variety of traffic parameters, such as density, travel time, vehicle path, volume, and speed. These advanced detectors provide more accurate data; parameters that are not directly measured with previous instruments; inputs to area-wide surveillance and control of signalized intersections and freeways; and support of motorist information services. Furthermore, many of the advanced detector systems can be installed and maintained without disrupting traffic flow.

1.2 PURPOSE OF THE PROJECT

The objectives of the Federal Highway Administration (FHWA)-sponsored *Detection Technology for IVHS* project are to:

- Determine the traffic parameters and their corresponding accuracy specifications needed for future IVHS applications;
- Perform laboratory and field tests with detectors that apply technologies compatible with above-the-road, surface, and subsurface mounting to determine the ability of state-of-the-art detectors to measure traffic parameters with acceptable accuracy, precision, and repeatability;
- Determine the need and feasibility of establishing permanent vehicle detector test facilities.

In performing the technology evaluations and in analyzing the data, focus was placed on the underlying technology upon which the detectors were based. It was not the purpose of the program to determine which specific detectors met a set of requirements, but rather whether the sensing technology they used had merit in measuring and reporting traffic data to the accuracy needed for present and future applications. Obviously, there can be many implementations of a technology, some of which may be better exploited than others at any time. Thus, a technology may show promise for future applications, but the state-of-the-art of current hardware or software may be hampering its present deployment.

The project consisted of 12 major tasks:

Task A. Develop a working paper that defines IVHS traffic parameter specifications for the following application areas:

- Interconnected Intersection Control,
- Isolated Intersection Control,
- Freeway Incident Detection,
- Traffic Data Collection,
- Real-Time Traffic Adaptive Control,
- Vehicle-Roadway Communications.

Task B. Select sites for detector field tests. Test sites in three different regions of the country will be selected to provide a range of environmental and traffic conditions broad enough to ensure the utility of the test results on a nationwide basis.

Task C. Develop vehicle detector laboratory test specifications and a laboratory test plan.

Task D. Select and obtain vehicle detectors for testing.

Task E. Conduct laboratory detector tests and generate a report describing the results.

Task F. Develop vehicle detector field test specifications and field test plan.

Task G. Install vehicle detectors at field test sites and collect detection technology evaluation data.

Task H. Generate detection technology field test results.

Task I. Determine which of the currently available vehicle detectors meet the IVHS criteria of Task A.

Task J. Determine the need and feasibility of establishing permanent vehicle detector test facilities.

Task K. Prepare a draft final report.

Task L. Prepare the final report that incorporates comments received from FHWA and others.

1.3 ORGANIZATION OF THE FINAL REPORT

The final report documents the planning and the conclusions of the *Detection Technology for IVHS* program that ran from September 1991 through January 1995.

Section 1 contains an introduction to the project that outlines the various tasks that were included in the program and the contents of the final report.

Section 2 summarizes Task A by including descriptions of traffic parameters needed to characterize free flow and interrupted flow on freeways and surface streets. The accuracies of the parameters for several future IVHS applications are summarized in tables at the end of the section. The accuracies represent those needed for input data to as yet undefined future algorithms and paradigms that support the selected applications. As such, they are subject to revision as the specific algorithms, strategies, and applications become better known.

Section 3 describes the field test and evaluation site locations that were visited. The information for this section is taken from the Task B Report.

Section 4 discusses the detector selection process using information in the Task D Report. On-bench photographs of each detector and manufacturer's specifications are given.

Section 5 describes the theory of operation of the detector technologies and the types of information typically available from each. These technologies include those for above-the-road mounted detectors, namely video image processing, microwave, active (transmit and receive) and passive (receive only) infrared, imaging infrared, passive acoustic arrays, and ultrasound, as well as those for conventional and newer applications of beneath-the-surface inductive loop, magnetic, and magnetometer detectors. Communications technologies, such as those used for automatic vehicle identification, are also discussed.

Section 6 reviews the Task C report by explaining the need for laboratory tests before venturing out for field tests and by describing the types of laboratory tests conducted.

Section 7 summarizes the results from the laboratory tests that were originally published in the Task E reports. These tests were conducted in the City of Los Angeles and at the Hughes Aircraft Company facility in Fullerton, CA.

Section 8 contains a summary of the Task F field test plan and procedures. Detector installation requirements are listed. The data logger hardware and software that played a major role in the data acquisition are discussed in this section and in Appendix C.

Section 9 describes the detector technology data collection and evaluation processes. Photographs and line drawings of the field sites with the installed detectors and the detector locations are shown. The data analysis process of converting the raw data files into Paradox database format is explained as are the ground truth procedures. Tabulations of the amount of data collected at each site are given.

Section 10 describes how to access the data storage media, presents the analyzed detector output data from several runs at each test site, and interprets the results. Not all the collected data have been analyzed as a part of this phase of the project. However, representative data have been plotted to show the types of results and analyses that can be performed on the extensive data set.

Section 11 compares the detector specifications for future IVHS applications developed in Section 2 with the performance of the presently available detectors. The accuracies of the detectors that were evaluated and their application to current traffic management areas are summarized. Where possible, recommendations are made as to how to improve the detector design to bridge the gap between the data and accuracy of present detectors and those needed for some specific IVHS applications.

Section 12 gives the general conclusions from the program and makes recommendations for future research.

Appendix A documents the results of Task J, determining the need and feasibility of establishing one or more permanent vehicle detector test facilities.

Appendix B lists the detector manufacturers and contact personnel that provided detectors and information during the evaluation program.

Appendix C describes the data logger hardware and software design and the formats used to record the analog, digital, and serial information output by the detectors in the technology evaluation study.

Appendix D illustrates the concepts involved in designing a continuous wave microwave radar to detect multiple vehicles in a given lane on a roadway.

Appendix E contains the pipe tree installation and intersection plan-view drawings used at the Minneapolis field sites.

Appendix F gives the azimuth and elevation ground footprints of the detectors as a function of mounting height, azimuth and elevation aperture beamwidth, and angle of incidence (with respect to nadir).

Appendix G contains the specifications for the inductive loops installed by the states that hosted the field tests.

Appendix H documents the connections made during the field tests from the detectors to the data logger and power supplies.

Appendix I contains pipe tree installation and selected construction plans for the State Route (SR 436) overpass at Interstate 4 (I-4) that describe the design of the truss for the sign bridge and the design of the SR 436 span over I-4.

Appendix J contains climatological data from the Minneapolis, Orlando-Altamonte Springs, Phoenix, and Tucson field sites as tabulated by the National Oceanic and Atmospheric Administration through the National Climatic Data Center in Asheville, North Carolina.

Appendix K contains listings of the FORTRAN programs that were written to analyze the detector output data.

2. TASK A SUMMARY

DEVELOPMENT OF IVHS TRAFFIC PARAMETER SPECIFICATIONS

A working paper was developed in Task A to define traffic parameter specifications for IVHS applications that include:

- Interconnected intersection control,
- Isolated intersection control,
- Freeway incident detection,
- Traffic data collection,
- Real-time traffic adaptive control, and
- Vehicle-to-roadway communications.

Traffic parameters of value in these applications are described in this section. Projected accuracies for the measurement of the traffic parameters in support of future IVHS applications such as signalized intersection control, freeway incident detection, and freeway metering are then presented.

2.1 TRAFFIC FLOW PARAMETERS

Vehicle flow, speed, and density parameters are fundamental to the management of highway traffic. Over a given section of open roadway, such as a freeway, they are related through equation 2-1 and their values are usually expressed on a per lane basis. Hence,

Flow (vph) = Speed (mi/h) x Density (vpm) (2-1)

where

vph = vehicles per hour per lane,
mi/h= miles per hour, and
vpm = vehicles per mile per lane.

Flow or volume flow rate is the time rate of flow in vehicles per hour used to characterize traffic volume. A transition in terminology is occurring as "flow" or "flow rate" has taken the place of "volume."(1) Because of the mix of old and new terminology, there is some inconsistency in the use of "volume" and "flow rate" in the literature.

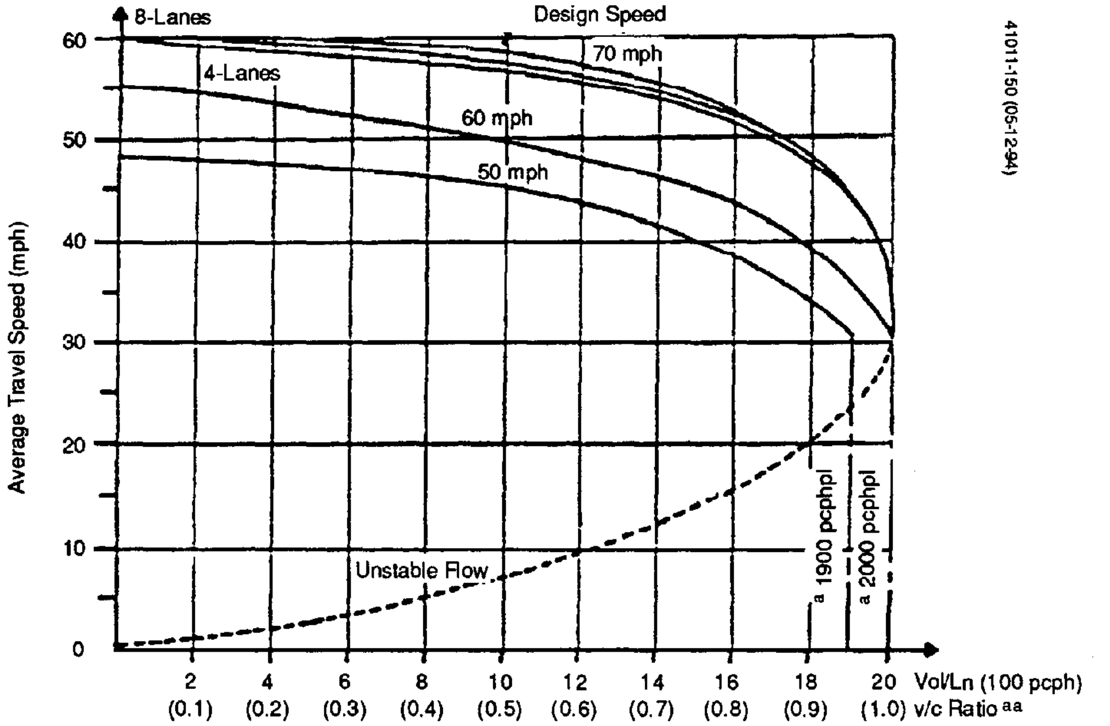
This can be seen in the capacity curves of Figure 2-1 that illustrate the relation between speed and flow on the open roadway. Capacity is expressed as "volume/lane" in units of flow rate (passenger cars per hour). The term "flow" is also used to describe the general condition of traffic on the roadway, such as "free-flow" or "congested flow."(2)

The volume flow rate data by themselves are not sufficient to define how well traffic is moving. For example, if counts show a flow rate of 1200 vehicles per hour, it is not known whether traffic is moving briskly at 55 mi/h (88.5 km/h) or is congested and creeping along at 10 mi/h (16.1 km/h).

On the other hand, by measuring density and knowing the speed-flow characteristic for a given highway type, speed-density and flow-density curves can be estimated as shown in Figures 2-2 and 2-3, respectively. When density is a performance indicator, as shown by the shape of the curve in Figure 2-2, there is no longer any ambiguity with respect to speed. If density is measured at 20 vehicles per mile per lane (32 v/km/lane), then speed is 55 mi/h (88.5 km/h). If density is 120 vehicles per mile per lane (192 v/km/lane), then speed is 10 mi/h (16.1 km/h). Likewise, Figure 2-3 shows that a flow rate of approximately 1200 vehicles per hour per lane (1920 v/h/lane) corresponds to these same density measurements of 20 and 120 vehicles per mile per lane, respectively.

2.2 TRAFFIC PARAMETERS FOR INTERRUPTED FLOW

Flow, speed, and density are used to characterize traffic flows on freeways and other open sections of roadway not affected by control devices such as traffic signals, stop signs, and ramp metering. When interrupted flow conditions are encountered, such as at signalized intersections, other traffic flow characteristics appear and additional

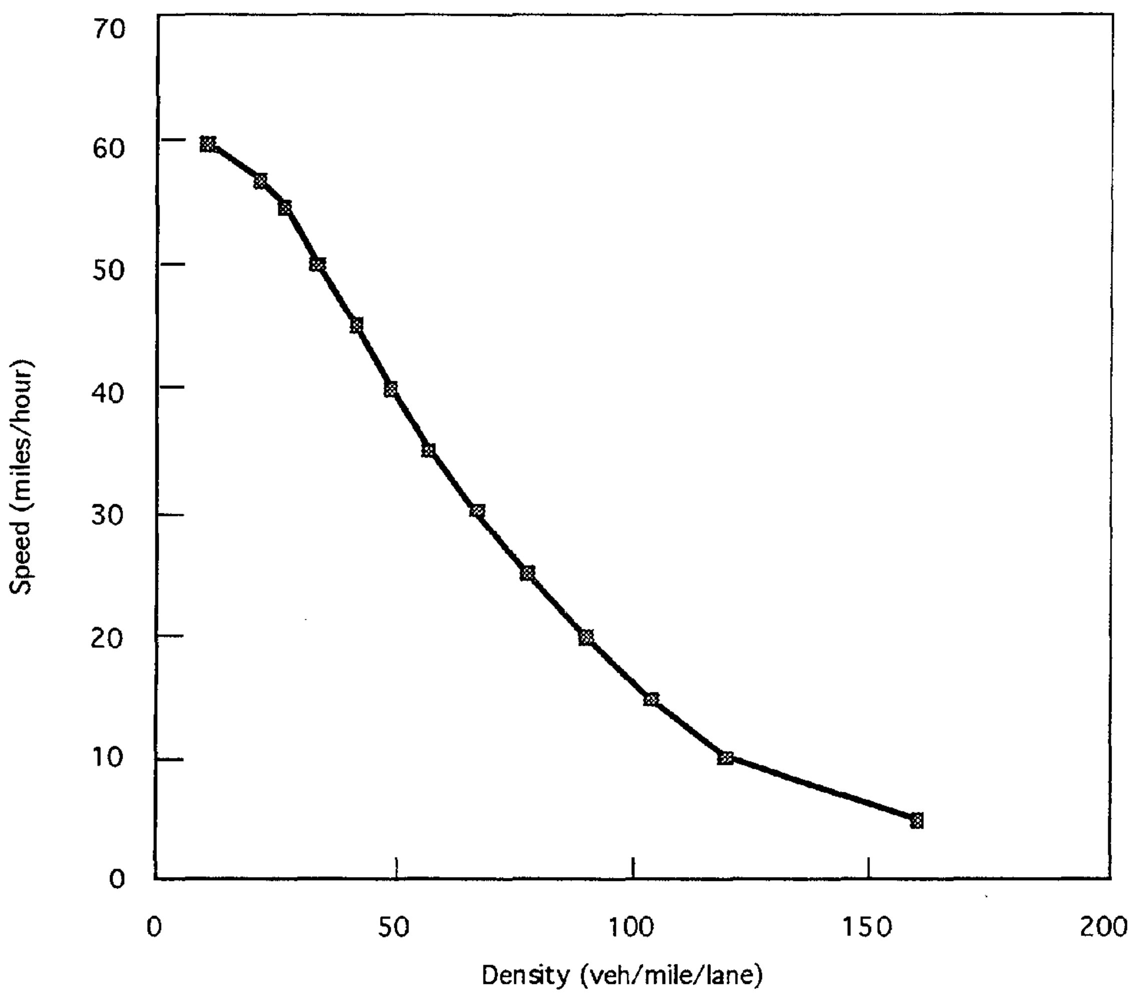


a capacity
aa v/c ratio based on 2000 pcphpl valid only for 60 and 70 mph design speeds

Source: Highway Capacity Manual, FHWA, 1985.

1 mi/h = 1.6 km/h

Figure 2-1. Highway Capacity Curve Showing Relation Between Speed and Flow Under Ideal Conditions

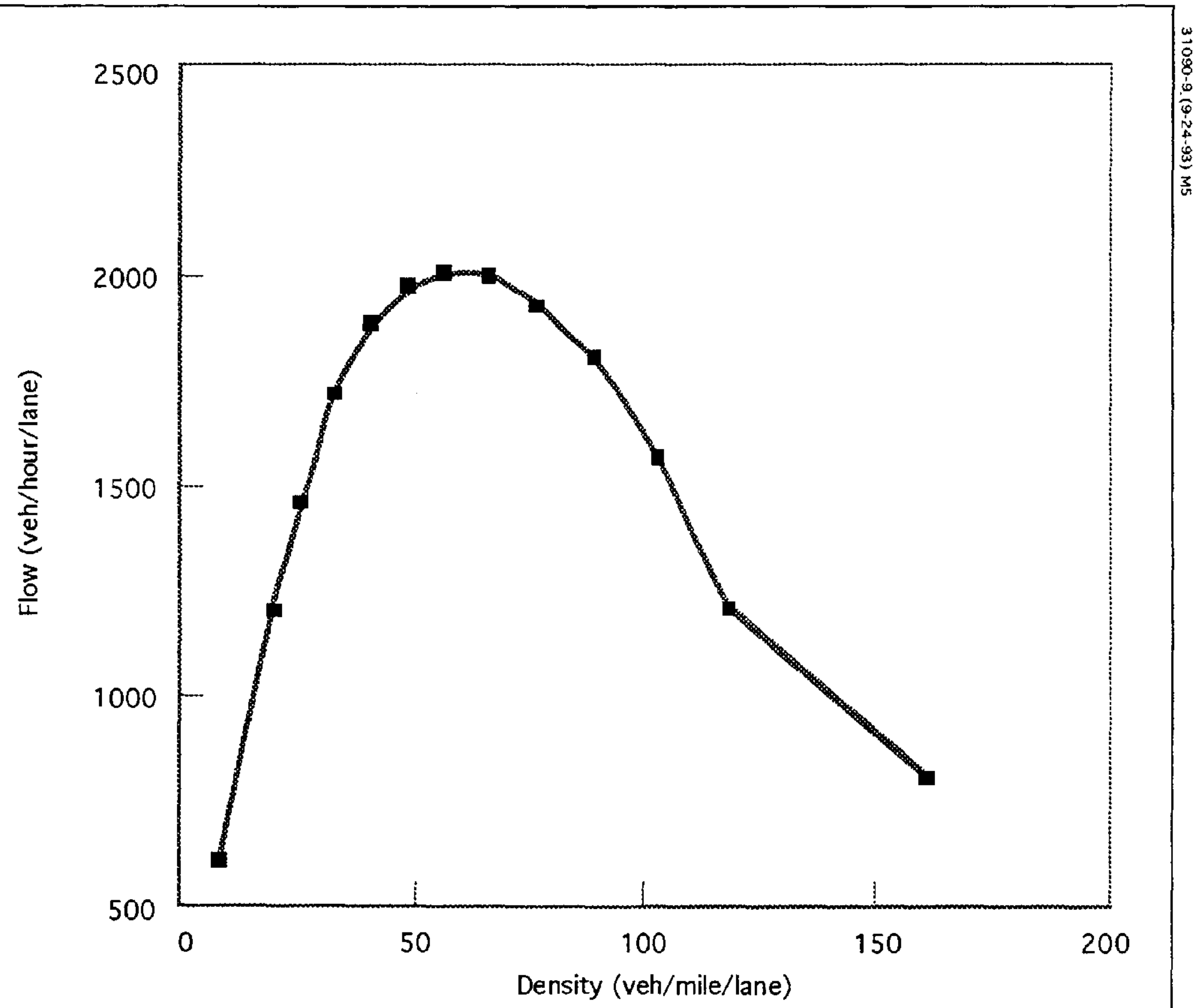


This figure was calculated using the 70 mph design speed shown in the Highway Capacity Curve of Figure 3-1 and the application of the relation Flow = Speed x Density.

31090-8 (9-24-93) MS

1 mi/h = 1.6 km/h

Figure 2-2. Speed-Density Curve



This figure was calculated using the 70 mph design speed shown in the Highway Capacity Curve of Figure 3-1 and the application of the relation Flow = Speed x Density.

1 mi/h = 1.6 km/h

Figure 2-3. Flow-Density Curve

measures of flow are needed. Flow, speed, and density are still required by current and future IVHS applications for efficient management of interrupted flow, but to these are added measures such as delay, stops, and turning movements.

Some of the parameters are directly measurable in real time, while others are mathematically derived or estimated from the measurable parameters. Still others must be estimated from collected historical data. A generic discussion of commonly used traffic parameters considered relevant to IVHS is presented below, although specific parameters and accuracies will be a function of the IVHS application and the detector technology deployed.

2.3 TRAFFIC PARAMETER DEFINITIONS

Parameters that characterize traffic flow can be classified in terms of one of the following:

- *Quantity Measures:* How much or at what rate is traffic moving or waiting to move?;
- *Quality Assessment Measures:* How well is traffic moving?;
- *Movement Measures:* Where is traffic coming from and going to?; and
- *Composition/Classification Measures:* What kind of traffic is moving?

Parameters which fall into each of the above categories are discussed below.

2.3.1 Quantity Measures

Traffic quantity measures include volume, demand, time headways, and throughput.

2.3.1.1 Volume

Volume data are generally expressed in terms of flow rate. Flow rate is a temporal quantity measure defined as the number of vehicles passing a point in a given period of time, usually 1 hour. Flow rate q is the inverse of the average of the time headways measured over the same period such that

$$q = \frac{3600}{h} \qquad (2\text{-}2)$$

where

q = hourly flow rate (vehicles per hour),

h = average time headway (seconds per vehicle), and

3600 = number of seconds per hour.

Flow rates, both measured and forecasted, have many applications in traffic engineering, including developing traffic trends, analyzing accident data, determining sites for traffic signals, estimating future toll revenues, developing design requirements for new or reconstructed highways, and investigating operational improvements using capacity analysis.

On most facilities, traffic flow rates vary throughout the day and by direction. Figure 2-4 depicts these variations on the San Francisco-Oakland Bay Bridge, a 10-lane urban highway without shoulders. In addition, highways exhibit monthly variations in traffic flow rates that are dependent on the highway type and location. These variations are a function of urban versus rural facilities and recreational versus nonrecreational facilities, for example.

Traffic flow measurements can have different interpretations depending upon the conditions upstream and downstream of the measurement site, as well as at the detector locations. For example, if there is no congestion at the site (or upstream of it) to limit the arrival rate of the vehicles being measured, then the flow rate is equal to the existing demand. If, on the other hand, queuing exists at the site, then the measured flow rate reflects the downstream bottleneck capacity.

2.3.1.2 Demand

Demand is "the amount of traffic volume (or flow rate) that occurs on a facility under some given set of travel conditions." When not constrained by a highway's capacity, the actual flow rate measured on the highway will equal its demand. However, in cases where highway demand exceeds capacity, some queuing will occur and actual measured flow rates will be less than the demand.

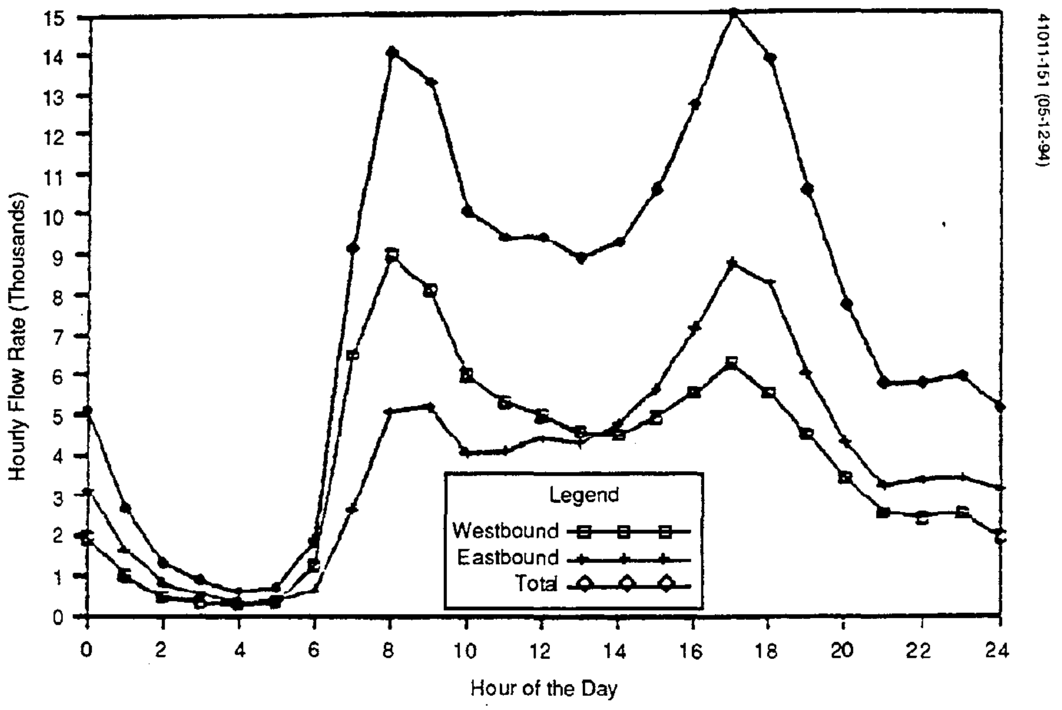


Figure 2-4. Hourly Traffic Flow on the San Francisco-Oakland Bay Bridge

Many IVHS applications make a distinction between volume and demand values. For optimal decision making, traffic control and traffic advisory subsystems often need the anticipated traffic demand for a given road at a future time (not just its current volume). For example, when advising motorists to use an alternate route around a freeway incident, an estimate of the expected demand for the alternate route is needed.

Unfortunately, demand values are difficult to obtain directly. If congestion is present either upstream of the diversion point on the freeway or on the alternate route, then measured flow rates may understate potential demand. Furthermore, the demand for a particular alternate route will vary over time and with the actual number of motorists being diverted. To predict the consequences of a routing decision, estimates for demand on the alternate route segments are projected for the future time when diverted motorists will encounter these demands along their route. Current and historic flow rate data and diversion percentage estimates are key inputs for such projections. In addition to projecting future flow rates, on-line traffic assignment techniques are used to estimate traffic demand on alternate routes.

2.3.1.3 Time Headway

Time headway between vehicles is defined as: "the elapsed time between the passage of an identical observation point by consecutive vehicles in the traffic stream." Time headway measurement can be performed manually with a stopwatch and automatically with any presence-type detector or with video image processors. Since the average of vehicle time headways past a point over some time interval is the reciprocal of the flow rate past that point, time headways present microscopic measures of flow past a point. Time headways are also frequently used as a quantitative measure of service or productivity at traffic signals and toll collection stations, that is, as a service headway expressed in terms of average number of seconds per vehicle.

The space-time diagram of Figure 2-5 shows the paths of several vehicles as they pass an observation point and the two components that make up time headway. The first component is the time it takes the vehicle to pass the observation point, or occupancy time. The second component is the time between the rear of one vehicle and the leading edge of the next, or gap time.

Highway capacity depends primarily on the gap times that individual drivers are comfortable with on the particular highway. Opportunities for passing, merging, or crossing are also determined by gaps provided by the appropriate time headway distributions. Two measures of the level of service closely associated with time headways are the percentage of time one vehicle is forced to follow another on two-lane highways and the frequency of speed adjustments that a driver makes to maintain a minimum headway.

2.3.1.4 Throughput

Throughput is defined as: "the vehicle-miles of travel carried by a given length of roadway for a given period of time." It is determined by measuring flow rates for each section of highway between points of entry or egress. It is often used to characterize the efficiency of a highway facility and to evaluate the "before-and-after" effects of operational improvements. Appropriate comparisons are obtained by calculating the throughput for each travel direction and for comparable times of day.

2.3.2 Quality Assessment Measures

Quality measures determine how well traffic is flowing on a given roadway. They include speed, density, delay, and stops.

2.3.2.1 Speed

Speed is one of the three macroscopic traffic flow measures, the others being volume and occupancy. Speed expresses the rate at which traffic is moving and, therefore, is a natural measure of the quality of the flow. Three types of speed measurements are described below: spot speed, time mean speed, and space mean speed.

Spot speed is defined as: "the speed of an individual vehicle as it passes an observation point of the traffic stream." As spot speeds are instantaneous speeds of individual

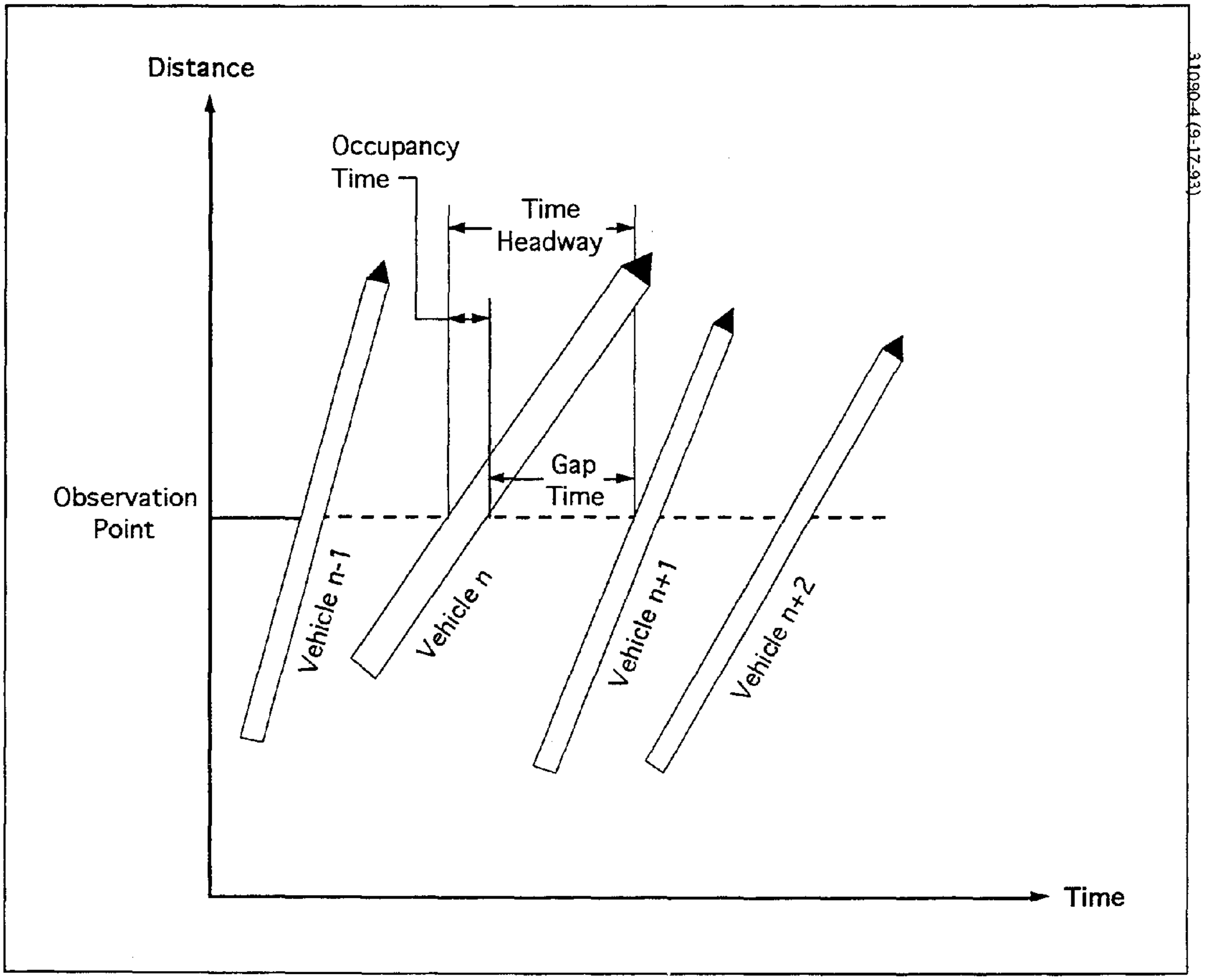


Figure 2-5. Time Headways of Consecutive Vehicles

vehicles, they can be determined from the slope of the vehicle traces on a space-time diagram such as Figure 2-5. Speed can be measured in several practical ways. First, using a speed trap station, a pair of detectors is placed on a length of roadway. Speed is calculated from the time it takes vehicles to transverse the distance between the start of the detection zones of the two detectors. Measurement accuracy depends on the distance between the detectors, the average speed of the traffic, and the detector sampling rate. Detectors used for this application include pneumatic tubes, piezoelectric strips, inductive loops, infrared, video image processors, and any other type of presence detector.

A second method for measuring spot speed is with a single-loop detector and an assumed average vehicle length. This approximate technique is employed by the Urban Traffic Control System (UTCS) to compute average speed S as

$$S = \frac{0.6818\,VC\,(LL+VL)}{O} \qquad (2\text{-}3)$$

where

S = speed in mi/h,

0.6818 = constant to convert from ft/s to mi/h,

VC = vehicle count during the time period,

LL = loop length in ft,

VL = vehicle length in ft, and

O = seconds of loop occupancy during the time period.

With current Inductive Loop Detector (ILD) technology, speed estimates from a single loop vary from the true value by as much as 30 percent. To obtain even these relatively crude measurements, volume, vehicle length, and occupancy must be known to within an error rate no greater than ±10 percent. Of these, vehicle length is the most difficult to estimate accurately due to variations in the real-time vehicle mix. Its value is typically based on historical data.

Other techniques for spot speed measurement exist. Imagery from video cameras measures spot speeds based on vehicle movement across a calibrated distance in the field of view. Radar technologies, such as laser radar that transmits multiple beams and microwave radar that divides its field of view into multiple zones, determine spot speed by measuring the time it takes a vehicle to move between the beams or zones. Detector technologies such as ultrasound and Doppler microwave exploit the Doppler shift in the received signal to measure spot speed.

Time mean speed is defined as: "the arithmetic mean of individual spot speeds that are recorded for vehicles passing an observation point over a selected time period." An adequately sized sample of spot speeds is needed to ensure that the time mean speed approximates the population mean to within the desired accuracy.

Space mean speed is defined as: "the harmonic mean of individual speeds which are recorded for vehicles passing an observation point over a selected time period." The harmonic mean is calculated by converting the individual spot speeds to individual travel time rates, then calculating the average travel time rate, and finally inverting the average travel time rate to obtain an average speed.

The relationship between time mean speed and space mean speed is given by

$$\text{Time Mean Speed} = \text{Space Mean Speed} + \frac{\text{Variance of Space Mean Speed}}{\text{Space Mean Speed}} \qquad (2\text{-}4)$$

Space mean speed can also be calculated from sample travel times gathered over a known length of highway and computing the inverse of an average travel time rate (in units of time divided by units of distance). Travel times can be obtained by matching license plates or some other distinctive vehicle feature, using image processing for example, or with floating cars used as probes. In the future, vehicles equipped with automatic vehicle identification (AVI) transponders will be another source of these data.

2.3.2.2 Density Characteristics

Density, or the density rate, is a spatial measure that describes the quantity of vehicles occupying a section of roadway. The 1985 Highway Capacity Manual bases its freeway level-of-service descriptions on density rather than speed because, as previously noted, there is a wide range of flow rates where speed is relatively constant.(2) Moreover, the freedom to maneuver and the proximity to other vehicles are equally important factors that are directly related to density. Common density-related measures include density rate, occupancy, and distance headway.

Density is defined as: "the number of vehicles occupying a given amount of roadway space (generally a lane-mile)." While density is a fundamental measure of traffic flow, its use in freeway traffic assessment and control has been limited due to the difficulty in obtaining and analyzing the required data. Until recently, the only way to directly measure density rates was through photographs taken from a high vantage point (usually aerial photography). The vehicles in a given section of roadway were then manually counted from the photograph image. Density can also be estimated from speed and flow measurements or from percent occupancy measurements. With the development of imaging techniques, density data may be obtained automatically for real-time application to IVHS.

Occupancy is defined as: "the percent of time the detection zone of a detector is occupied by some vehicle." Occupancy and density are spatial parameters and their values are related. Both occupancy and density depend on the length of the vehicles in the traffic stream and the spacing between the vehicles.

Distance headway between vehicles is defined as: "the distance between identical points on consecutive vehicles in single file." Distance headways can be thought of as a microscopic view of density. The space-time diagram of Figure 2-6 shows the distance headway components and the location of the vehicles on the highway. As with time headways, distance headways have two parts: the actual length of the vehicle and the gap distance between vehicles. Distance headways and their statistical distributions are used for developing car-following models and for investigating the stability of traffic flow.

2.3.2.3 Delay Measures

Delay measures are used for freeways and signalized intersections to evaluate the benefits of operational improvements and to estimate cost-effectiveness.

Freeway delay occurs when travel speeds are less than some arbitrary "free-flow" threshold, usually 35 or 45 mi/h (56.3 or 72.4 km/h). The delay is measured in terms of flow rate and travel time in excess of the free-flow value. Delay is expressed in vehicle-hours (or person-hours).

Speed and travel time data were historically recorded on "tachograph" charts by equipment installed in floating car vehicles and were reduced manually. Newer methods record and store the data in electronic form, allowing them to be downloaded into a personal computer for easier analysis. For example, a surveillance system containing speed and traffic flow detectors spaced at 1/3-mi (1800-ft [548.6-m]) increments or less, depending on the desired accuracy of the delay estimate, can be used to construct speed profiles. With computer assistance, vehicle hours of delay can be calculated from the profiles without deploying floating vehicles. The automatic data collection approach also makes it easier to gather data samples at more frequent time intervals during a day or on more days during a week.

Intersection delay can be characterized by stopped delay, time in queue delay, and approach delay. Figure 2-7 depicts the time-space trace of a vehicle that comes to a stop several times on the same signalized intersection approach. This trace might occur at a congested location during peak volumes when a queue of stopped vehicles is not completely discharged during one green phase. It also represents a situation where there is considerable compression of the queue during a red phase, or where a lane is carrying both through and left-turn movements, or stop-and-go conditions exist.

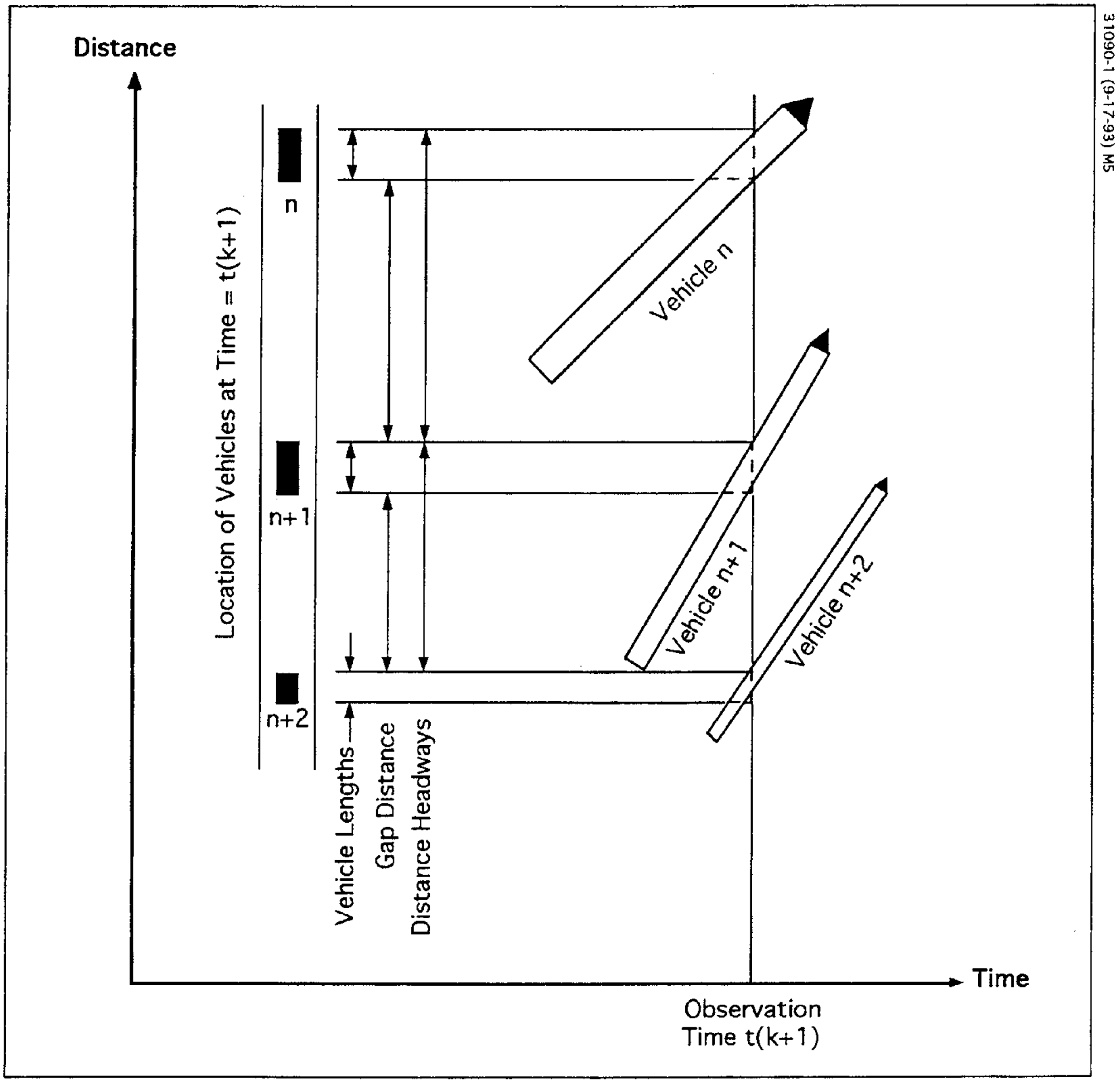
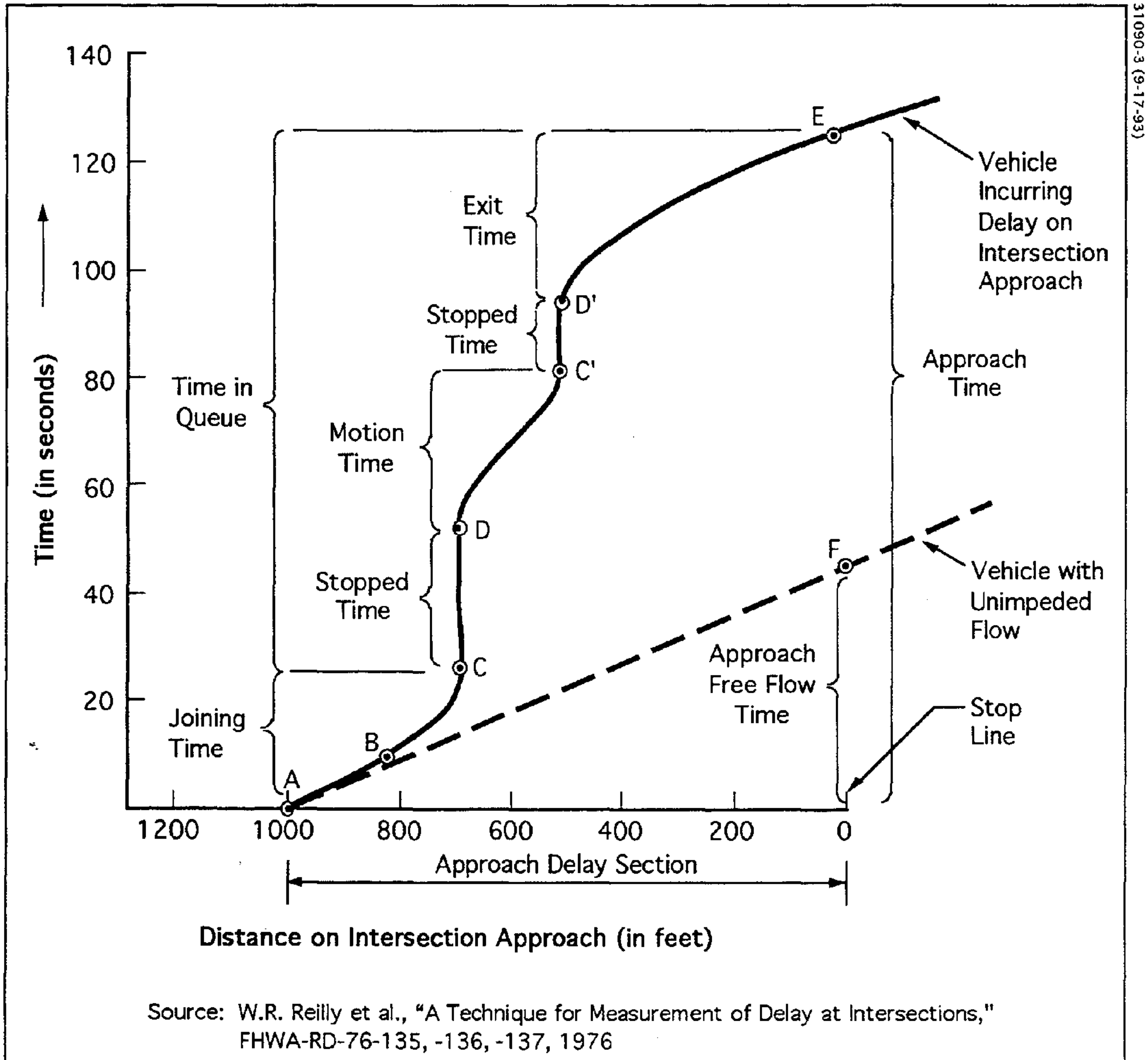


Figure 2-6. Distance Headways of Consecutive Vehicles at a Particular Time



Source: W.R. Reilly et al., "A Technique for Measurement of Delay at Intersections," FHWA-RD-76-135, -136, -137, 1976

1 ft = 0.305 m

Figure 2-7. Time-Space Relationship for Vehicle with Multiple Stops

- Stopped Delay: The sum of the stopped times, shown in Figure 2-7, equals the total stopped delay. Stopped delay, an obvious measure of traffic to the motorist, is also important when evaluating environmental impacts such as vehicle emissions. Comparisons of stopped delay between intersections may be misleading when one intersection is operating under conditions where the time of stop is short, but low speed movement in a long sluggish queue follows the stop. An associated parameter, percent of vehicles stopping, while not strictly a delay measure, is a useful statistic, particularly in evaluating both fuel consumption and emissions. It is defined as the number of vehicles that stop at least once, divided by the total number of vehicles using the approach, and is expressed as a percent.

- Time in Queue Delay: The time in queue is the sum of stopped time, motion time, and exit time as shown in Figure 2-7. It is equivalent to the total approach time minus the joining time. The time in queue delay is set equal to the time in queue, even though some progress is being made through the intersection during this time.

  Time in queue delay often falls between stopped delay and approach delay. Time in queue delay can also be greater than approach delay because approach delay is equal to the difference between the actual time on the approach and the free-flow time of an unimpeded vehicle over the same distance.

- Approach Delay: The approach time is the total time required to traverse the approach section under study. The approach delay is equal to the approach time less the time required for an unimpeded vehicle to travel through the same section under free-flow conditions. Approach delay can be used directly in the analysis of road-user time costs. This measure also compares the efficiency of intersections having different modes of control, such as stop or yield signs and pretimed or vehicle-actuated traffic signals.

Delay data collection techniques have been primarily manual. However, the advent of area-wide traffic control and system-collected detector and signal status data have increased the information available for estimating delay at signalized intersections. Data collection techniques include point sample, input-output, and path trace.

The point sample method periodically samples the intersection approach to record the number of stopped vehicles at equally spaced time intervals. It determines the average number of stopped vehicles, calculates the total stopped time by multiplying the average number of stopped vehicles by the duration of the sample interval, and then calculates the average stopped delay by dividing the total stopped time by the number of vehicles passing the study section. It is analogous to taking a series of snapshots at regular intervals.

The input-output method samples data during intervals, rather than between intervals. It addresses the flow rates at the upstream and downstream boundaries of the approach area. The SCOOT adaptive traffic control system and the UTCS-enhanced area-wide traffic control system use the input-output technique.

The vehicle path trace method is essentially the same as the two other data collection techniques. Sample data are obtained by either running test vehicles through the approach area, measuring the various passage times of selected sample vehicles, or obtaining trace data from detector imaging techniques.

2.3.2.4 Intersection Stops

Intersection stops characterize the quality of traffic flow at signalized intersections. Stops are normally expressed as total stops or percent stops. Total stops are defined as the number of stops made by vehicles approaching an intersection. Percent stops is the percent of approaching vehicles making at least one stop. Both measures can be collected manually, although some traffic signal control systems estimate them using real-time flow data in combination with signal display status.

2.3.3 Movement Measures

Movement measures are based on data that describe the movement of vehicles in terms of the path they follow. The travel path may comprise an entire trip, as when origin-destination data are collected, or it may occur within a small area, as when intersection turning movements are studied.

2.3.3.1 Origin-Destination Data

Origin-destination (O-D) data help to specify traffic flow volumes between established geographic zones or points of origin and destination. Hence the data are useful in evaluating traffic operations strategies and in making control decisions. In the past, the data have been difficult to obtain as expensive manual methods were needed to gather information from license plate surveys or traveler interviews. In the future, two-way communications between the vehicle and the operations center, such as with automatic vehicle location technology, may allow O-D data to be collected and acted upon in real time. In-vehicle navigation equipment may also be useful for some of the latter applications.

2.3.3.2 Turning Movements

Turning movement data define the volume or percent of traffic turning left, right, or traveling straight through an intersection approach. Today, most turning movements are collected manually using either a counter board or a notebook computer. Left and right turn and through movements at each intersection are typically counted separately for each approach and for each signal phase on that approach.

Detector imaging techniques are being developed to permit automatic recording of intersection turning movements. This will allow data to be collected over many more days than is presently feasible, and may result in more accurate data than with the manual method. Potentially, the resulting real-time data can significantly enhance the value of on-line control algorithms.

2.3.4 Composition and Classification Measures

Many traffic management strategies, including those for IVHS, require the identification of individual vehicles and their length, weight, or cargo specifications as an input to a vehicle classification process. These strategies include assessing fares for automatic toll collection, as well as law enforcement actions related to stolen vehicles, high-occupancy vehicle (HOV) violations, and peak period travel restrictions in central business districts. They are also used to improve commercial vehicle operations through automatic identification, weigh-in-motion, and hazardous material tracking.

Because of requirements to provide a broad spectrum of vehicle data, classification data can best be obtained through automatic vehicle identification and vehicle-to-roadside communications. However, until these technologies are more universally deployed, other means of vehicle detection and data gathering will continue to be used. Three types of vehicle classification categories are currently employed: function, configuration, and weight.

2.3.4.1 Functional Classification Data

Vehicles are frequently classified according to their function, such as passenger cars, vans, trucks, and buses. Some inductive loops, coupled with specially adapted digital detectors, can distinguish among these various types of vehicles from the unique signatures they produce while passing over the detector. Traffic signal systems with a bus priority feature have demonstrated this application.

The number of passengers per vehicle is another type of vehicle function data that may be required for HOV planning, lane enforcement, and transit operations. Loop detectors cannot provide this information, but it is conceivable that a future type of in-vehicle sensor-transmitter combination could sense the number of seats occupied and transmit the data via vehicle-to-road communications. The persons-per-vehicle count can be transmitted from the vehicle to a roadside communications device and, hence, to the operations center. Another approach to obtaining the number of passengers per vehicle may be with video image processing technology. By properly situating cameras, the number of passengers could be conceivably ascertained, while simultaneously observing privacy considerations that may be demanded by the public.

2.3.4.2 Configurational Classification

Tolls are often assessed based on the configuration of the vehicles passing through the toll plaza. Historically, separate schedules are developed for passenger vehicles and trucks, and these are further classified according to the number of axles. Overheight, overwidth, and overweight vehicles also need to be identified for safety and structural reasons. By tradition, these data are collected at truck inspection stations for commercial vehicles. With automatic vehicle identification tags, automatic classification and billing is technically feasible, especially for commercial vehicles. Because of the monetary aspects of toll collection, vehicle classification accuracy requirements can be greater for these than for other IVHS applications.

Improved commercial vehicle operations (CVO) are also obtained by expediting vehicle identification, for example, by using optical detectors to measure vehicles and weigh-in-motion equipment to speed trucks through weigh stations. Advantage I-75 and Crescent are two projects evaluating methods for improving CVO. The technologies demonstrated include vehicle-to-roadside communications to minimize the number of inspections requiring stops and the amount of paper work for trucks traveling between regions covered by the system.

Advantage I-75 uses a decentralized management approach and automatic vehicle identification to allow mainline preclearance of commercial vehicles. The Crescent Project is the demonstration phase of HELP (Heavy Vehicle Electronic License Plate), a long-term program to develop and use automatic vehicle classification, weigh-in-motion, onboard computers, and beacon technologies. Crescent uses a centralized system to electronically verify operating credentials and to monitor vehicle weights.

2.3.4.3 Weight Classification Data

The primary uses of vehicle weight information are to ensure the safety of roadway structures such as bridges and viaducts and to ensure that heavy, overweight trucks do not break down the pavement. These enforcement functions have traditionally required that data be obtained at truck inspection stations operated by highway police. Since enhanced commercial vehicle operations is a goal of IVHS, weigh-in-motion sensors are being deployed in these programs.

The same weight data required for enforcement are also valuable in updating planning and design information related to bridge live-load specifications and in establishing the required strength of highway pavements.

2.4 TRAFFIC PARAMETER AND ACCURACY SPECIFICATIONS FOR FUTURE IVHS APPLICATIONS

The traffic parameter accuracy specifications shown in this section are believed to be representative of requirements for selected IVHS applications. However, no claim is made as to their widespread applicability since traffic parameter specifications will necessarily vary with the particular traffic management system architecture, implementation strategies, selected components and signal processing algorithms, and system operational procedures.

The traffic parameter measurement accuracy specifications for a given management strategy must primarily take into account the data processing and traffic control algorithms for which these parameters serve as inputs. Specification of traffic parameter accuracy, therefore, cannot be separated from the overall system-level analysis and design process. For each contemplated IVHS service, there are likely to be many different system algorithms, procedures, and detection subsystem design options. Evaluating alternative implementations for a particular service is the responsibility of system analysts and designers. This discussion cannot serve as a substitute for a thorough systems analysis and design effort. Nonetheless, a suggested process for the development of traffic parameter specifications, including data types, collection interval, and accuracy, is proposed.

To structure the discussion and presentation of detector performance specifications, three general categories of traffic parameters are defined based on their intended use and the required timeliness of their input for the real-time traffic management strategy. These categories are *tactical*, *strategic*, and *historic*. While the same raw inputs may often feed each of the categories, each presents a somewhat different set of detection performance and sampling requirements. In fact, these differences can result in a detector technology or product being adequate for some applications and not for others.

The traffic parameter input ranges and accuracies identified are for some of the more common IVHS services, including signalized intersection control, freeway incident management, and freeway metering control. Traffic parameter range and accuracy requirements are derived or inferred from the values needed for use in a particular algorithm (when it is known) and from practical experience with operating systems. Many of the historic and strategic category parameters may also be applicable to a host of other static and dynamic trip/route planning-related IVHS services. However, for these and other services where established strategies and algorithms are less commonly applied, a system-specific parameter requirements analysis is suggested. Such analysis is beyond the scope of this document.

Factors that may drive future IVHS traffic parameter and algorithm specifications are discussed at the end of the section. To a large extent, current traffic management systems are input constrained. That is, a complete microscopic (vehicle-by-vehicle) view of the traffic stream is not available in today's systems because of the lack of applicable real-time input data, even though the accelerating advances in computer processing and distributed system designs make possible advanced traffic optimization modeling and control in near real time. In this case, current systems rely heavily on prestored turning movement and origin-destination (O-D) data to supplement incomplete real-time data. In real-time control, the analysis and response to external events are performed and determined within specified time limits, usually on the order of seconds or milliseconds. In near real-time control, the feedback response is calculated within longer time intervals that are not small enough to respond to the stimuli in real time, but are sufficiently small to still have a positive impact on the events caused by the stimuli.

Future applications will not likely require a whole new set of traffic parameters. Rather, advanced detector technologies will provide greater area coverage with better vehicle characterization (e.g., presence, speed, classification, and turning movements), increased reliability, and reduced costs. Advanced control systems with vehicle tracking capabilities are also being developed and tested. These technology trends will be key enabling factors in the widespread deployment of control algorithms that may include neural network and expert system techniques. The net result will be an increased emphasis on tactical type inputs and on requirements for increased accuracy and precision.

2.4.1 Detector Specification Development

Figure 2-8 shows a formal process for development of traffic detector specifications. The first phase requires a detailed up-front systems analysis to properly specify all the subsystems that are part of the IVHS architecture. Among these is the detection subsystem highlighted by Figure 2-8. The critical first step in defining traffic parameter specifications, such as signal processing algorithms, types of output data (count, speed, occupancy, etc.), parameter accuracies, sample interval, and spatial resolution, is the identification of the overall IVHS requirements, shown as inputs to the systems analysis process. These are normally based on a higher level evaluation of system goals and objectives.(3)

To meet the requirements for a particular traffic management application, a number of subsystem architectures, algorithms, and traffic parameters can be selected to function either singularly, or in combination with one

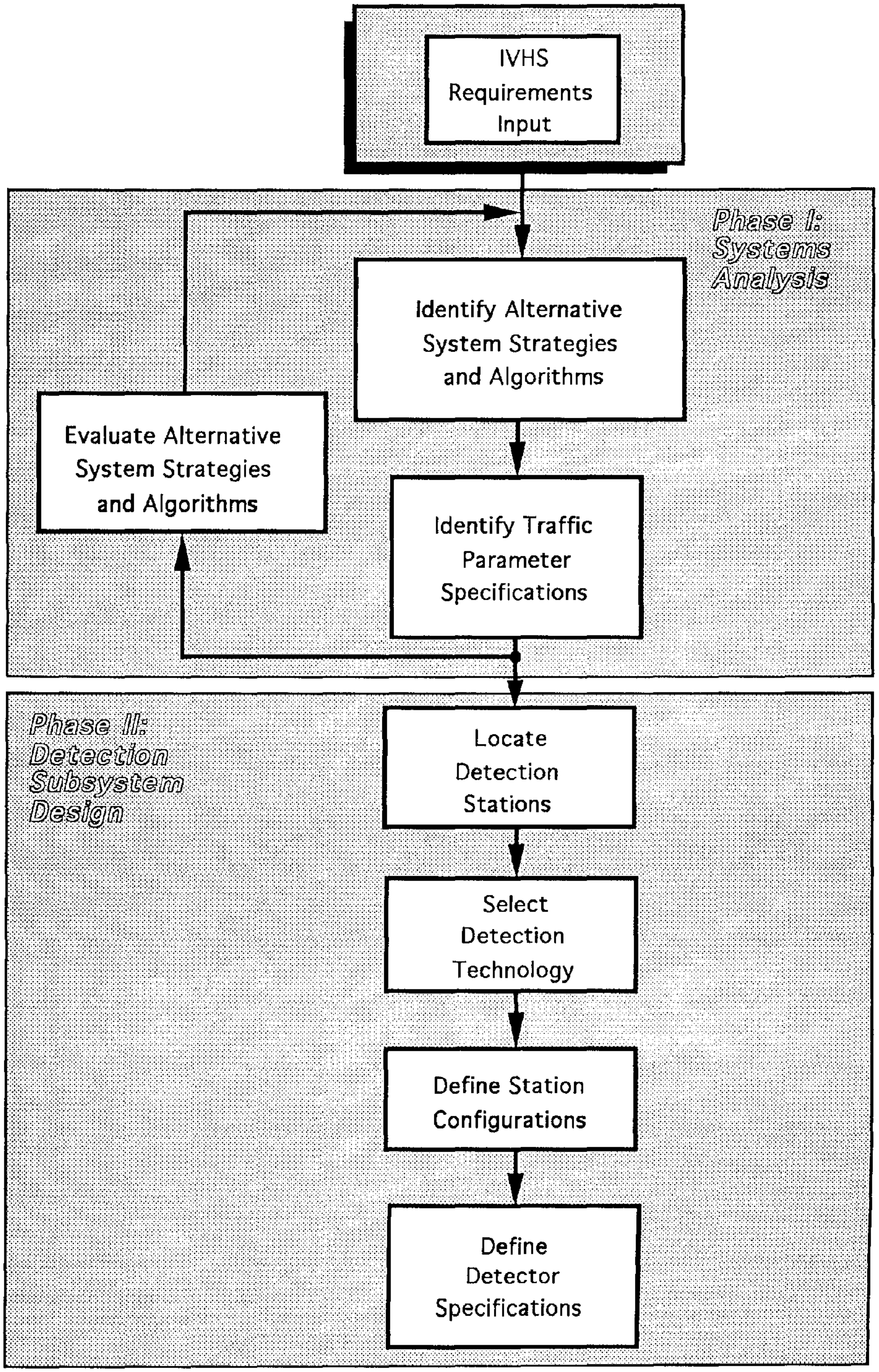


Figure 2-8. IVHS Detector Specification Process

another. The alternatives must then be analyzed and their performance compared with the overall system goals and objectives. The analysis of the alternatives not only requires a knowledge of the basic system requirements, but also a detailed understanding of the system's targeted operating environment and the constraints imposed by the available technologies that are a part of the solution. Knowledge of key technical specialty areas is needed so that they may be applied effectively in the development and implementation of traffic management systems. These specialties include traffic surveillance and control algorithm design, traffic flow theory, statistics and sampling theory, computer technology, communications technology, and detector technology.

Once the systems analysis phase is complete, the detection subsystem design phase can begin. The major components of this phase are location of the detector stations, selection of detector technologies (there may be more than one), definition of station configurations, and definition of detector specifications.

2.4.2 Traffic Parameter Categories

The definition of traffic parameter specifications for IVHS takes into account three categories of parameters: tactical, strategic, and historic. Each suggests different usage of the data by a traffic management application that, in turn, generally dictates a different set of parameter specifications, including data collection time interval, range, and accuracy.

2.4.2.1 Tactical Input Parameters

Tactical parameters are those utilized in tactical decision making. For this discussion, tactical decisions are defined as the expedient decisions made by a control system in response to real-time traffic parameter inputs. Tactical decisions are typically based on rote logic embedded in a predefined algorithm. One example is the real-time adjustment of a traffic adaptive controlled signalized intersection in response to the measured cyclic traffic flow profiles on each approach. Another example is the decision to declare a freeway "incident" condition in response to a mainline lane parameter value exceeding a prescribed threshold.

Because tactical decisions are made in quick response to changing real-time traffic variables, tactical parameters are generally collected over short time intervals (usually on the order of a few seconds). They may also be event driven, as, for example, a vehicle detected by a presence detector. Since tactical parameters are collected on these shorter intervals, fewer vehicles are included in each sample. Variation from sample to sample will be exhibited due to the random nature of vehicle arrivals. The limited sample size will usually impose increased accuracy and precision on the measurement of tactical parameters. For example, the measurement of approach speed as an estimate of travel time for vehicles approaching a signalized intersection requires increased accuracy and precision when traffic signal offset decisions are being made, as compared to measuring average approach speeds for strategic background "plan-based" decision making.

2.4.2.2 Strategic Input Parameters

Strategic input parameters support strategic-level decisions. These traffic control and management decisions generally operate at a higher level in the system hierarchy than do tactical decisions. Strategic decisions are typified by the activation of a preplanned management strategy in response to broad indicators of traffic flow conditions.

Strategic-level decisions are often broader in geographic scope than tactical ones and often change the mode of an entire system or a large subsystem. Strategic decisions can be expert system rule-based, as in the Los Angeles Smart Corridor Management System, or algorithm-based, as used in UTCS plan selection. They frequently employ predefined scenarios and operator confirmation and approval processes.

Strategic traffic parameters are usually collected over a period of minutes rather than seconds; as a result, samples are larger. Most currently deployed freeway management and centralized traffic signal control systems use running averages and other filtering techniques to smooth out short-term variations in the traffic stream data. Strategic traffic parameters are often input to maintain on-

on-line databases of current traffic conditions used by the management systems.

One example of a strategic-level decision process is the selection of an incident management plan in response to a detected incident on a surface street network. When an incident is declared, the strategic decision process might monitor overall network conditions and implement an appropriate control plan overriding or adjusting the tactical-level decision-making process.

Under conditions of light to moderately heavy congestion, adaptive traffic signal network optimization methods, such as SCOOT and SCATS that operate largely at the tactical-level, provide excellent results.(4-10) However, in cases of very heavy congestion, such as those caused by an incident where severe blocking of intersections results and natural or controlled route diversion occurs, these tactical-level procedures begin to break down. Strategic-level decision logic is successfully used to solve such problems.

2.4.2.3 Historic Input Parameters

Historic input parameters are those used to maintain or update on-line historic traffic databases. These data bases typically include traffic data collected over periods of 5 minutes or greater and are archived by time of day and day of week, or by time of day and date. The primary purpose of these historic databases is to provide information for off-line planning and design operations. However, historic data are also commonly used as inputs to on-line tactical and strategic decision processes. For example, most freeway management systems maintain a file of historic flow-rate data. This file is regularly used on-line as input for predicting future near-term traffic demands. In addition, some UTCS applications use historic flow-rate data as input to on-line detector failure monitoring logic.

2.4.3 Matching Traffic Parameter Needs to Selected IVHS Services

Individual traffic parameters and accuracies required for a given application are specified by the algorithms, strategies, and operating procedures used to implement that application. A list of criteria which can help select traffic parameters for use in a particular IVHS application includes:

- Convenience of parameter measurement;
- Amenability of resultant data to real-time processing;
- Existence of significant differences in parameter values within the range of traffic conditions that must be monitored.

Traffic parameters are identified below for signalized intersection control, freeway incident management, and freeway metering. Parameter range, collection interval, and accuracy specifications for these services are given in Tables 2-1 through 2-3. Unfortunately, the search of the available literature uncovered little universally applicable information regarding the required accuracy of traffic parameters for these or other IVHS services. Consequently, the specifications are based on: (1) the data that were located, (2) operating experience, and (3) sensitivity analyses developed during the study or found in the literature. The estimates are considered representative of those for the selected traffic parameters and are consistent with the general requirements of the particular application. However, a detailed analysis is recommended to derive parameter specifications for a specific system design or for IVHS services not covered. Such analyses are outside the scope of this report.

2.4.4 Signalized Intersection Control

Table 2-1 gives selected traffic parameter specifications for advanced signalized intersection control applications. Parameters are listed for the tactical, strategic, and historic categories. Tactical parameters include those relating to flow, speed, and occupancy measurements. For advanced signal control systems, typical flow-related parameters may include cyclically collected intersection approach flow rates, flow profile data, and turning volumes.

Tactical information related to intersection control is often collected on a cyclic basis and normalized to hourly rates. This minimizes the short-term parameter fluctuations caused

Table 2-1. Signalized Intersection Control Traffic Parameter Specifications

Tactical Parameters

Parameter	**Units**	**Range**	**Collection Interval**	**Allowable Error**
Approach Flow Profiles	vehicles	0-3	1 second	± 2 veh/signal cycle
Turning Movement Vol	vehicles	0-200	1 cycle	± 2 veh/signal cycle
Average Link Travel Time	seconds	0-240	1 cycle	± 2 seconds
Average Approach Speed	mi/h	0-100	1 cycle	± 2 mi/h (0-55 mi/h)
Queue Length	vehicles/lane	0-100	1 second	± 2 vehicles
Demand Presence	Yes/No	-	10 Hz (minimum)	No missed vehicles
Average Approach Delay	s/veh	0-240	1 cycle	± 2 seconds
Approach Stops	stops	0-200	1 cycle	± 5% of stops

Strategic Parameters

Parameter	**Units**	**Range**	**Collection Interval**	**Allowable Error**
Flow Rate (Volume)	veh/h/lane	0-2500	5 min	± 2.5% @ 500 veh/h/lane
Occupancy	%/lane	0-100	5 min	± 5%
Average Speed	mi/h	0-100	5 min	± 2 mi/h (0-55 mi/h)
Average Delay	s/veh	0-240	5 min	± 2.5 seconds
Percent Stops	%	0-100	5 min (approx)	± 5%

Table 2-1. Signalized Intersection Control Traffic Parameter Specifications (continued)

Historic Parameters

Parameter	Units	Range	Collection Interval	Allowable Error
Turning Movement Vol	veh/movement	0-2000	15 min	± 2.5% @ 500 veh/h
Flow Rate (volume)	veh/h/lane	0-2500	15 min	± 2.5% @ 500 veh/h
Occupancy	%	0-100	15 min	± 5%
Average Speed	mi/h	0-100	15 min	± 2 mi/h (0-55 mi/h)

1 mi/h = 1.61 km/h

by data collection intervals being inconsistent with whole multiples of the cycle length. Fluctuations can also be minimized by maintaining weighted running averages and other smoothing techniques.(11)

Speed-based parameters are also of benefit to advanced signal control algorithms. From a tactical viewpoint, vehicle approach speeds can be used to estimate link travel time. However, speed accuracy is critical here because a small difference in measured speed can have a significant effect on calculated travel time. (This depends, of course, on the length of the approach section.) An error in calculated travel time of only a few seconds can have an adverse effect on operations if travel time is used as the basis for offset calculations. Another useful speed measure is the distribution of approaching vehicle speeds. The standard deviation of the measured speed can be an important input to the modeling of platoon dispersion from one signalized intersection to another.

Occupancy-based measures such as queue length, delay, and percent of stops collected on a cycle basis can also be tactical inputs to advanced signal control algorithms. Data from traditional inductive loop traffic detectors on an approach to a signalized intersection provide estimates for these parameters using an input-output model that receives the current green state of the traffic signal. These parameters provide feedback on the effectiveness of the current traffic control operation. Stop bar demand presence and queue overflow presence are two other occupancy-related parameters used by some signal control algorithms. The strategic-level parameters most often used by intersection control logic include smoothed volume, occupancy, and average speed indicators. Some systems also tabulate average approach delay and percent of vehicles stopping or total stops by approach. Strategic data are normally kept as smoothed values (weighted running averages) with collection intervals ranging from 1 to 5 minutes. In most instances, the purpose of strategic volume data collection is to tabulate current demands for network links. Similarly, occupancy parameters are often used to monitor the extent of current congestion on the roadway network. As discussed in a previous example, strategic traffic parameters can be useful for implementing incident management strategies designed for surface-street applications.

Historic parameters used in intersection signal control applications include link-based volume, occupancy, and speed. Turning movement and O-D pattern information are also important as inputs to demand prediction algorithms. These data are currently available from manual studies.

2.4.5 Freeway Incident Management

Table 2-2 identifies selected parameter specifications for freeway incident management. Tactical parameters serve as key inputs to automated incident detection algorithms. Basic tactical inputs include lane-specific mainline flow rate, occupancy, and average speed. Other tactical parameters derived from these basic parameters include spatial occupancy differential and spatial average speed differential. For incident detection logic based on California-type algorithms, the spatial differential parameters provide measures of the difference in lane-specific values of occupancy or speed between successive upstream and downstream detection stations for a given direction of travel. These types of algorithms rely on the identification of an incident between mainline stations from significant differences in the measured values of parameters between the two stations. Another algorithm uses the standard deviation of vehicle speed to predict when freeways are reaching capacity and to initiate strategies such as speed limit reduction or metering .(12)

Strategic-level parameters are important as traffic monitoring inputs to the overall incident management process. Strategic-level parameters include mainline lane-specific flow rate, occupancy, average speeds, and freeway on-ramp and off-ramp flows. Alternative route data are also collected when applicable. As a minimum, flow rates and link speed or travel times should be maintained for significant alternate routes in the system. Strategic parameters are generally maintained on-line as 5-minute running averages.

Table 2-2. Freeway Incident Detection and Management Traffic Parameter Specifications

Tactical Parameters (Detection)

Parameter	Units	Range	Collection Interval	Allowable Error
Mainline Flow Rate	veh/h/lane	0-2500	20 s	± 2.5% @ 500 veh/h/lane
Mainline Occupancy	% (by lane)	0-100	20 s	± 1%
Mainline Speed	mi/h (by lane)	0-80	20 s	± 1 mi/h
Mainline Travel Time	min	–	20 s	± 5%

Strategic Parameters (Incident Management)

Parameter	Units	Range	Collection Interval	Allowable Error
Mainline Flow Rate	veh/h/lane	0-2500	5 min	± 2.5% @ 500 veh/h
Mainline Occupancy	%	0-100	5 min	± 2%
Mainline Speed	mi/h	0-80	5 min	± 1 mi/h
On-Ramp Flow Rate	veh/h/lane	0-1800	5 min	± 2.5% @ 500 veh/h/lane
Off-Ramp Flow Rate	veh/h/lane	0-1800	5 min	± 2.5% @ 500 veh/h/lane
Link Travel Time	seconds	–	5 min	± 5%
Current O-D Patterns	veh/h	–	5 min	± 5%

Table 2-2. Freeway Incident Detection and Management Traffic Parameter Specifications (continued)

Historic Parameters (Planning)

Parameter	Units	Range	Collection Interval	Allowable Error
Mainline Flow Rate	veh/h/lane	0-2500	15 min or 1 hour	± 2.5% @ 500 veh/h/lane
Mainline Occupancy	%	0-100	15 min or 1 hour	± 2%
Mainline Speed	mi/h	0-80	15 min or 1 hour	± 1 mi/h
On-Ramp Flow Rate	veh/h	0-1800	15 min or 1 hour	± 2.5% @ 500 veh/h
Off-Ramp Flow Rate	veh/h	0-1800	15 min or 1 hour	± 2.5% @ 500 veh/h
Link Travel Times	seconds	-	15 min or 1 hour	± 5%
Current O-D Patterns	veh/h	-	15 min or 1 hour	± 5%

1 mi/h = 1.61 km/h

As with intersection control, historic parameters play a major role in many, if not most, freeway incident management systems. Parameters which parallel the strategic parameters described above are typically stored as historic files. Data are often maintained for a particular time of day and day of week for each detection station. New data are smoothed with data for the corresponding time interval of the previous week. In this way, files are maintained that represent typical time of day and day of week conditions on the highway network. These files are used for on-line demand estimation and are often archived for planning and design purposes. Historic parameters are typically collected in 15-minute intervals, although 5-minute and 1-hour intervals are also used. Some systems, such as the Burlington Skyway in Ontario, Canada and the Denver, CO Freeway Traffic Management System, store 5-minute values, but can derive 15-minute and 1-hour values upon request.

2.4.6 Freeway Metering Control

Table 2-3 contains selected parameter specifications for freeway metering control. Tactical parameters for this application include queue length, demand presence, passage count, approach volume, and queue overflow presence. When a queue length is used in current applications, it is typically estimated based on approach and passage volumes or is derived from data produced by one or more presence detectors on the approach to the metering signal. Other tactical inputs to the metering control algorithm include mainline occupancy, speed, and flow rate as described under freeway incident management.

Strategic parameters for metering include mainline and metered traffic flow rates. Mainline values are generally lane-specific and include volume, occupancy, and average speeds. Derived average freeway speeds based on volume and occupancy data from a single inductive loop detector will give reasonable results for strategic decisions because collection intervals are typically 5 minutes or longer and smoothing procedures are normally used.

Historic parameters of value in freeway metering include those already identified as strategic plus on-ramp and off-ramp flow rates. The collection interval for historic data is lengthened to 15 minutes or 1 hour, to correspond to the intervals used with freeway incident detection and management.

2.4.7 Future Traffic Parameter Specifications

It is difficult to calculate the accuracy required of traffic parameters for applications where algorithms do not exist or where improved algorithms are being sought. Nonetheless, one can speculate that increased measurement accuracy will be required as advanced algorithms are deployed. These advanced algorithms will place a heavier reliance on tactical-type inputs for real-time control decisions. Future algorithms will not likely require new traffic parameters sets per se. Advances in detection technology will decrease data collection costs and, in some cases, will allow parameters such as queue lengths and origin-destination patterns to be more directly measured or estimated in real time.

Two technologies that will enable advanced algorithms to be deployed are imaging detectors and probe vehicle sampling, including AVI. Imaging detectors that track individual vehicles through a traffic scene have the advantage of monitoring actual vehicle traffic movements as they happen, thus allowing algorithms to be more demand responsive. Furthermore, stopped vehicle counts and standing queues can be directly monitored with imaging methods. Since queue buildup directly impacts delay, number of stops, fuel consumption, and emissions output, improved data and, therefore, control optimization will be possible.

AVI readers and other vehicle probe-based detection technologies are now being operationally tested. These have the potential to statistically monitor travel movements through a roadway network and provide automated collection of O-D data and travel time samples on a link-specific basis. Up-to-the-minute O-D data will enable improved incident and congestion management

Table 2-3. Freeway Metering Control Traffic Parameter Specifications

Tactical Parameters (Local Responsive Control)

Parameter	**Units**	**Range**	**Collection Interval**	**Allowable Error**
Ramp Demand	Yes/No	-	0.1 s	0% (No missed vehicles)
Ramp Passage	Yes/No	-	0.1 s	0% (No missed vehicles)
Ramp Queue Length	vehicles	0-40	20 s	± 1 vehicle
Mainline Occupancy	%	0-100	20 s	± 2%
Mainline Flow Rate	veh/h/lane	0-2500	20 s	± 2.5% @ 500 veh/h/lane
Mainline Speed	mi/h	0-80	20 s	± 5 mi/h

Strategic Parameters (Central Control)

Parameter	**Units**	**Range**	**Collection Interval**	**Allowable Error**
Mainline Occupancy	%	0-100	5 min	± 2%
Mainline Flow Rate	veh/h/lane	0-2500	5 min	± 2.5% @ 500 veh/h/lane
Mainline Speed	mi/h	0-80	5 min	± 5 mi/h

Historic Parameters (Pretimed Operations)

Parameter	**Units**	**Range**	**Collection Interval**	**Allowable Error**
Mainline Occupancy	%	0-100	15 min or 1 hour	± 2%
Mainline Flow Rate	veh/h/lane	0-2500	15 min or 1 hour	± 2.5% @ 500 veh/h/lane
Mainline Speed	mi/h	0-80	15 min or 1 hour	± 5 mi/h
On-Ramp Flow Rate	veh/h	0-1800	15 min or 1 hour	± 2.5% @ 500 veh/h
Off-Ramp Flow Rate	veh/h	0-1800	15 min or 1 hour	± 2.5% @ 500 veh/h

1 mi/h = 1.61 km/h

strategies. The availability of link travel time data in real time should significantly improve the performance of automated incident detection algorithms by reducing detection times and false alarm rates.

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3. TASK B SUMMARY

SELECT FIELD SITES FOR DETECTOR FIELD TESTS

3.1 TEST SITE SELECTION AND CRITERIA

Freeway and surface-street field test sites were selected in Minneapolis, Minnesota; Orlando, Florida; and Phoenix and Tucson, Arizona. In Minnesota and Florida, both types of sites are in the same cities. In Arizona, the freeway site is located in Phoenix and the surface-street site in Tucson. By choosing test sites in different climatic regions of the country, a variety of environmental test conditions were encountered as described by Table 3-1.

Test sites were selected to meet the following criteria:

- Mounting structures available for installing above-the-road detectors over the central portion of the lanes at heights prescribed by the manufacturers;
- Mounting available or easily put in place on the side of the road to install side-looking detectors;
- Power available for the detectors under test;
- Communications in place, or readily installed, for transmitting traffic data and video to a central processing facility (traffic operations center or traffic management center) or another environmentally controlled data collection location;
- Inductive loop detectors in place or capable of being installed;
- Traffic flows that range from light to heavy during a 24-hour period;
- Weather-protected roadside controllers available in which to install detector amplifiers and other signal processing equipment.

3.2 MINNESOTA TEST SITES

Seven potential field test sites were visited in Minneapolis and St. Paul, four suitable for monitoring traffic flows on freeways and three for surface-street arterials. The detector installation and intersection plan-view drawings for the selected Minneapolis sites are contained in Appendix E. The Minneapolis freeway test site was located on I-394 at the Penn Avenue crossing. I-394 is an east-west freeway linking the western suburbs with Minneapolis and is built along the U.S. Highway 12 right-of-way. The freeway has two unrestricted lanes in each direction at this location, as well as two reversible high-occupancy vehicle (HOV) lanes that are used during morning and evening rush hours. The HOV lanes are located between the normal eastbound and westbound lanes. Inductive loop detectors are installed at 0.5-mi (0.8-km) spacing to monitor traffic on I-394. The bridge crossing at Penn Avenue has a changeable message sign (facing westbound traffic) and various exit signs installed.

The eastbound lanes and the HOV lane closest to the eastbound lanes were used as the test bed. The photograph in Figure 3-1 was taken from the Penn Avenue Bridge looking west at eastbound traffic into Minneapolis. The photograph in Figure 3-2 shows the area that was monitored by the detectors on the east side of the bridge. The above-ground detectors were installed to observe downstream traffic moving away from the detectors into Minneapolis, as there is no obstruction on the east side of the bridge over the eastbound lanes. Similarly, detectors were mounted over the HOV lanes to monitor the westbound traffic out of Minneapolis during the afternoon and evening rush hours. Speed-measuring inductive loop detector pairs were installed in the three monitored lanes to obtain vehicle count and speed data to compare with those from radar, infrared, ultrasonic, acoustic, and video image processor (VIP) detector technologies. A camera was placed on the Penn Avenue bridge structure along with the overhead detectors to

Table 3-1. Test Conditions Satisfied at Proposed Test Locations

Test Condition	Minnesota		Florida		Arizona	
	Freeway	Surface Street	Freeway	Surface Street	Freeway	Surface Street
Times of Day						
Daylight	x	x	x	x	x	x
Dawn	x	x	x	x	x	x
Dusk	x	x	x	x	x	x
Night	x	x	x	x	x	x
Vehicles						
Passenger cars	x	x	x	x	x	x
Trucks	x	x	x	x	x	x
Semi-trailers	x	x	x	x	x	x
Buses	x	x	x	x	x	x
Emergency vehicles	x	x	x	x	x	x
Motorcycles	x	x	x	x	x	x
Bicycles		x		x		x
Road equipment	x	x	x	x	x	x
Traffic patterns						
Multiple lanes	x	x	x	x	x	x
Normal traffic	x	x	x	x	x	x
Turning vehicles		x		x		x
Congestion	x	x	x	x	x	x
Long queues*	x	x	x	x	x	x
Stopped vehicles	x	x	x	x	x	x
Adjacent-lane vehicles	x	x	x	x	x	x
Lane straddlers	x	x	x	x	x	x
Weather						
Clear	x	x	x	x	x	x
Overcast	x	x	x	x	x	x
Fog			x	x		
Abrupt lighting changes (luminaries, lightning)			x	x	x	x
Cold temperature extremes	x	x				
Hot temperature extremes			x	x	x	x
Heavy snow	x	x				
Heavy rain			x	x	x	x
Smog**					x	
Haze			x	x		
Artifacts						
Shadows	x	x	x	x	x	x
Sun glare	x	x	x	x	x	x
Electromagnetic interference	x	x	x	x	x	x
Wind sway and vibration	x	x	x	x	x	x

* Long queues: For freeway application, on-ramps and mainline during congested hours.
For surface-street application, at traffic signals.

** Experienced also during the laboratory tests of available detectors conducted in Los Angeles during Summer 1992.

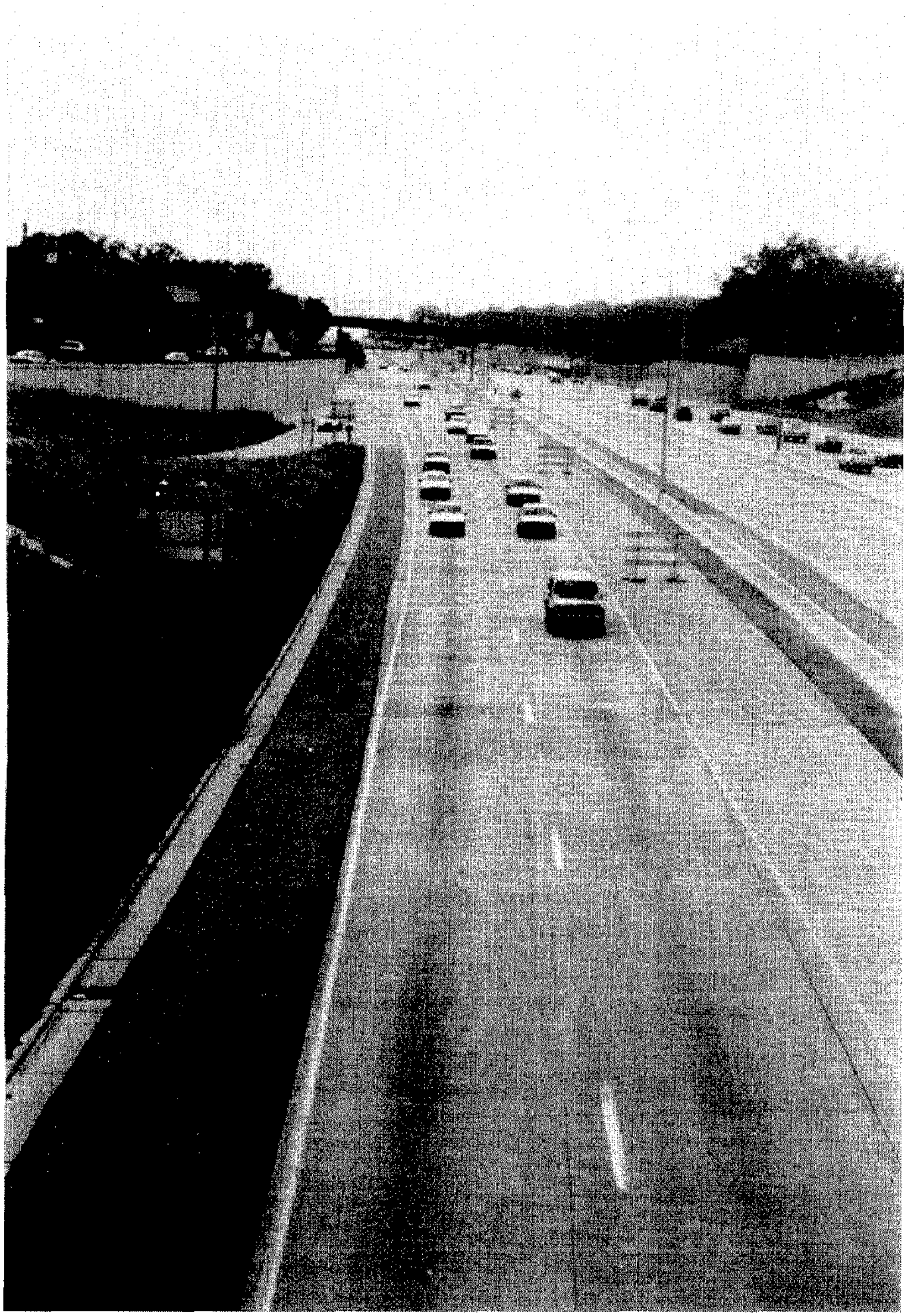


Figure 3-1. I-394 Freeway Test Location Photograph Looking at Eastbound Traffic into Minneapolis Approaching Penn Avenue

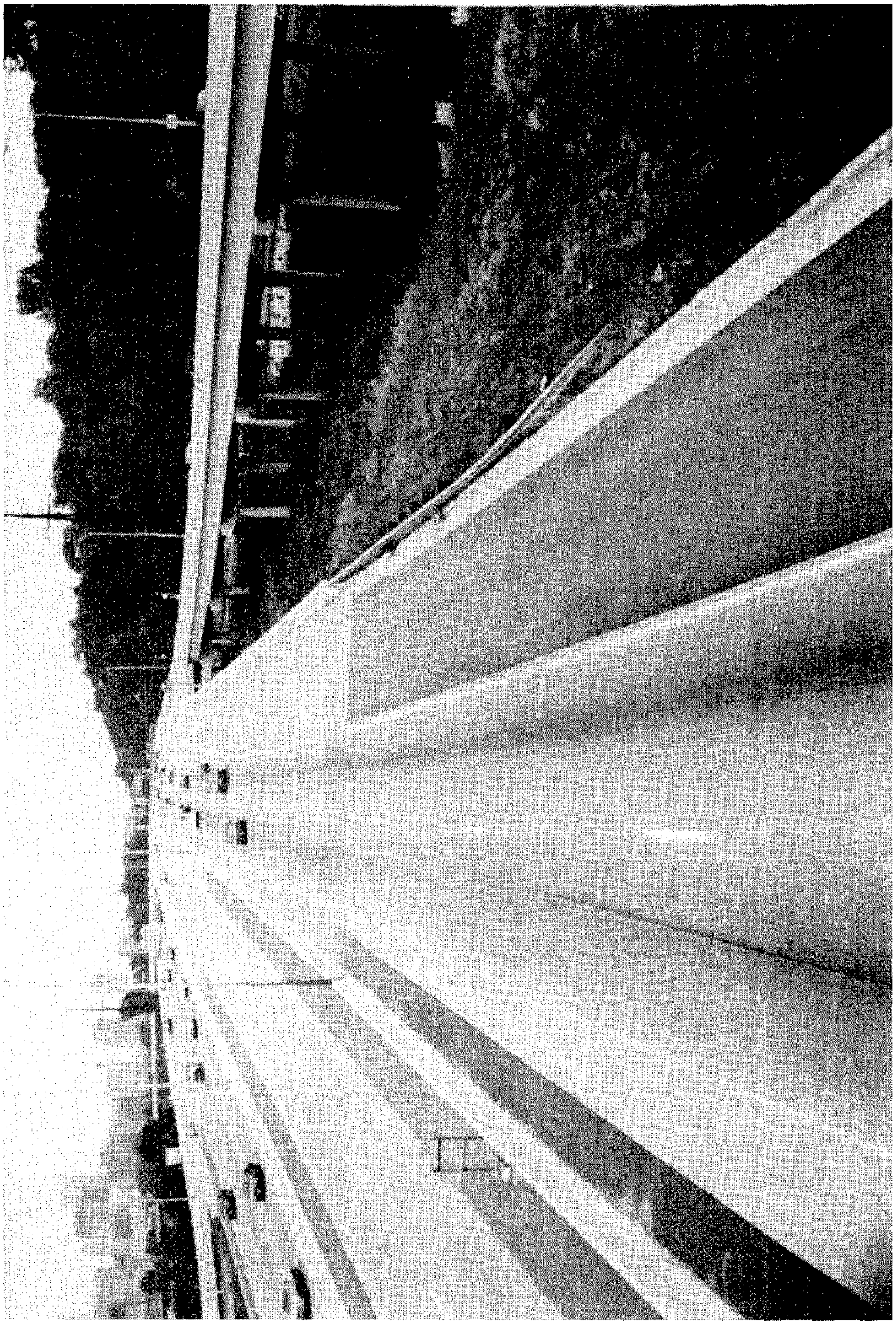


Figure 3-2. I-394 Freeway Test Location Photograph of Eastbound Lanes on East Side of Penn Avenue Bridge as Seen by Detectors

obtain imagery of the traffic flow for ground truth and to serve as an input to the VIPs.

A trailer located on the southeast corner of the Penn Avenue/I-394 intersection was used for recording the outputs of the detectors. Type 170 controllers are used by the Minnesota Department of Transportation (MnDOT).

The selected Minneapolis surface-street site was located on Olson Highway (TH-55) between Lyndale Avenue North and Oak Lake Avenue just east of the I-94 overpass. A sign bridge spans the westbound lanes of TH-55 as shown in Figures 3-3 and 3-4. Detectors were mounted on the rear of the sign to monitor downstream traffic.

Westbound Olson Memorial Highway has three through-traffic lanes and a left and right turn pocket as it approaches Lyndale Avenue as shown in the figures. Fifty-foot (15.2-m) light poles were also available to install detectors for side-looking configurations. A set of single loops were already installed for signal control. The city installed a second loop in each lane to measure vehicle speed during the tests. National Electronic Manufacturers Association (NEMA) controllers are used by the City of Minneapolis.

A trailer located on the south side of Olson Highway was used for recording the outputs of the detectors.

3.3 FLORIDA TEST SITES

Several freeway test sites along Interstate 4 were explored in the Orlando area. The I-4 and SR 436 intersection in Altamonte Springs, north of Orlando, was selected because it accommodated both freeway and surface-street data acquisition and, thus, potentially minimized the setup time. It has an excellent alignment of the overpass with respect to the interstate for mounting the detectors. The detector installation and SR 436 overpass construction plans are contained in Appendix I.

The freeway contains three lanes in both the east and west directions at this location, with the innermost lanes reserved for car pools during peak traffic hours. The SR 436 bridge provides a mounting structure for the detectors overlooking the freeway. The three lanes of I-4 westbound traffic into Orlando, shown in Figure 3-5, were monitored from this vantage point where data from upstream (approaching) vehicles were acquired. A camera was mounted directly over the middle of the monitored freeway lanes to obtain ground truth of the freeway traffic and imagery for the VIPs. Double-loop inductive detectors were installed in all three westbound lanes to measure vehicle count and speed.

The westbound SR 436 surface-street test location, shown in Figure 3-6, has three through lanes and two left-turn lanes that lead to an entrance ramp for I-4 West toward Orlando. The sign bridge for mounting the overhead detectors is located directly over the freeway median. The signal controller cabinet is located on the Northwest corner at the end of the I-4 West off-ramp for SR 436. Double-loop inductive detectors were installed on the SR 436 through lanes to measure vehicle count and speed. A camera was mounted on the pipe tree over the middle lane to view the stop bar and traffic moving away from the overhead detectors.

3.4 ARIZONA TEST SITES

Two freeway sites were visited in Phoenix. The selected test site location, shown in Figures 3-7 and 3-8, is the east-west stretch of I-10 called the Papago Freeway near Thirteenth Street, just east of the tunnel.

There are three mainline westbound lanes and one high occupancy vehicle lane as shown in the figures. A changeable message sign hangs over lane 3 (the rightmost lane). The overhead detectors were mounted directly on the sign bridge structure without using the pipe trees. This was the only test location where the pipe trees were not used. Figure 3-9 shows the build plan for the freeway at the test site location. Double-loop speed measuring inductive detectors were installed in the three mainline lanes to assist in the technology evaluation.

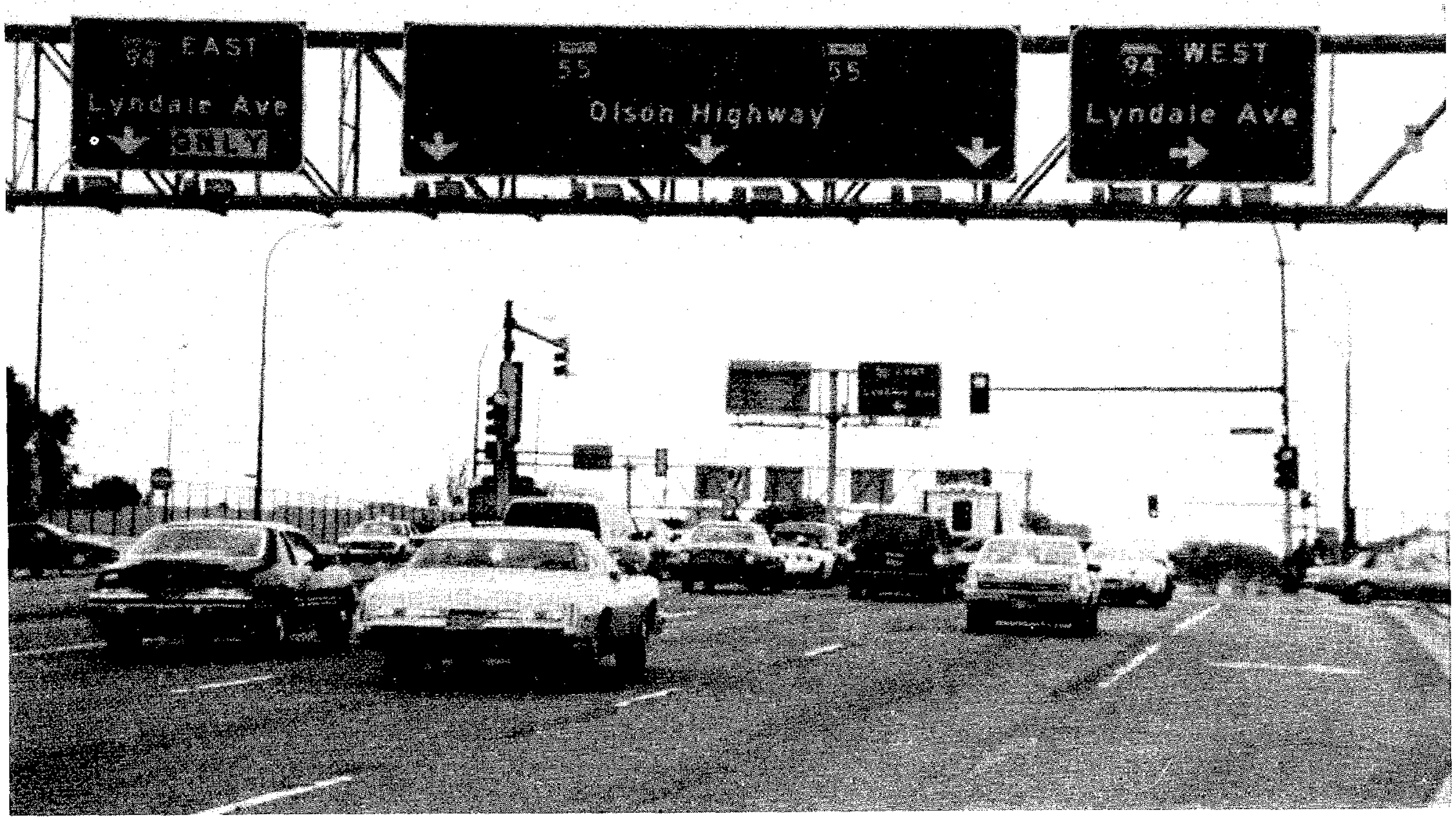


Figure 3-3. Olson Memorial Highway Surface Street Test Location Photograph of Westbound Traffic Lanes – Front of Sign Bridge

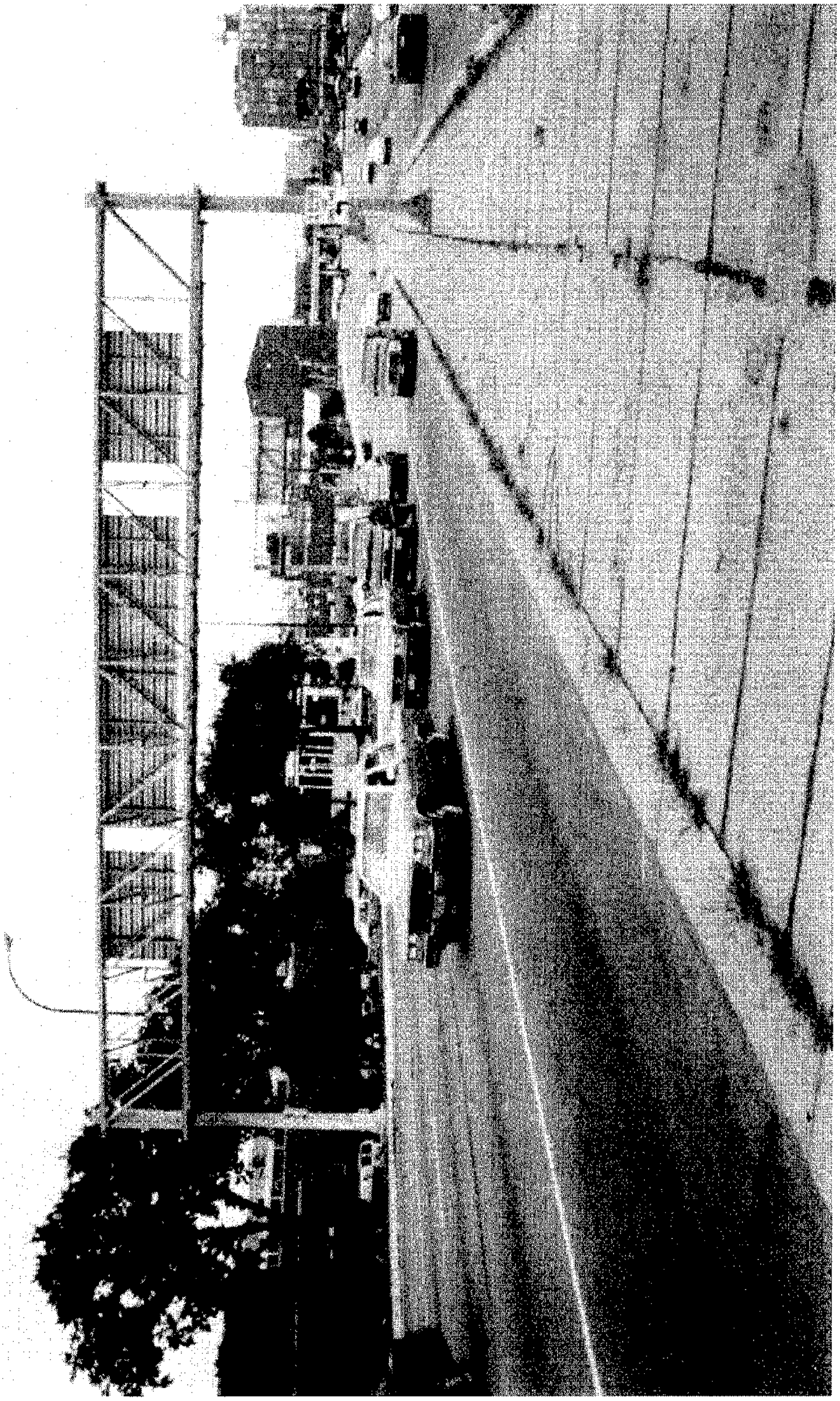


Figure 3-4. Olson Memorial Highway Surface Street Test Location Photograph of Westbound Traffic Lanes – Back of Sign Bridge

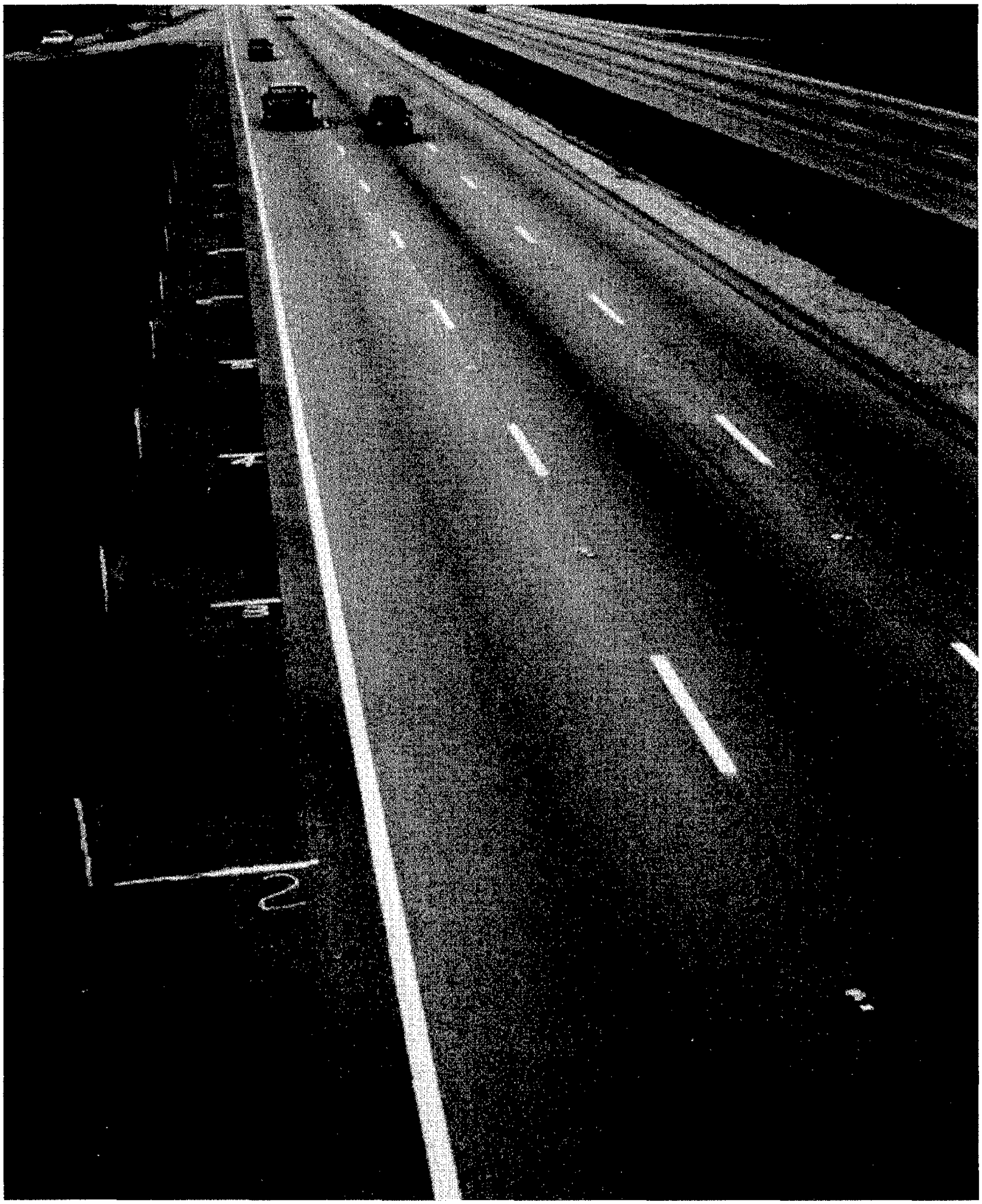


Figure 3-5. I-4 at SR 436 Freeway Test Site Photograph Showing Traffic on I-4 Westbound into Orlando

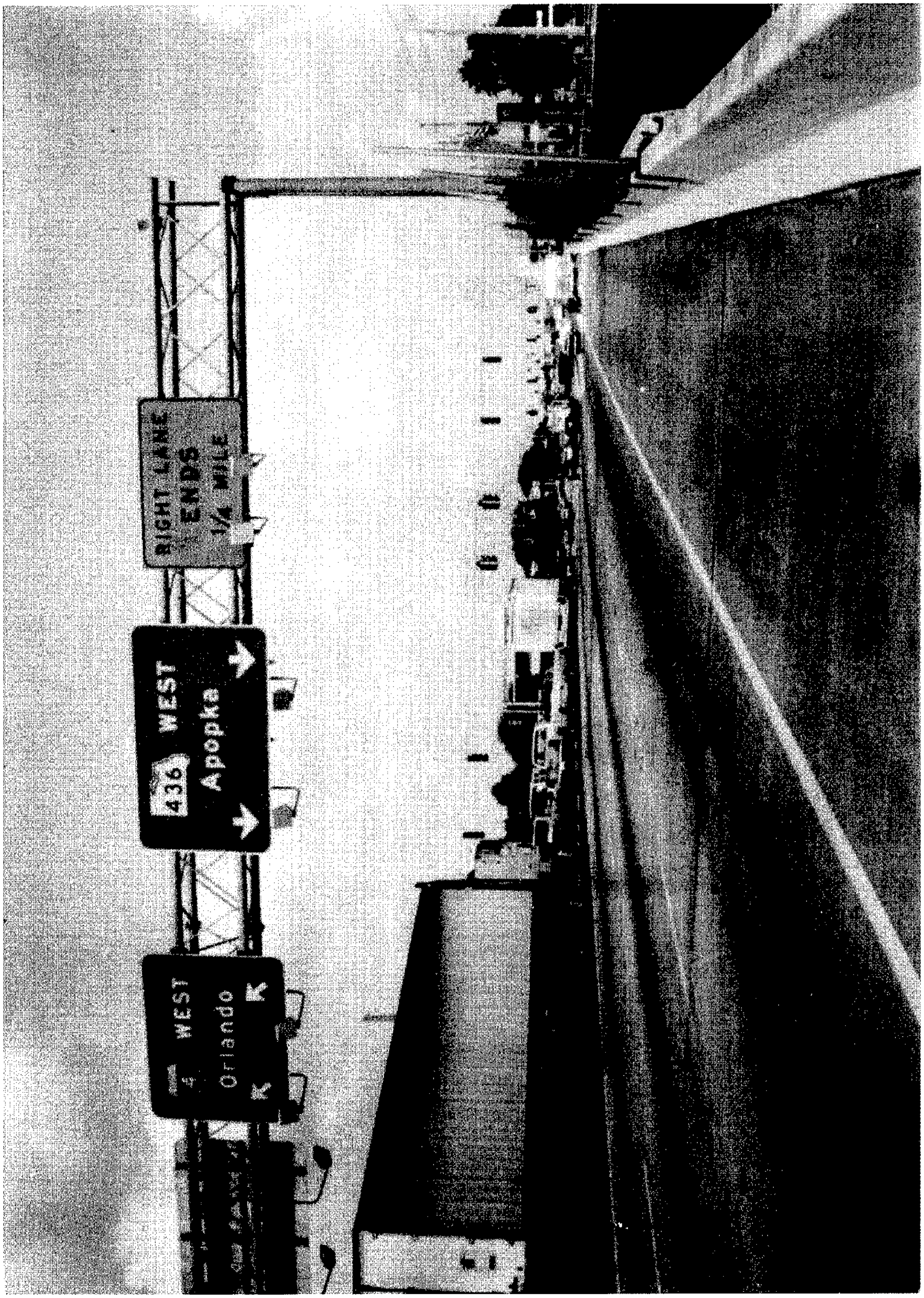


Figure 3-6. SR 436 Surface Street Test Site Photograph Showing Westbound Traffic

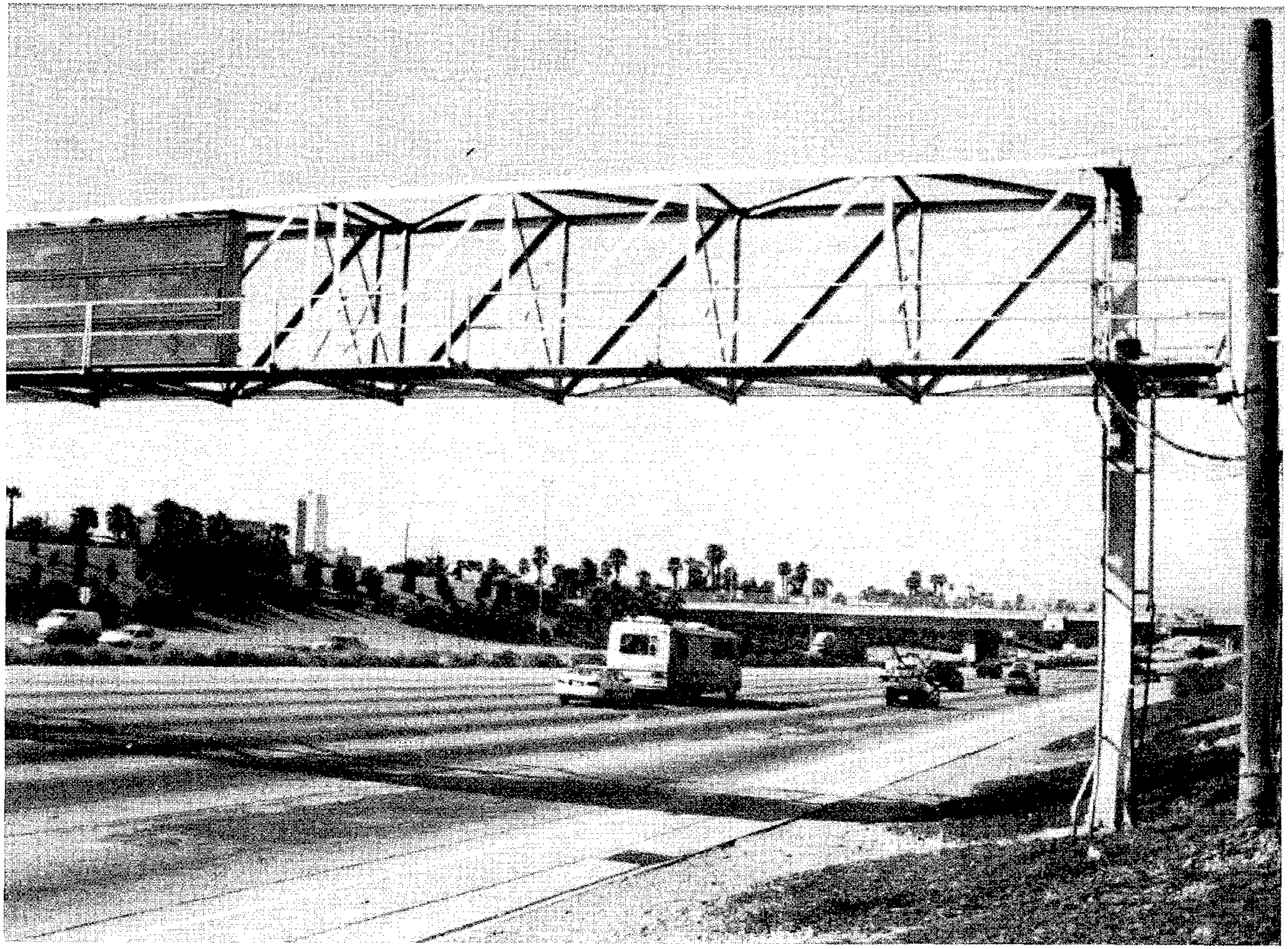


Figure 3-7. Phoenix Freeway Test Site Photograph Showing Westbound I-10 Traffic at Thirteenth Street

Figure 3-8. Phoenix Freeway Test Site Photograph Showing Westbound I-10 Traffic Leaving Deck Tunnel and Heading Toward Thirteenth Street

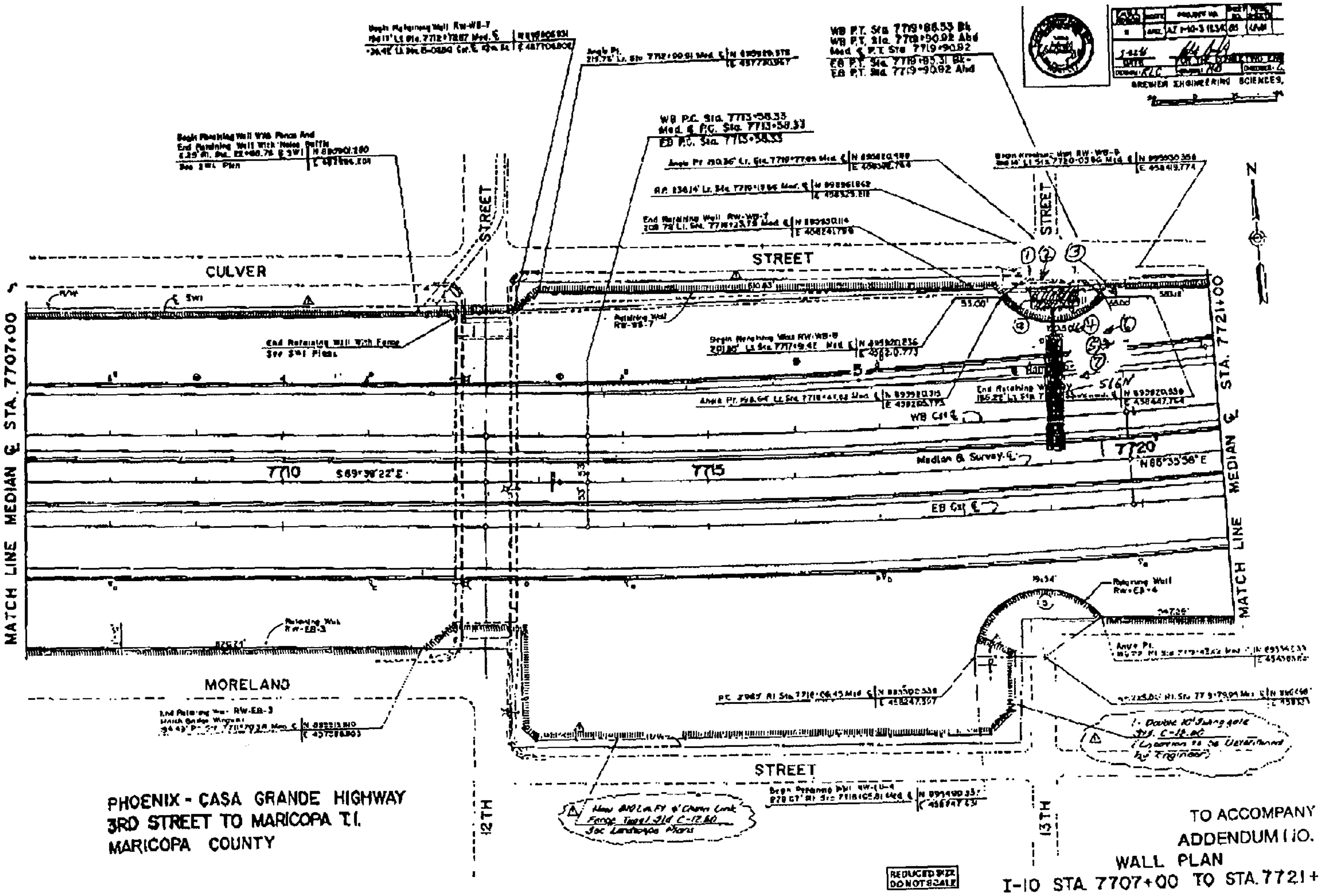


Figure 3-9. Plan-View Drawing for I-10 Freeway Near Thirteenth Street Showing Location of Sign Bridge

Six surface-street arterial test sites were visited in Tucson. The selected site was along Oracle Road at the intersection with Auto Mall Drive and across the street from the largest shopping mall in Tucson. Three lanes in each direction support north-south traffic. According to the City of Tucson, the traffic is well funneled into these lanes by the stoplight on the north side of the intersection. The overhead detectors were mounted on pipe trees and were supported by the signal light mast arm that controls southbound traffic as shown in the southbound view in Figure 3-10. Oncoming traffic southbound on Oracle Road is shown in Figure 3-11.

Double 6-ft by 6-ft (1.8-m by 1.8-m) rectangular loops were installed in the curb and center lanes, round loops in the curb lane, and pairs of microloop detectors in the curb and center lanes in order that these types of loop data may be compared against one another, as well as against the overhead detector data. A trailer situated on the southwest corner of the intersection housed the data recording and analysis equipment.

The city-owned controller cabinet was used to supply the green phase signal for the southbound Oracle Road traffic. Temperatures in the cabinet can reach 170°F (77°C) without a fan during hot weather. The City of Tucson requires equipment to be specified for 80°C (176°F) operation. 115 VAC power came from the pole that supports the traffic signal mast arm.

Figure 3-10. Tucson Surface Street Test Site Photograph Showing Southbound Lanes on Oracle Boulevard

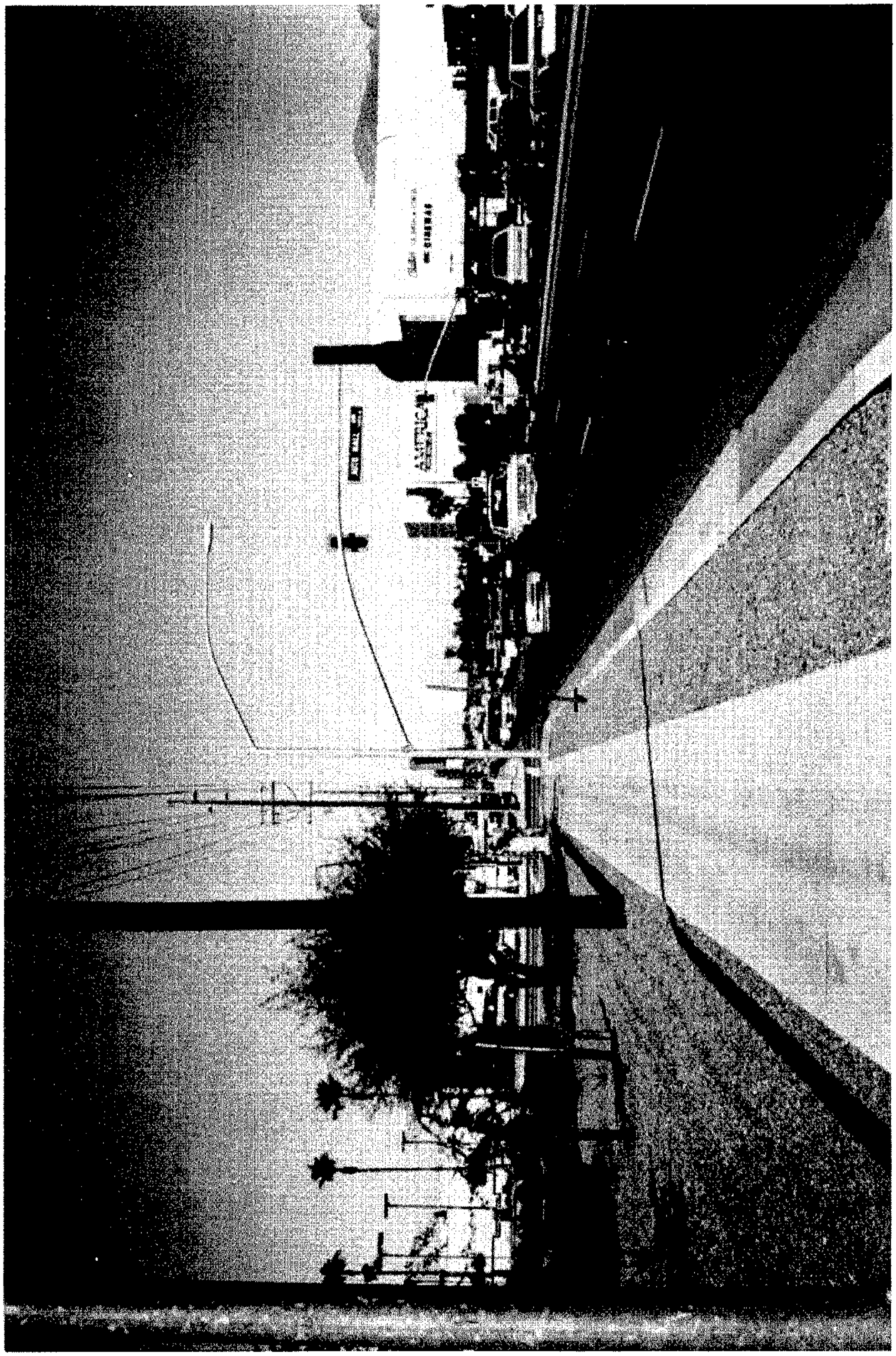


Figure 3-11. Approaching Southbound Traffic on Oracle Road

4. TASK D SUMMARY

SELECT AND OBTAIN VEHICLE DETECTORS

4.1 SELECTION CRITERIA

The criteria used to select vehicle detectors for use in the laboratory tests of Task E and the field tests of Task G were:

- Availability,
- Demonstrated capability,
- Compatibility with controllers in place at the field test locations,
- Representative of current technology, and
- Vendor support.

Availability implies that one or more units would be supplied by the vendor in time to support the field tests beginning in October 1992. This criterion was tightened to include delivery to support the laboratory tests scheduled to begin in May 1992 when possible.

Demonstrated capability implies that the detectors have either been tested by a municipality or Department of Transportation (DOT), or have undergone substantial testing by the vendor.

For compatibility with the controllers used at the test sites, an appropriate interface between the detector or amplifier and the controller must exist, or the interface must be capable of being easily put in place by personnel working for the DOTs.

To be representative of current technologies, a detector must contain design features that allow it to respond to moving and/or stationary vehicles of different sizes and colors; operate in light and heavy traffic flows under most weather conditions; be capable of day and night operation; and be immune to artifacts such as shadows and glint, and false detections from shoulder or adjacent lane objects and vehicles. The effects of these scenarios on each technology is different, as addressed in Section 5.

Vendor support implies cooperation in supplying requested data and operating and mounting instructions, and in resolving problems that arise during the tests.

These criteria were applied to vehicle detectors representative of the following technologies:

- Ultrasonic,
- Infrared (Passive and Active),
- Microwave,
- Video Image Processing,
- Acoustic Arrays,
- Inductive Loop, and
- Magnetic.

4.2 SELECTION PROCESS

Two general paths for selecting detectors for the field tests were considered. The first is an ideal path shown in the upper part of Figure 4-1. It is suitable if present-day detectors meet the IVHS requirements of the future as specified in Section 2.

The ideal detector selection path begins by establishing user requirements through discussions with city, county, state, regional, and federal transportation agencies and other major interested parties such as equipment manufacturers. These requirements are then analyzed and consolidated into categories that represent the IVHS applications and services surfaced through the discussions. Detectors that meet the requirements undergo further screening in laboratory tests, checking for operational compatibility with field site support services and anticipated traffic conditions (e.g., mounting configuration, communications, and weather and traffic volume environments), and verifying non-interference with the operation of other detectors. Finally, those detectors that pass the screen are chosen for further evaluation in the field tests.

In our case, it was found that none of the available detectors would meet all of the requirements developed in Section 2. Therefore, the detector selection path shown in the lower part of Figure 4-1 was used. Here the capabilities of currently available detectors are determined from the Federal Highway Administration (FHWA), user evaluations, vendors, conferences, journals, and other personal contacts. Instead of eliminating detectors that do not pass all IVHS requirements, all detectors are allowed to enter the screening process. Those that perform to the vendor's specifications are selected for further evaluation in the field tests.

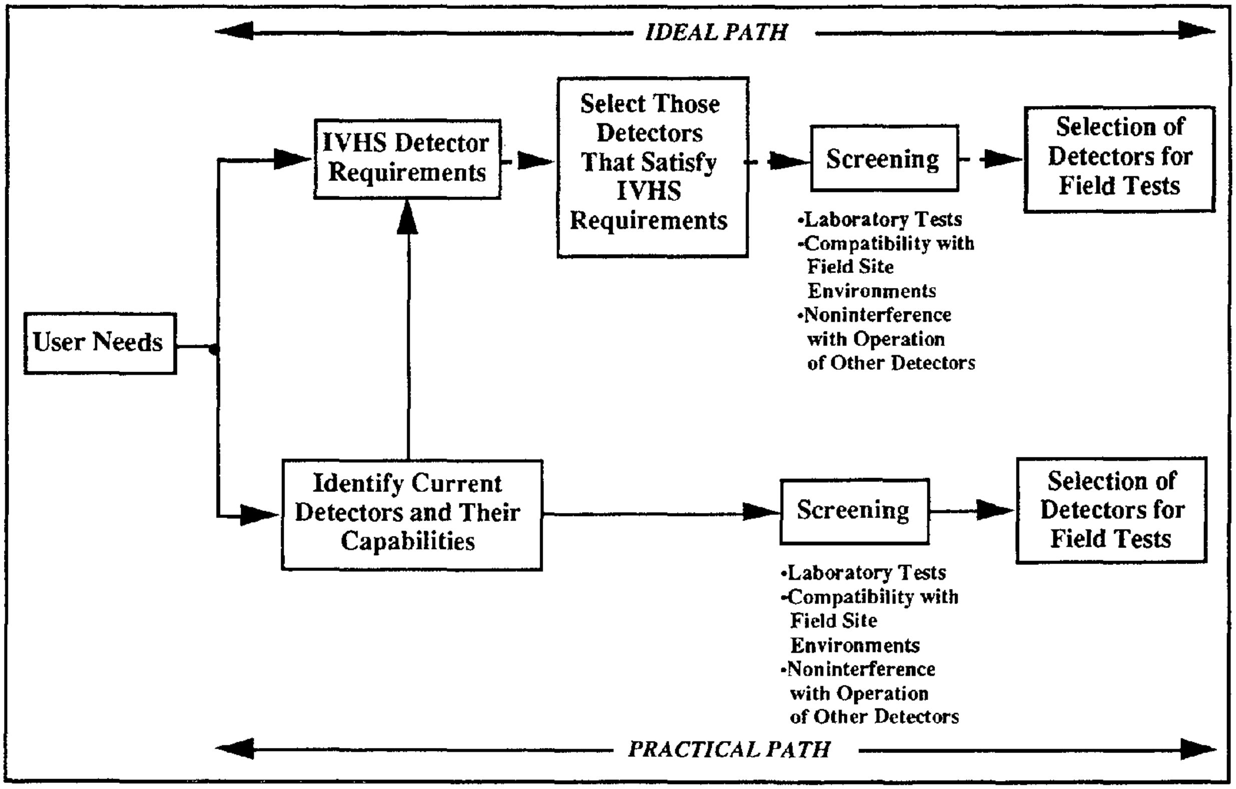


Figure 4-1. Detector Selection Processes

In applying the process just described, municipalities such as the City of Los Angeles; DOTs in Minnesota, Florida, Arizona, and California; and other user organizations such as the Enterprise Group were contacted to gather information about potential manufacturers and test results on their products. These contacts sometimes led to studies that evaluated detector performance, such as those conducted by the Institute of Transportation Studies at Berkeley and the Transportation Research Group at the California Polytechnic State University at San Luis Obispo.(1,2) As the *Detection Technology for IVHS Program* progressed, other manufacturers were made known to the principal investigator by the Contracting Officer's Technical Representative (COTR) and personnel within Hughes Transportation Management Systems. Still other sources of detectors were gathered from reviews of industry journals, such as those published by the Institute of Transportation Engineers (ITE), and from attendance at conferences sponsored by the Transportation Research Board (TRB), IVHS America, American Society for Testing and Materials (ASTM), and ITE. Manufacturers also contacted the principal investigator at technical meetings and exhibits where they were present.

Lists of detector models and specifications by technology are shown in Tables 4-1 through 4-8 for above-the-road and in-ground

Table 4-1. Specifications of Ultrasonic Vehicle Detectors Evaluated

Detector	Detectable Objects	Transmit Frequency	3 dB Beam-width	Speed Measurement Range	Speed Measurement Accuracy	Detection Range	Min Vehicle Separation	Peak Output	Pulse Repetition Period (T_o)	Pulse Width (T_p)	Signal Hold Time (T_h)
Sumitomo Vehicle Speed Detector SDU-200	Subcompact cars and larger	25.5 KHz ± 1 KHz	15 deg	4-120 km/h (2.5-75 mph)	± 10%	8 m (26 ft)	< 10 m (33 ft)	14 ± 3 V_{pp}	Not Applicable	Not Applicable	Not Applicable
Sumitomo Vehicle Detector SDU-300	Subcompact cars and larger	26 KHz ± 1 KHz	≈13 deg	Not Applicable	Not Applicable	1.5 to 8 m (4.9 to 26 ft)	1.2 m + vehicle speed in m/sec x 0.15 sec	<10 watts	33 ± 3 msec	2 ± 0.5 msec	115 msec ± 10%
Microwave Sensors TC-30C	Pedestrians, bicycles, and all motorized vehicles	49.7 KHz	≈20 deg	Not Applicable	Not Applicable	7 m (23 ft)	1.5 m (5 ft) at 70 mph	Transmitted acoustic energy is 110 dB at 20 µpascals at 1 m	100 msec	0.02 msec	0.25 to 10 sec

Table 4-2. Specifications of Active Infrared Detectors Evaluated

Detector	Instantaneous Field of View (FOV)	Vehicle Classification	Speed Measurement Range	Detection Range	Response Time	Flow	Presence Hold Time
Schwartz Electro-Optics 780D1000	•2 beams, each 1 mrad (El) by 9.5 deg (Az) •Beam separation in El = 10 deg	Auto or truck	0 to > 80 mi/h with ±1 mi/h accuracy up to 70 mi/h	1.5 - 15 m (5 - 49 ft)	≈10 ms	0 to >1800 veh/h	For as long as vehicle is in FOV of detector

1 mi/h = 1.61 km/h

Table 4-3. Specifications of Passive Infrared Detectors Evaluated

Detector	Detectable Objects	Detection Range and Footprint	Response Time	Maximum Speed at Which Vehicles Are Counted	Hold Time
Eltec 842*	Bicycle and any motorized vehicle	6.4 - 16 m (21 - 54 ft) slant range with corresponding footprints (El x Az) of 93.2 x 99.8 cm to 237.0 x 490.5 cm (36.7 x 39.3 in to 93.3 x 193.1 in)	<250 ms	>100 mi/h (160.9 km/h)	True presence detector with 6 minutes maximum hold time for vehicles in FOV of detector
Eltec 833*	Bicycle and any motorized vehicle	5 - 30 m (16 - 98 ft) down range with corresponding footprint diameters of 0.4 to 2.2 m (1.3 to 7.2 ft)	50 to 100 ms	85 mi/h (136.8 km/h)	Pulse-type counting operation with count held for up to 4 seconds

* Photon-sensitive element is made of lithium tantalate (a type of pyroelectric material). Spectral response used is from 8 to 12 micrometers.

Table 4-4. Specifications of Microwave Detectors Evaluated

Detector	Detectable Objects	Transmit Frequency	Power Output	Polarization (Transmit & Receive)	3dB Beam-width	Speed Measurement Range	Speed Measurement Accuracy	Detection Range	Response Time
Microwave Sensors TC-20	Mopeds and larger traveling at speeds > 2 mph at signal-controlled intersections	10.525 GHz	-18 dBm (56,234 µV/m at 30 m distance)	Horizontal	16 deg Az, 15 deg El (Ant Gain = 16.4 dB)	Not Applicable	Not Applicable	1-30 m (3-100 ft)	0.165 sec
Microwave Sensors TC-26	Mopeds and larger traveling at speeds > 3 mph on city arterials and freeways	10.525 GHz	-18 dBm (56,234 µV/m at 30 m distance)	Horizontal	16 deg Az, 15 deg El (Ant Gain = 16.4 dB)	5-106 km/h (3-66 mph)	•Speed is segregated into 1 of 5 bins which together cover the range 5 to 106+ km/h •Speed is also available in terms of Doppler frequency shift to within ± 1 mph	Up to 61 m (200 ft) for autos; up to 107 m (350 ft) for trucks	0.165 sec
Whelen TDN-30	Any licensed motor vehicle separated by one car length and traveling at speeds > 5 mph	10.525 GHz	< 2.5 mW/cm^2	Horizontal	7 deg (1st sidelobe at -10 dB)	8 - 137 km/h (5 - 85 mph)	Within ± 2 mph at all speeds	Designed to project an ≈6-ft-diameter footprint at a mounting height of 32 ft	Not applicable since detector gives a direct speed measurement
Whelen TDW-10	Multiple-lane coverage of any licensed motor vehicle traveling at speeds > 5 mph	10.525 GHz	< 2 mW/cm^2	Horizontal	25 deg (1st sidelobe at -3 dB)	8 - 137 km/h (5 - 85 mph)	Within ± 3 mph at all speeds	Up to 30.5 m (100 ft)	Not applicable since detector gives a direct speed measurement

Table 4-4. Specifications of Microwave Detectors Evaluated (continued)

Detector	Detectable Objects	Transmit Frequency	Power Output	Polarization (Transmit & Receive)	3dB Beamwidth	Speed Measurement Range	Speed Measurement Accuracy	Detection Range	Response Time
Electronic Integrated Systems Remote Traffic Microwave Sensor (RTMS)	Presence and speed detector for motorcycles and larger	10.525 GHz	< 2.5 V/m at 3 m distance	Horizontal	15 deg Az, 25 deg El • Beam shaping results in a user-definable azimuth footprint of 10 to 15 ft at a range of 100 ft • Beam shaping results in an effective elevation beamwidth of 50 deg	0 - >160 km/hr (0 - >99 mph)	Within ± 10%	• Sidefire: Up to 12 lanes covered • Up to 60 m (200 ft) with resolution of 2 m (7 ft) in 12 detection zones • Overhead: 1 lane covered • Occupancy of a zone at < 2% error • Traffic volume in a zone at < 5% error	< 20 msec

Table 4-5. Specifications of Video Image Processors Evaluated

Manufacturer/ Model	Number of Traffic Lanes Monitored[a]	Speed Measurement Range	Speed Measurement Accuracy[b]	Detection Range	Vehicle Tracking
Econolite/ Autoscope 2003[d]	8	0 to > 80 mi/h	±2 mi/h	46 m (150 ft)[c]	No
Computer Recognition Systems/ Traffic Analysis System[e]	4	0 to > 80 mi/h	± 2 to 5%	46 m (150 ft)[c]	Yes
Traficon/ CCATS-VIP 2[f]	4	0 to 112 mi/h	–	46 m (150 ft)[c]	Yes
Sumitomo/ IDET-100[g]	4	0 to 100 mi/h (3 lanes), 0 to 75 mi/h (4 lanes)	± 5%	–	Yes
EVA/ 2000[h]	4	0 to 155 mi/h	–	29 m (95 ft)[h]	Yes

1 mi/h = 1.61 km/h

a. Per camera.

b. Function of frame rate, camera resolution, vehicle speed, and camera mounting height.

c. Based on vehicle occlusion as a function of camera mounting height, intervehicle gap, and vehicle height. Value in table reflects mounting height = 25 ft (7.6 m), intervehicle gap = 30 ft (9.1 m), and vehicle height = 5 ft (1.5 m).

d. Typical traffic data reported by Autoscope include volume (number of vehicles/time interval), lane occupancy (time vehicle is in detection zone divided by the time interval), headway over time (average number of seconds between consecutive vehicles during the time interval), speed of a single vehicle, average speed of all vehicles during the time interval, classification of a single detection based on vehicle length (three classes are available), and classification of time interval data.(3)

e. Typical traffic data reported by the Traffic Analysis System include mean speed of vehicles in each of three classes; overall mean speed; length of the vehicle; area of the vehicle; number of vehicles in each of the three classes; total number of vehicles; density of vehicles; occupancy; and per lane parameters that include number of vehicles, average speed, density, and occupancy.(4)

f. CCATS-VIP 2 incorporates a graphical data interpretation and display package that outputs total number of vehicles and number per lane, gap time between vehicles, occupancy per lane, vehicle classification (up to three types) based on length, mean length of all detected vehicles, and alarms at lower and upper thresholds set by user.(5)

g. Traffic data is reported by the IDET-100 by lane over an RS-232 interface. Data include vehicle detection with a 90 percent accuracy; vehicle type as small or large; velocity in km/h; vehicle motion as moving, recently stopped, or parked; and the pulse width of the detection signal. The maximum length of the detection zone is 20 meters. The speed measurement accuracy of ± 10 percent is based on a field test of approximately 250 units in Japan.(6,7)

h. EVA 2000 provides volume, average speed, density, occupancy, average spatial headway, and count, each on a per lane and vehicle type (two types are supported) basis. Tracks individual vehicles, even when they cross lanes.(8)

Table 4-6. Specifications of Passive Acoustic Detectors Evaluated

Manufacturer/ Model	Number of Traffic Lanes Monitored	Detection Frequency Band	Detection Beam Pattern	Detection Range	Response Time
AT&T/ SmartSonic TSS-1	Single detection zone in 1 lane from overhead mount	4 kHz to 6 kHz	6 deg (3 dB) 20 deg (10 dB)	20 to 35 feet (6.1 to 10.7 m)	50 ms

Table 4-7. Inductive Loop Detector Specifications

Parameter	NEMA TS-1 1989	California July 1989	Connecticut 1991-1992	Florida May 1991
Reference to NEMA specifications made	Not Applicable	No	No	No, but many NEMA sections included
Type of vehicle detected	Class 1: small motorcycle Class 2: large motorcycle Class 3: automobile	All motor vehicles that can be licensed in California	Not specified	Class 1: small motorcycle Class 2: large motorcycle Class 3: automobile
Speed Range	5 to 80 mph	Not specified	Parked and speeds greater than 0 mph	5 to 80 mph
Sensitivity	A minimum of 3 settings Shall be able to detect Class 1, 2, or 3 vehicle when connected to any test loop described below	A minimum of 7 selectable sensitivity settings Shall detect vehicle with minimum change in inductance of 0.02% at setting 6	Not specified	A minimum of 3 settings Shall be able to detect Class 1, 2, or 3 vehicle when connected to any test loop described below
Response Time	For Class 1 vehicle, less than 126 msec; For Class 3 vehicle, less than 51 msec	5 ± 1 msec for sensitivity setting 2	Not specified	For Class 1 vehicle, less than 126 msec; For Class 3 vehicle, less than 51 msec
Detection zone	3 feet maximum beyond loop	3 feet maximum beyond loop	Not specified	3 feet maximum beyond loop
Pulse Mode	Output between 100 - 150 msec when test vehicle enters detection zone	Output pulse of 125 ± 25 msec when test vehicle enters detection zone	Output pulse not specified	Output between 75 to 150 msec when test vehicle enters detection zone

Table 4-7. Inductive Loop Detector Specifications (continued)

Parameter	NEMA TS-1 1989	California July 1989	Connecticut 1991-1992	Florida May 1991
Presence Mode	When a Class 2 vehicle is over a test loop, the detector output shall be maintained for at least 3 minutes if vehicle remains that long	At sensitivity setting 6, the minimum duration of the detector output shall be 3 minutes if vehicle remains that long	Detection shall persist up to at least 10 minutes	When a Class 2 vehicle is over a test loop, the detector output shall be maintained for at least 3 minutes if vehicle remains that long
Recovery from sustained occupancy	Detector shall recover 90% of normal sensitivity within 1 sec after vehicle leaves detection zone	Detector shall recover normal sensitivity within 1 sec after vehicle leaves detection zone	Not specified	Detector shall recover 90% of normal sensitivity within 1 sec after vehicle leaves detection zone
Environmental change	Detector shall automatically adjust for changes in loop/ lead-in properties which might be reasonably expected	Detector shall compensate for a change in inductance of 0.001% per sec, up to a total change of ± 5.0% Temperature changes of up to 1 deg C per 3 minutes shall not affect detector operation	Detector shall compensate for environmental drift Detector shall operate properly between -30 deg F and 150 deg F	Detector shall automatically adjust for changes in loop/ lead-in properties which might be reasonably expected
Delay Operation	Detector output delayed from 0 to 15 sec in 1-sec increments, and from 16 to 30 sec in 2-sec increments	Not specified	Detector output delayed from 0 to 31 sec in 1-sec increments	Detector output delayed from 0 to 30 sec
Extended Operation	Detector output extended from time vehicle leaves loop by 0 to 7.5 sec in 1/2-sec increments	Not specified	Detector output extended from time vehicle leaves loop by 0 to 15.5 sec in 1/2-sec increments	Not specified

Table 4-7. Inductive Loop Detector Specifications (continued)

Parameter	Georgia	Missouri	New York June 1990	Oklahoma
Reference to NEMA specifications made	Not mentioned	Not mentioned	No	Yes
Type of vehicle detected	Not specified	Not specified	All licensed motor vehicles except mopeds	Not specified – see NEMA spec
Speed Range	0 to 80 mph	0 to 80 mph	Not specified	0 to 100 mph
Sensitivity	Shall detect a vehicle with minimum change in inductance of 0.02%	Not specified	A minimum of 7 selectable sensitivity settings Shall detect vehicles with minimum change in inductance of 0.02% at setting 6	Not specified – see NEMA
Response Time	Not specified	Not specified	5 ± 1 msec for sensitivity setting 2	Not specified – see NEMA
Detection Zone	Not specified	Not specified	3 feet maximum beyond loop	Not specified – see NEMA
Pulse Mode	Output pulse not specified	Output pulse not specified	Output pulse of 125 ± 25 msec when test vehicle enters detection zone	Required,but not specified – see NEMA
Presence Mode	When a Class 2 vehicle is over the test loop, the detector output shall be maintained for at least 3 minutes.if vehicle remains that long	At sensitivity setting 6, the duration of the detector output shall be 3 minutes if vehicle remains that long	Detection shall persist up to at least 10 minutes	When a Class 2 vehicle is over a test loop, the detector output shall be maintained for at least 3 minutes if vehicle remains that long

Table 4-7. Inductive Loop Detector Specifications (continued)

Parameter	**Georgia**	**Missouri**	**New York June 1990**	**Oklahoma**
Recovery from sustained occupancy	Detector shall recover 90% of normal sensitivity within 1 sec after vehicle leaves detection zone	Detector shall recover normal sensitivity within 1 sec after veh. leaves detection zone	Not specified	Detector shall recover 90% of normal sensitivity within 1 sec after vehicle leaves detection zone
Environmental change	Detection shall automatically adjust for changes in loop/ lead-in properties which might be reasonably expected	Detector shall compensate for a change in inductance of 0.001% per sec, up to a total change of ± 5.0% Temperature changes of up to 1 deg C per 3 minutes shall not affect detector operation	Detector shall compensate for environmental drift Detector shall operate properly between -30 deg F and +150 deg F	Detector shall automatically adjust for changes in loop/ lead-in properties which might be reasonably expected
Delay Operation	Detector output delayed from 0 to 15 sec in 1-sec increments, and from 16 to 30 sec in 2-sec increments	Not specified	Detector output delayed from 0 to 31 sec in 1-sec increments	Detector output delayed from 0 to 30 sec
Extended Operation	Detector output extended from time vehicle leaves loop by 0 to 7.5 sec in 1/2-sec increments	Not specified	Detector output extended from time vehicle leaves loop by 0 to 15.5 sec in 1/2-sec increments	Not specified

Table 4-8. Magnetometer Specifications

Parameter	Value
Operation Modes	Two, Pulse and Presence
Vehicle Types	Auto, trucks, buses, motorcycles, motor bikes, bicycles
Vehicle Speed	0 to 100 mi/h (160.9 km/h)
Selectivity	High steel concentrated area shall not affect operation
Output Signal	Pulse Mode: Relay contact closure of 25-ms minimum (Connecticut); 125 ± 25 ms (California) Presence Mode: Relay contact closure for duration of presence of the vehicle (Connecticut); same for California except add that indication shall cease within 100 ms
Detection Area	18 inches (457.2 mm) minimum on either side of sensing head
Distance Between Control Unit and Sensing Head	3000 feet (914.4 m) minimum
Power Interruption	The control unit shall return to normal operation within 3 minutes following a power interruption

detectors. The above-the-road models were evaluated during the laboratory and field tests. Inductive loops and magnetometers were evaluated with the above-the-road technology models during the field tests. The specific inductive loop detector amplifier models and magnetometers used in the field tests were selected in consultation with the host cities and states and the manufacturers. Inductive loops were cut using state-of-the-art installation techniques. The detector amplifi-ers were supplied by the host agency and were representative of state-of-the-art signal processing technology. Loop and magnetome-ter manufacturers and distributors, including Indicator Controls Corporation, Detector Systems, Saratec Traffic, and 3M, were contacted to obtain copies of specifications and performance data for their most current products.

4.3 TECHNICAL JUSTIFICATION

The technical justification for detector selection and rejection in the field tests was based on:

- Detector performance in freeway and surface street demonstration tests conducted by Hughes, DOTs, and other evaluation projects funded by states or FHWA;
- Detector design criteria that allow operation in anticipated weather environments;
- Availability of detectors in time to meet laboratory and field test and evaluation schedules;
- Manufacturer support to help interpret specifications and evaluation data, and make available RS-232 serial data protocols that describe the data output by the detector.

Detector performance was judged against the specifications provided by the manufacturer. If the laboratory or other demonstration test performance met the manufacturer's specifications and the specifications represented state-of-the-art performance, then the detectors were used in the field tests.

The manufacturers design criteria and test data helped determine if the detectors operated in cold, hot, fog, and wet weather environments and in electrical disturbances, such as lightning, anticipated for the field tests.

Availability of detectors became a consideration because of the lead time needed to set up equipment and build required mounting brackets and interface electronics. Some of the detectors are new development models whose production-model runs do not yet exist.

Manufacturer support in making available specifications, operating procedures, and test procedures not normally supplied with the detectors made the laboratory and field testing of these devices easier and more meaningful.

A selection matrix showing which of the technical criteria are satisfied by the detectors selected is given in Table 4-9.

All detectors that met these criteria were used in the field tests. As none of the detectors met all of the future IVHS requirements listed in Section 2, the field tests were instead used to verify performance of the current state-of-the-art detectors and to make recommendations for future improvements.

4.4 ON-BENCH PHOTOGRAPHS OF DETECTORS

Pages 4-16 through 4-26 contain photographs of the detectors that represent the technologies evaluated in the project. The detectors not shown were not available during the photography sessions. The manufacturers and specification summary corresponding to each detector model can be found in Tables 4-1 through 4-6. A brief description of each detector is given in Section 10.6.

Table 4-9. Detector Output Data and Operating Environments

Traffic Parameter / Detector Technology and Model	Data							Environment						Mount	
	Count	Presence	Speed	Speed Binning	Occupancy	Vehicle Length	Incident Detection	Adequate Range	Rain	Fog	Snow	Day	Night	Overhead*	Side Looking
Ultrasonic															
Sumitomo SDU-200 (RDU-101)	x		x		I	x	I	x	x	x	x	x	x	U	
Sumitomo SDU-300	x	x			x		I	x	x	x	x	x	x	N	
Microwave Sensors TC-30C	x	x			I		I	x	x	x	x	x	x	N	
Infrared (Active)															
Schwartz Electro-Optics	x	x	x		I	x	I	x	?	?	?	x	x	U,D	
Infrared (Passive)															
Eltec 842	x	x			I		I	x	?	?	?	x	x	U,D**	
Eltec 833	x						I	x	?	?	?	x	x	U,D	
Microwave Radar															
Microwave Sensors TC-20	x							x	x	x	x	x	x	U,D	x
Microwave Sensors TC-26	x			x			I	x	x	x	x	x	x	U,D	
Whelen TDN-30	x		x				I	x	x	x	x	x	x	U,D	
Whelen TDW-10	x		x				I	x	x	x	x	x	x	U,D	
Electronic Integ. Systems RTMS	x	x	x		x		I	x	x	x	x	x	x	U,D	x
Video Image Processing															
AutoScope 2003	x	x	x	x	x	x	x	x	?	?	?	x	x	U,D	x
Computer Recog. Systems TAS	x	x	x	x	x	x	x	x	?	?	?	x	x	U,D	x
Golden River Traffic C-CATS	x	x	x	x	x	x	x	x	?	?	?	x	x	U,D	x
Sumitomo IDET-100	x	x	x	x	x	x	x	x	?	?	?	x	x	U,D	x
EVA 2000	x	x	x	x	x	x	x	x	?	?	?	x	x	U,D	x
Acoustic Array															
AT&T TSS-1	x	x			x			x	?	x	?	x	x	D	
Inductive Loop Detectors	x	x	I		x		I	x	x	x	x	x	x		
Magnetometers	x	x	I		x		I	x	x	x	x	x	x		

* U = functions when viewing upstream, D = functions when viewing downstream, N = functions when viewing in nadir direction.

** Manufacturer recommends that Model 842 be mounted at an oblique angle to the traffic flow.

x represents either (1) data that are measured directly, (2) acceptable operating environments, or (3) side-mounted operation.

I represents information available through processing of detector data, i.e., indirectly available information.

? represents a possible degradation in performance dependent on the severity of the environment.

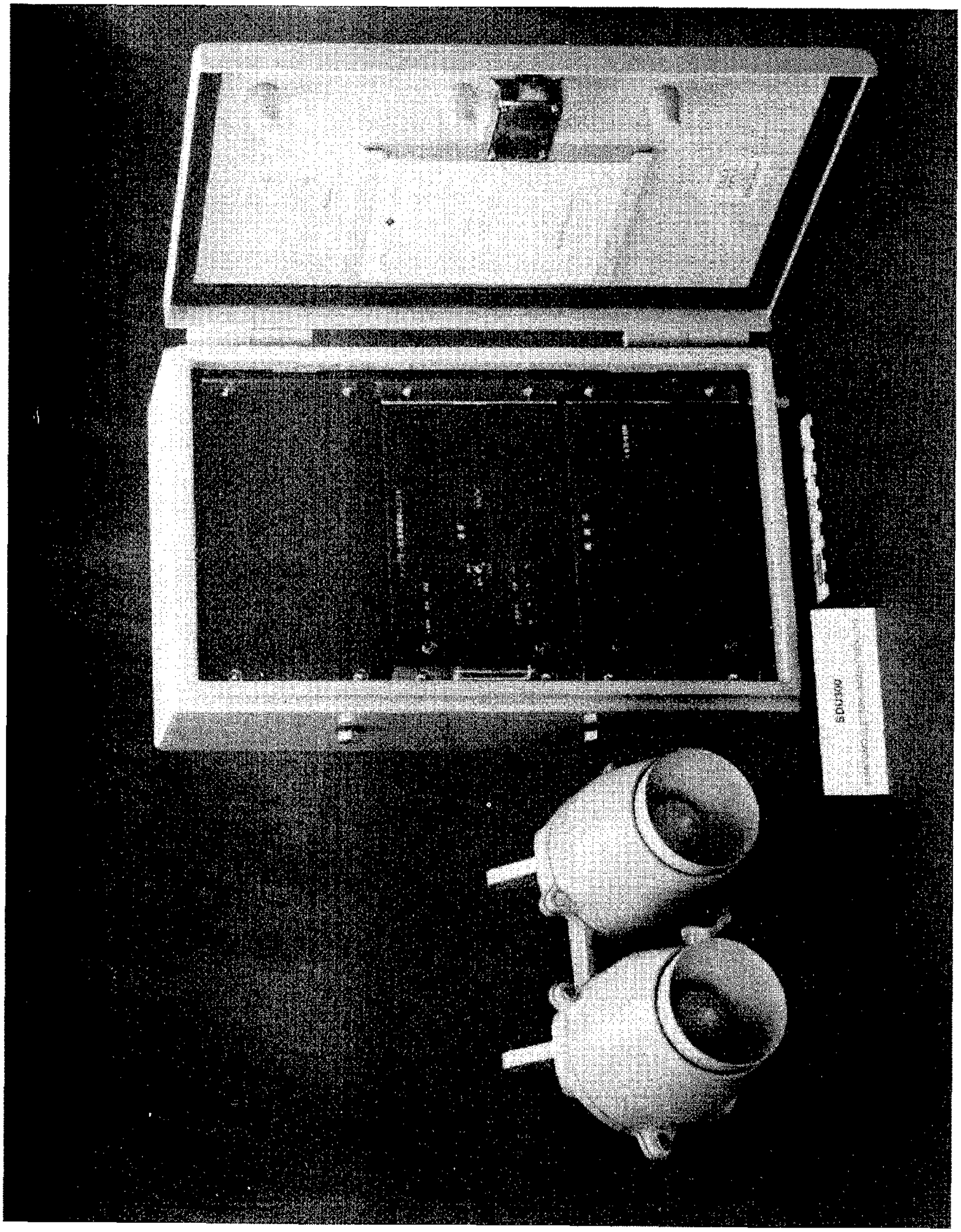


Figure 4-2. SDU-200 (RDU-101) Ultrasonic Detector

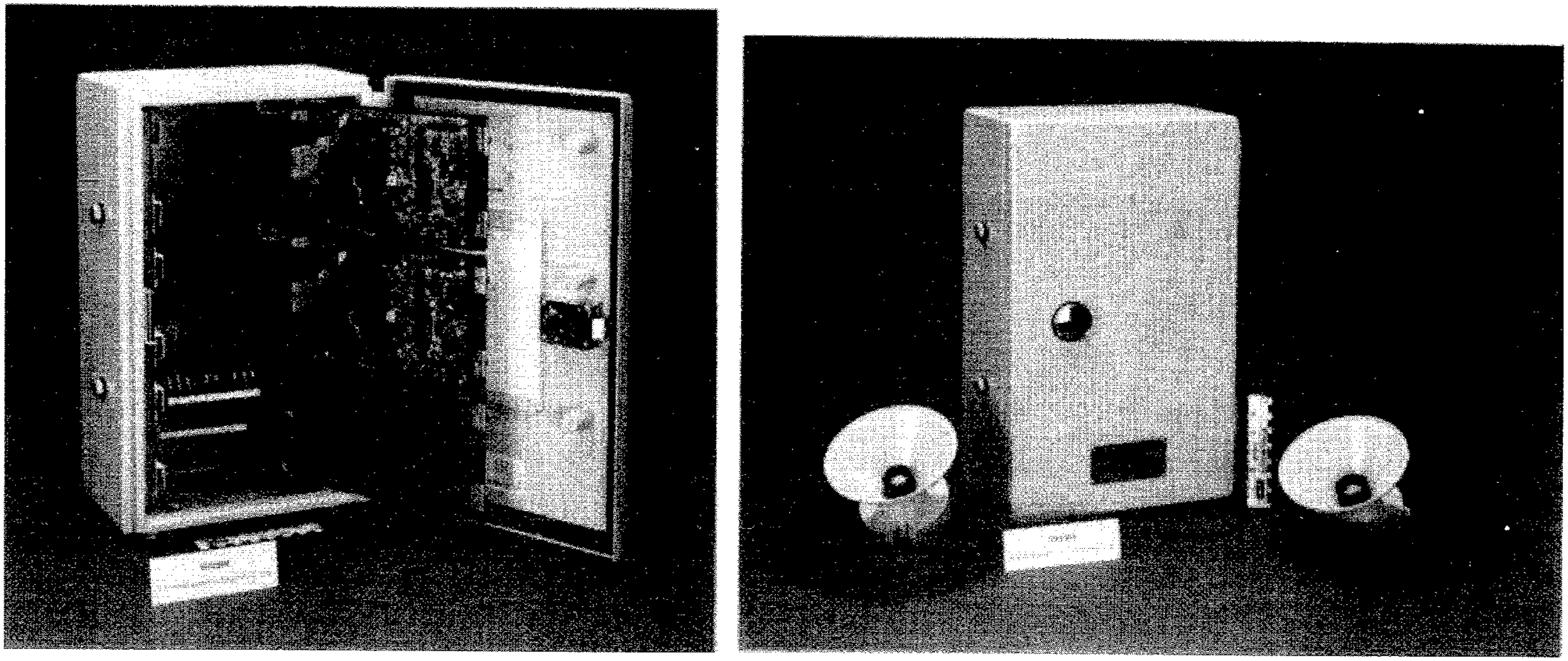


Figure 4-3. SDU-300 Ultrasonic Detector

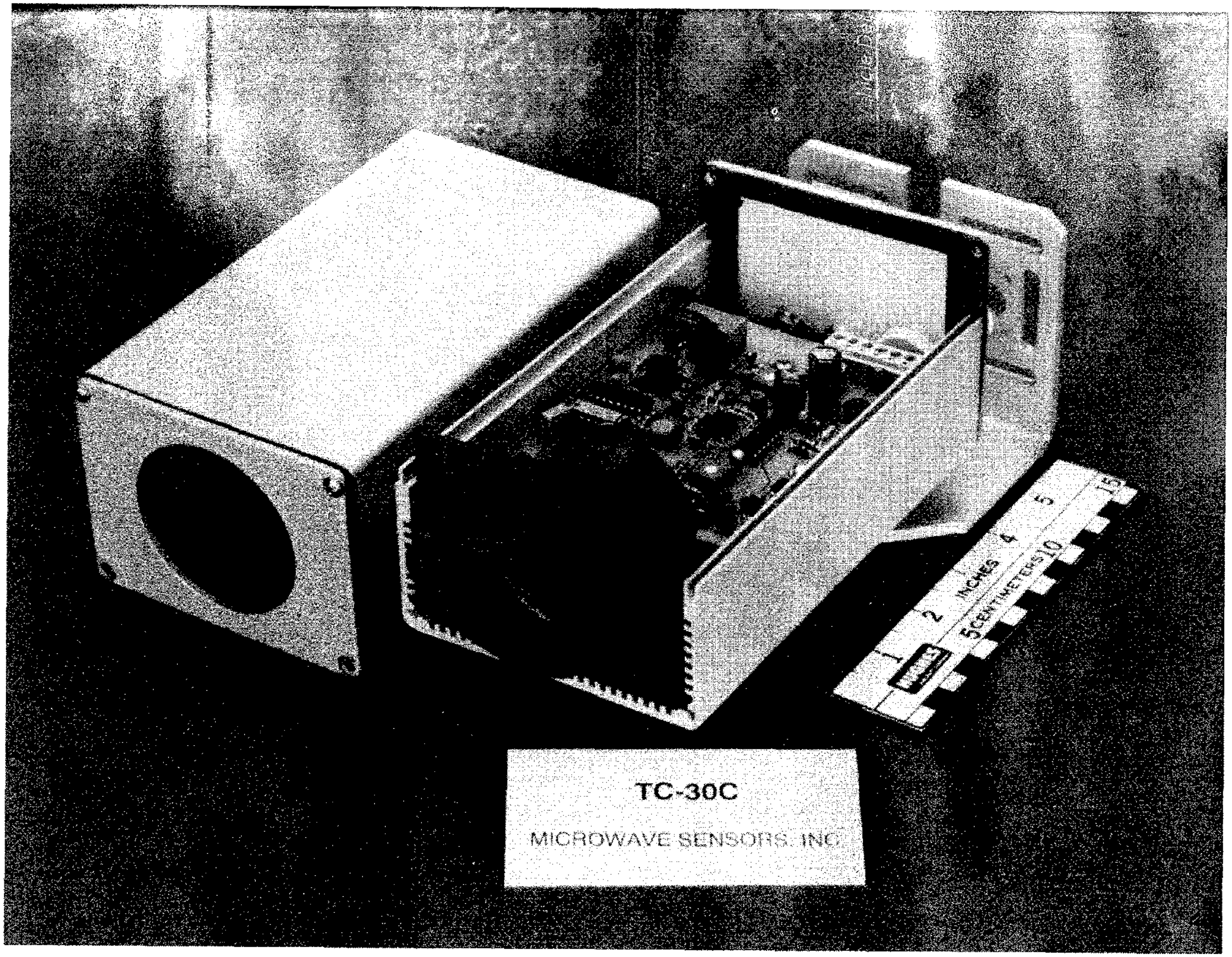


Figure 4-4. TC-30C Ultrasonic Detector

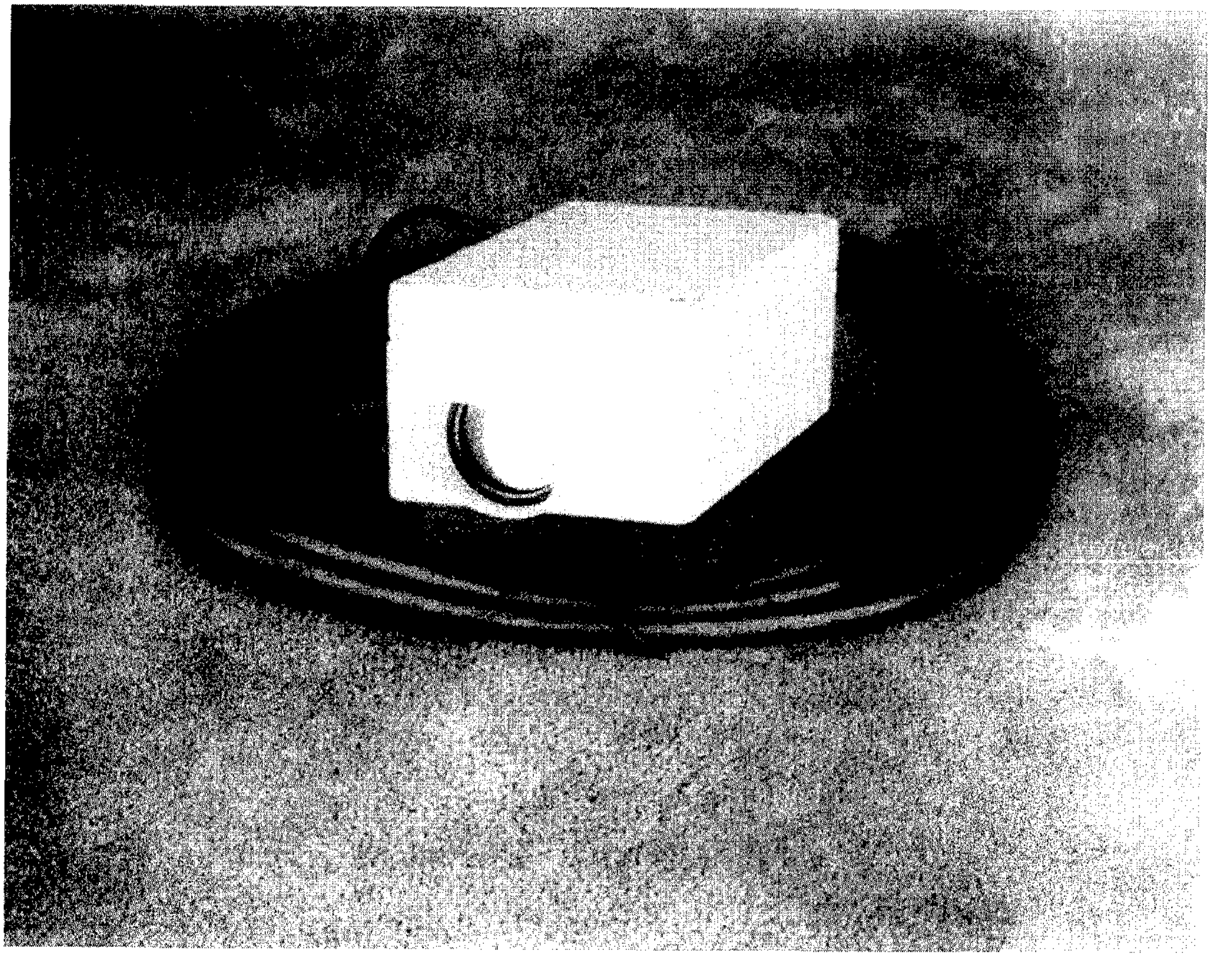


Figure 4-5. 842 Infrared Detector

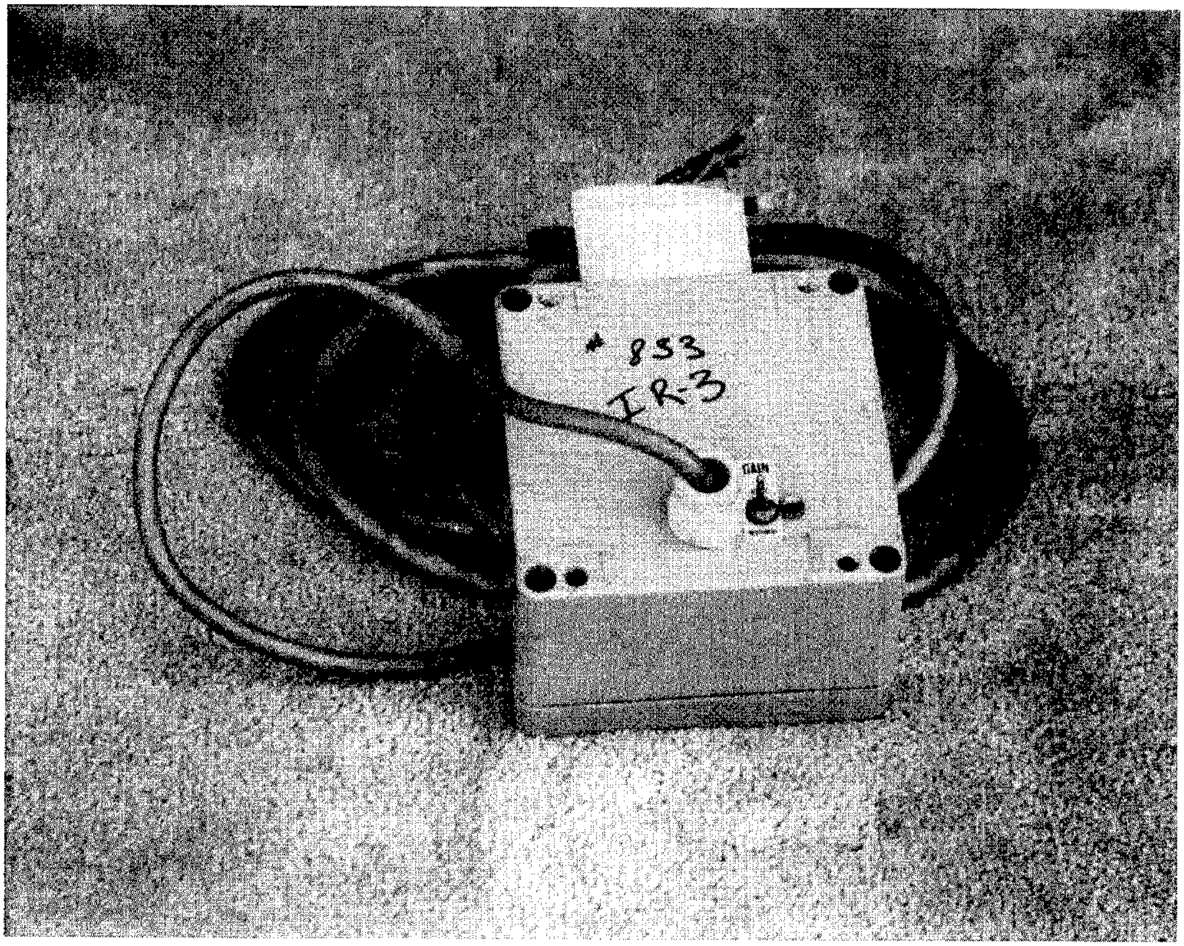


Figure 4-6. 833 Infrared Detector

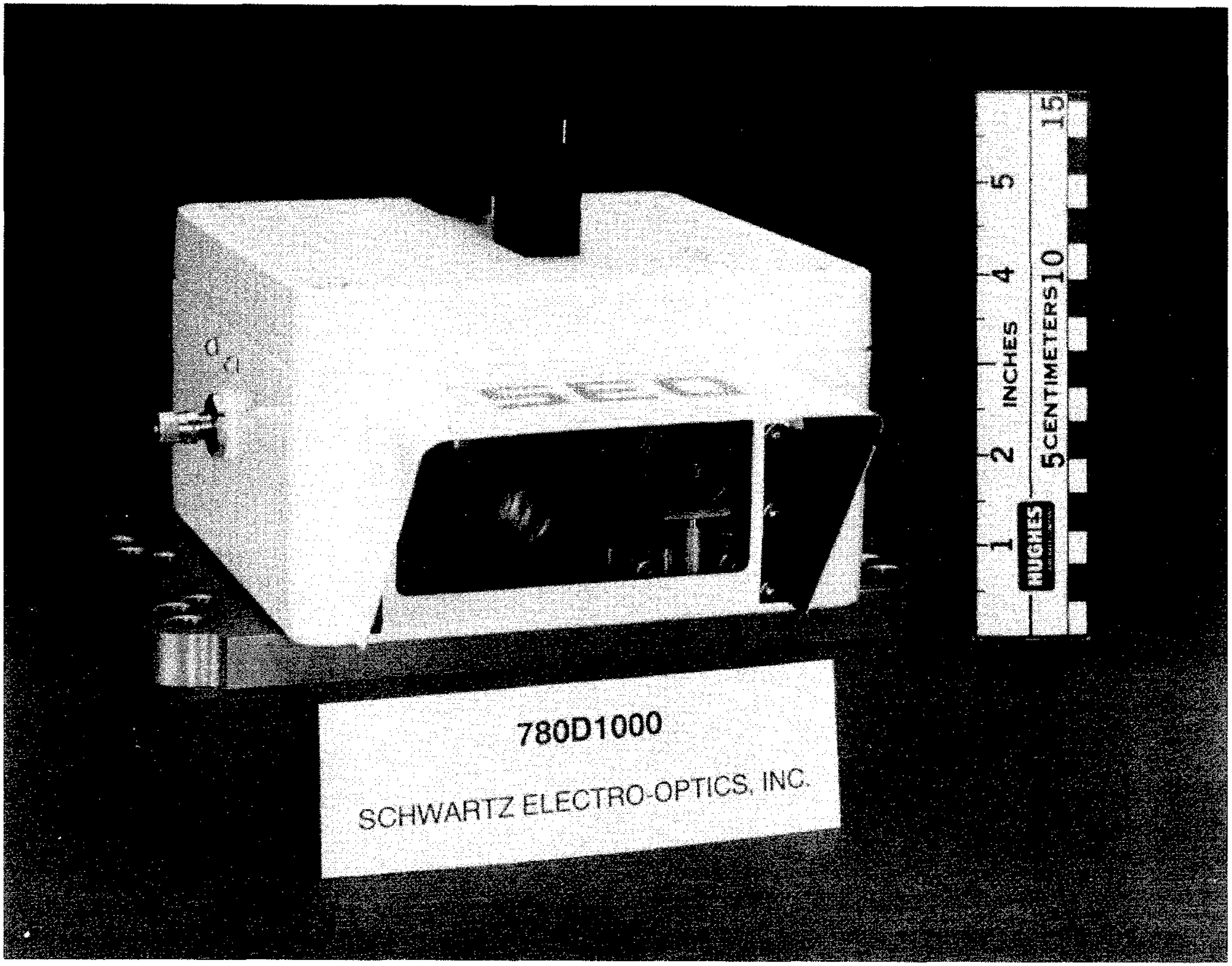


Figure 4-7. 780D1000 Laser Radar Detector

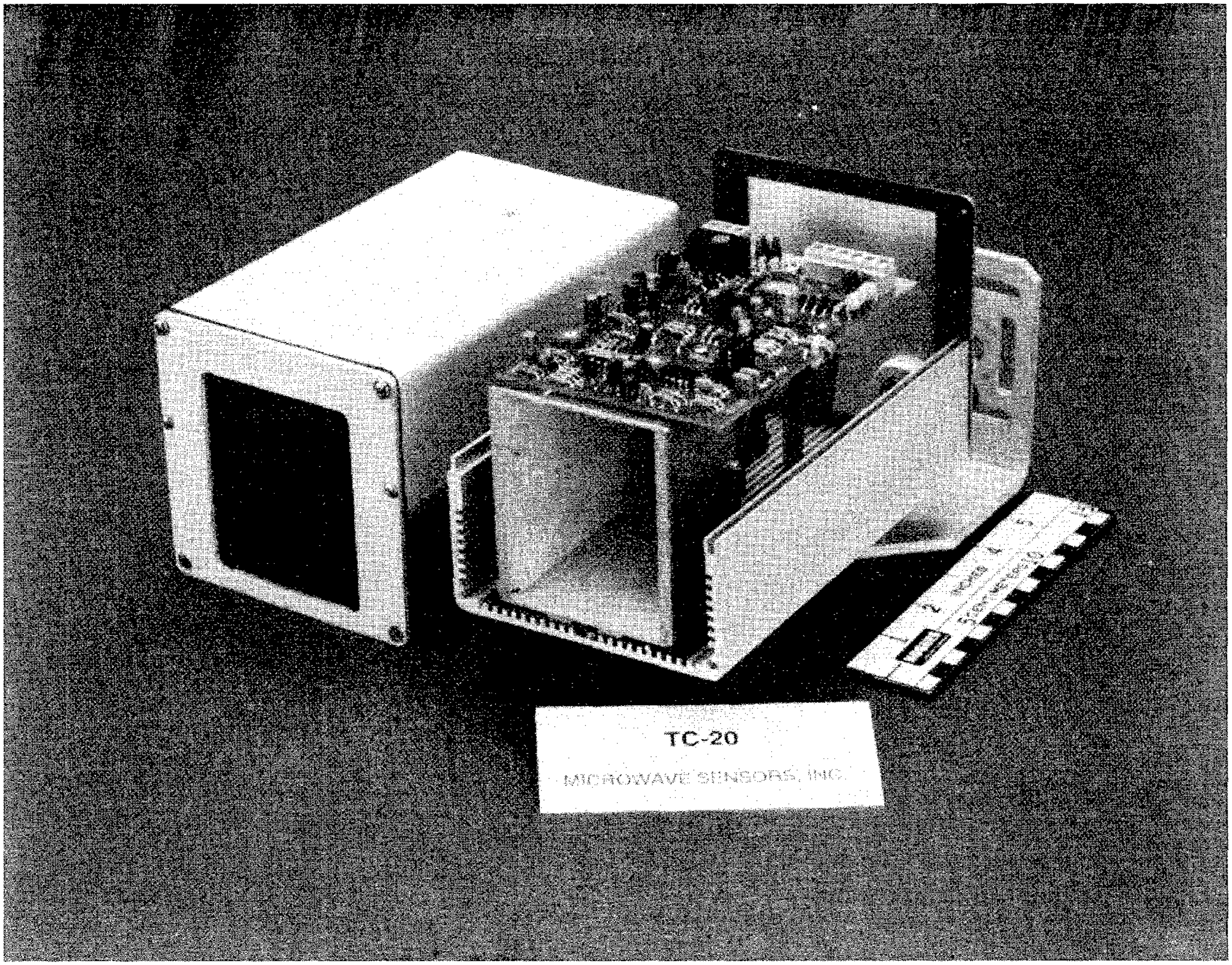


Figure 4-8. TC-20 Microwave Detector

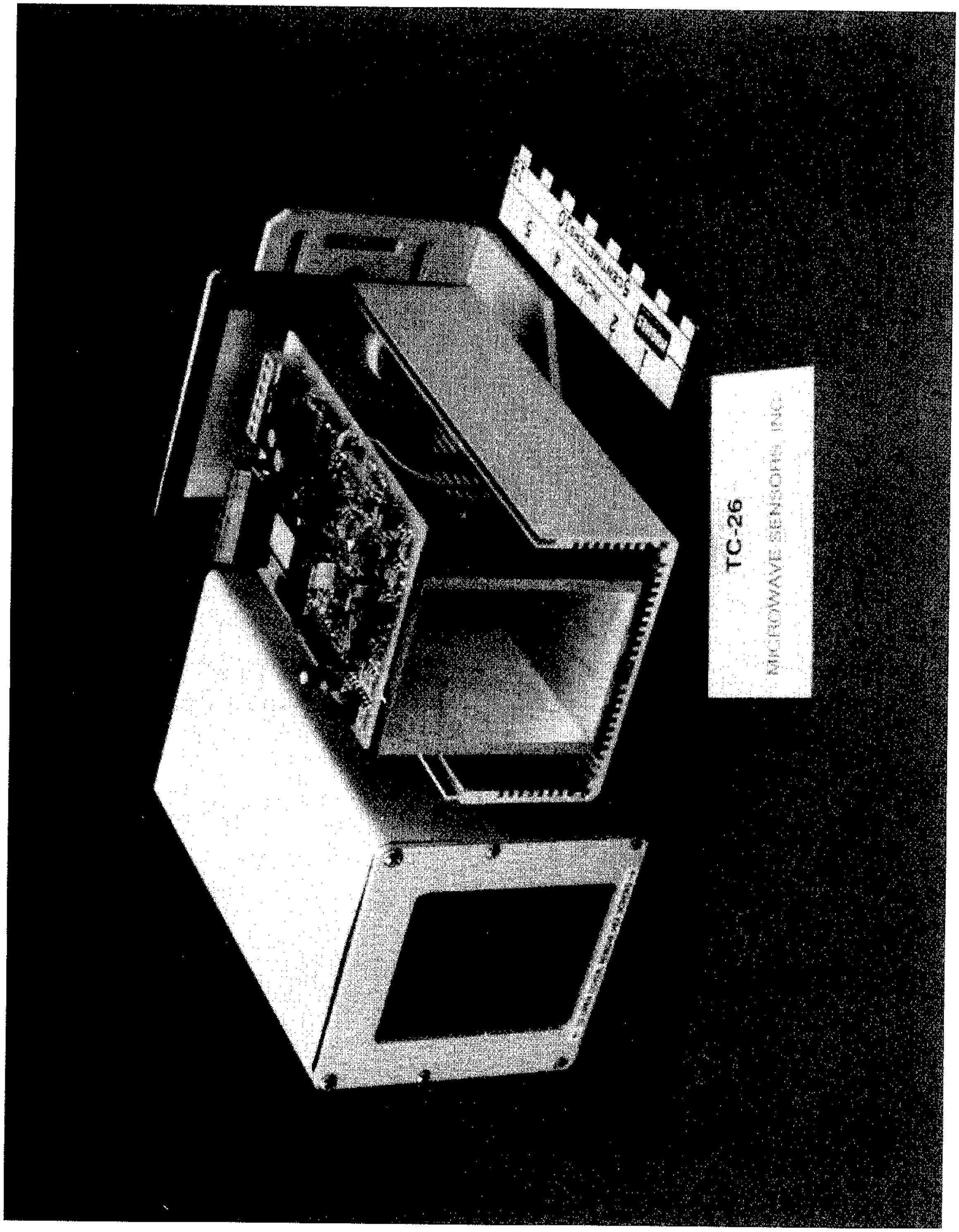


Figure 4-9. TC-26 Microwave Detector

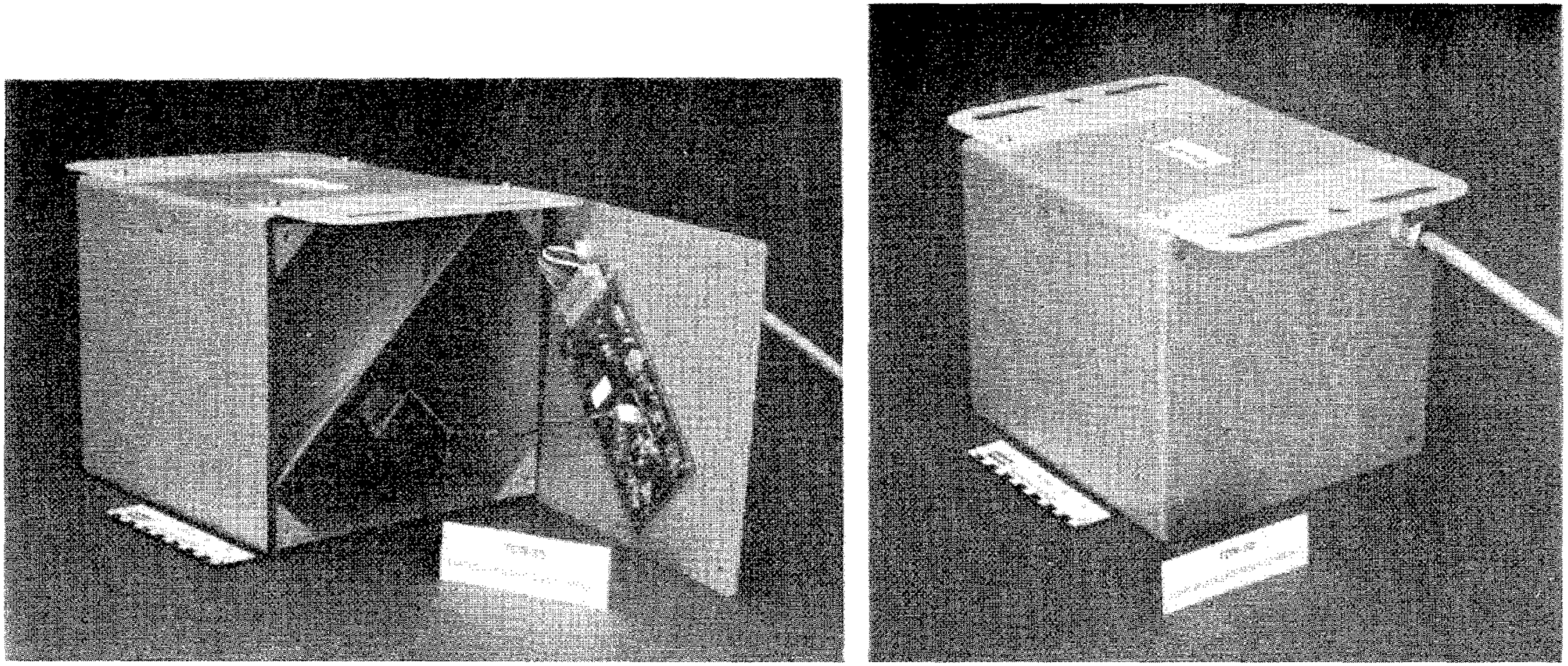


Figure 4-10. TDN-30 Microwave Detector

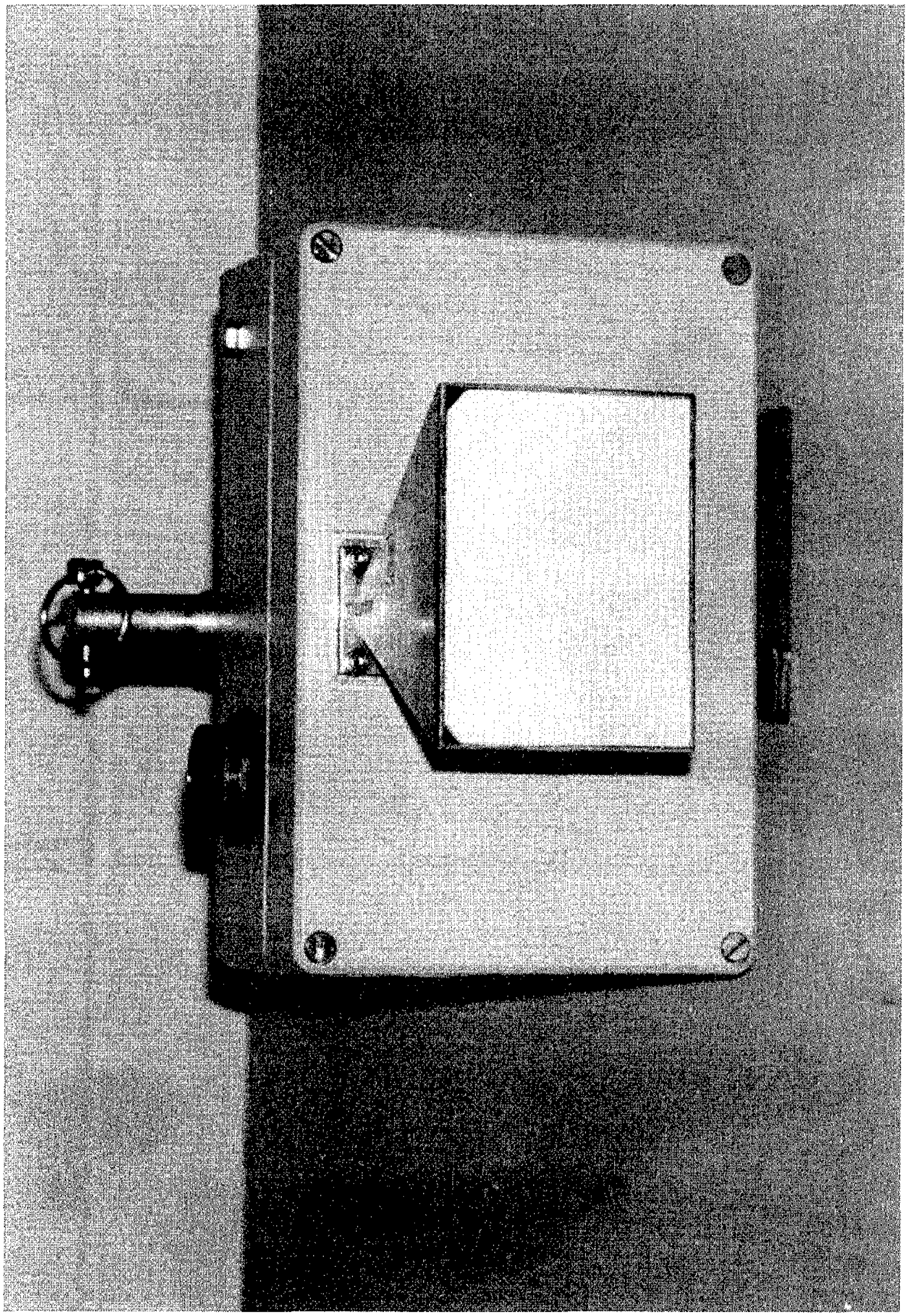


Figure 4-11. RTMS Microwave Detector

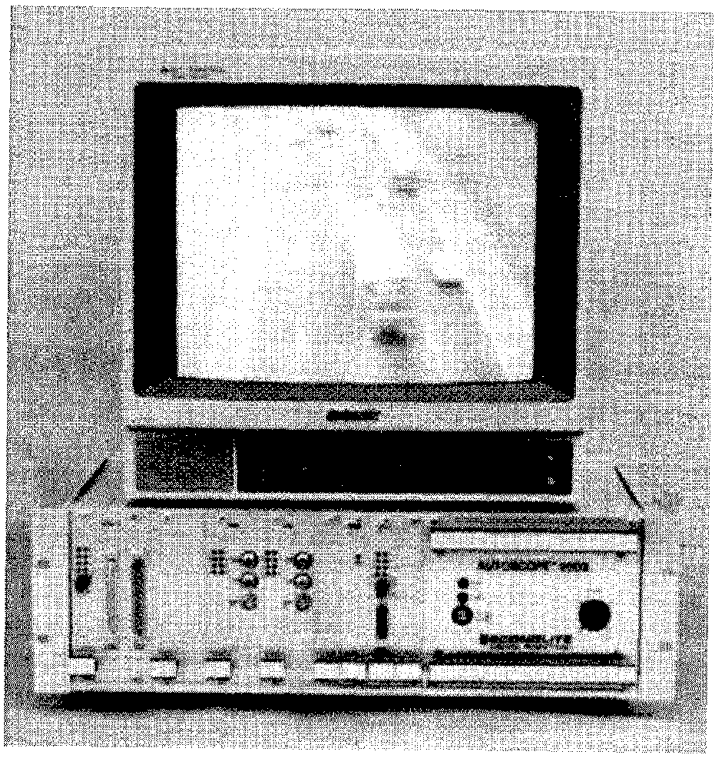


Figure 4-12. Autoscope 2003 Video Image Processor

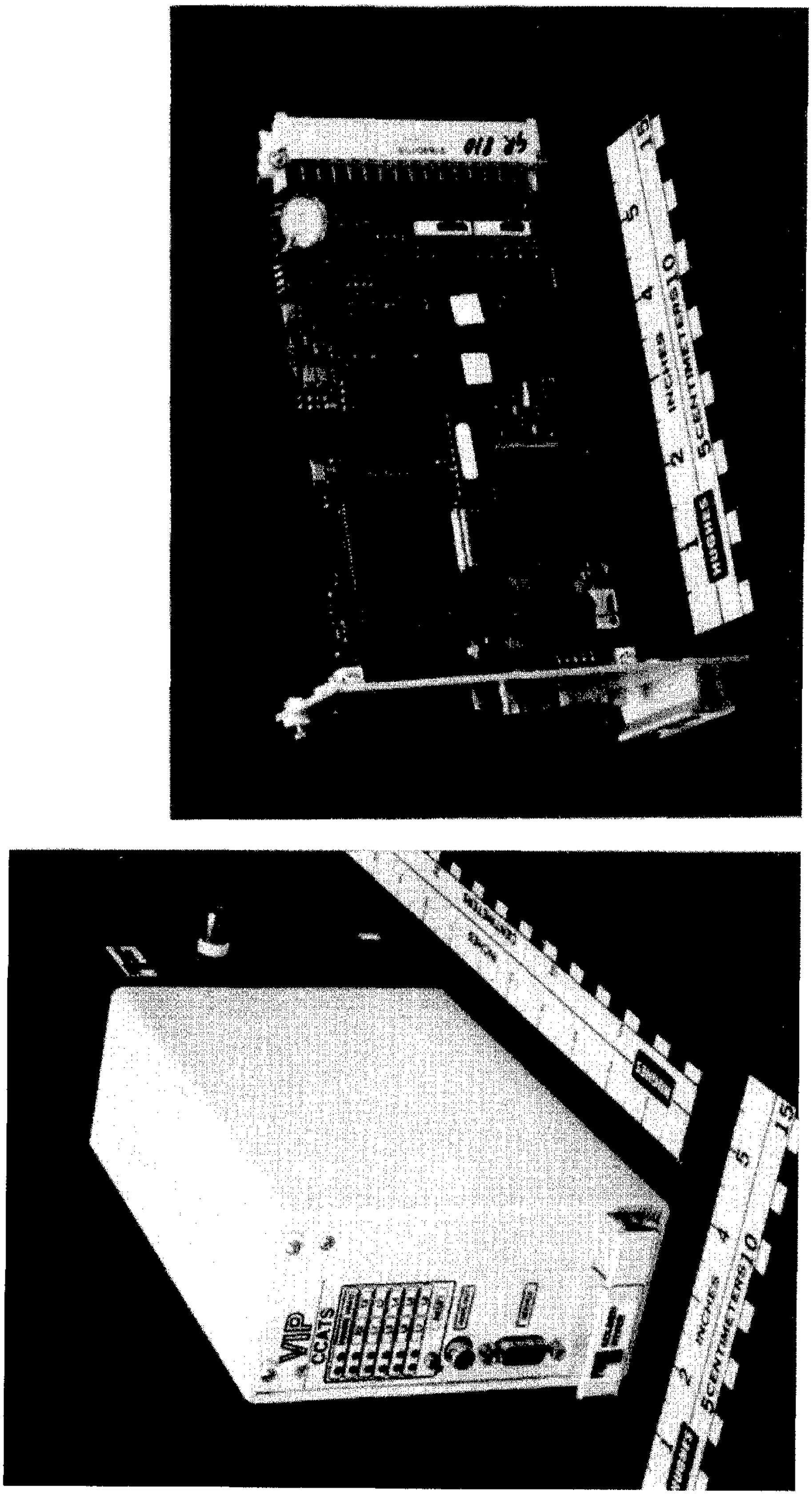


Figure 4-13. CCATS-VIP2 Video Image Processor

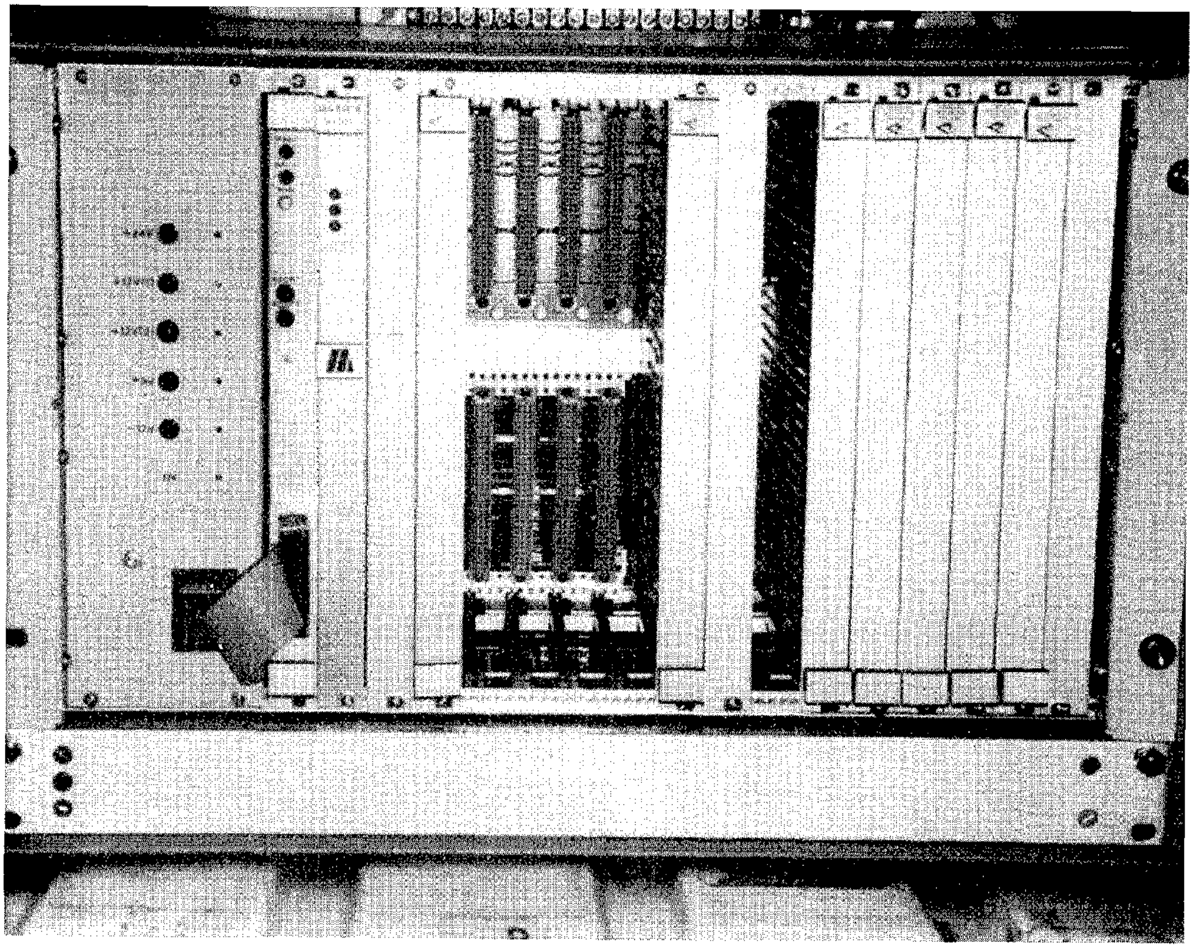
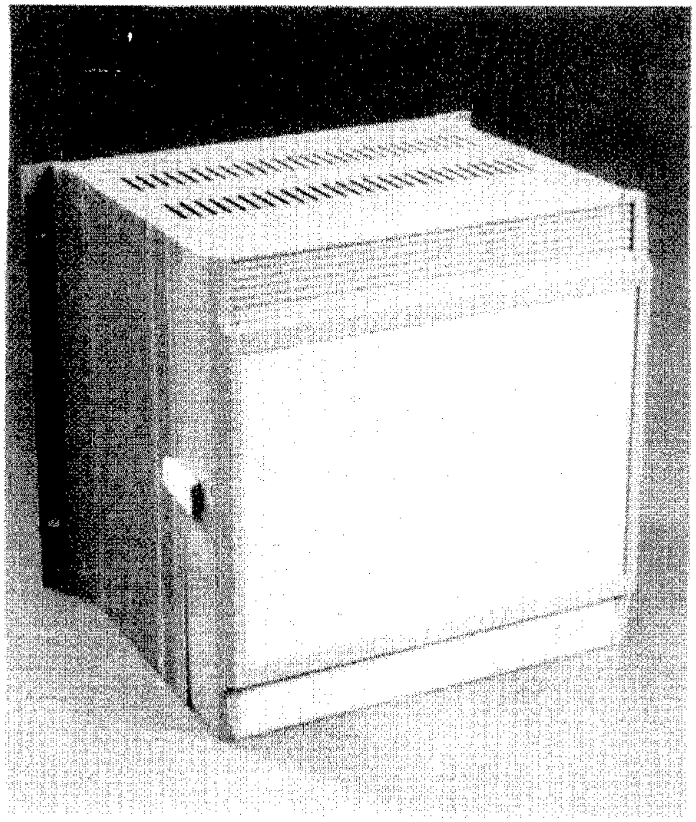


Figure 4-14. Traffic Analysis System Video Image Processor



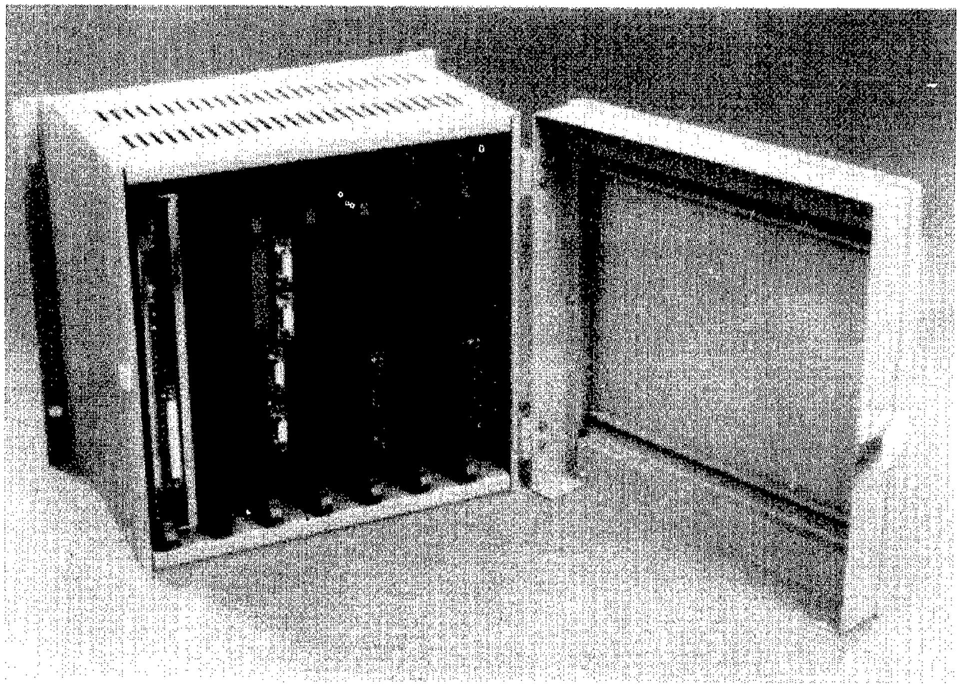


Figure 4-15. EVA 2000 Video Image Processor

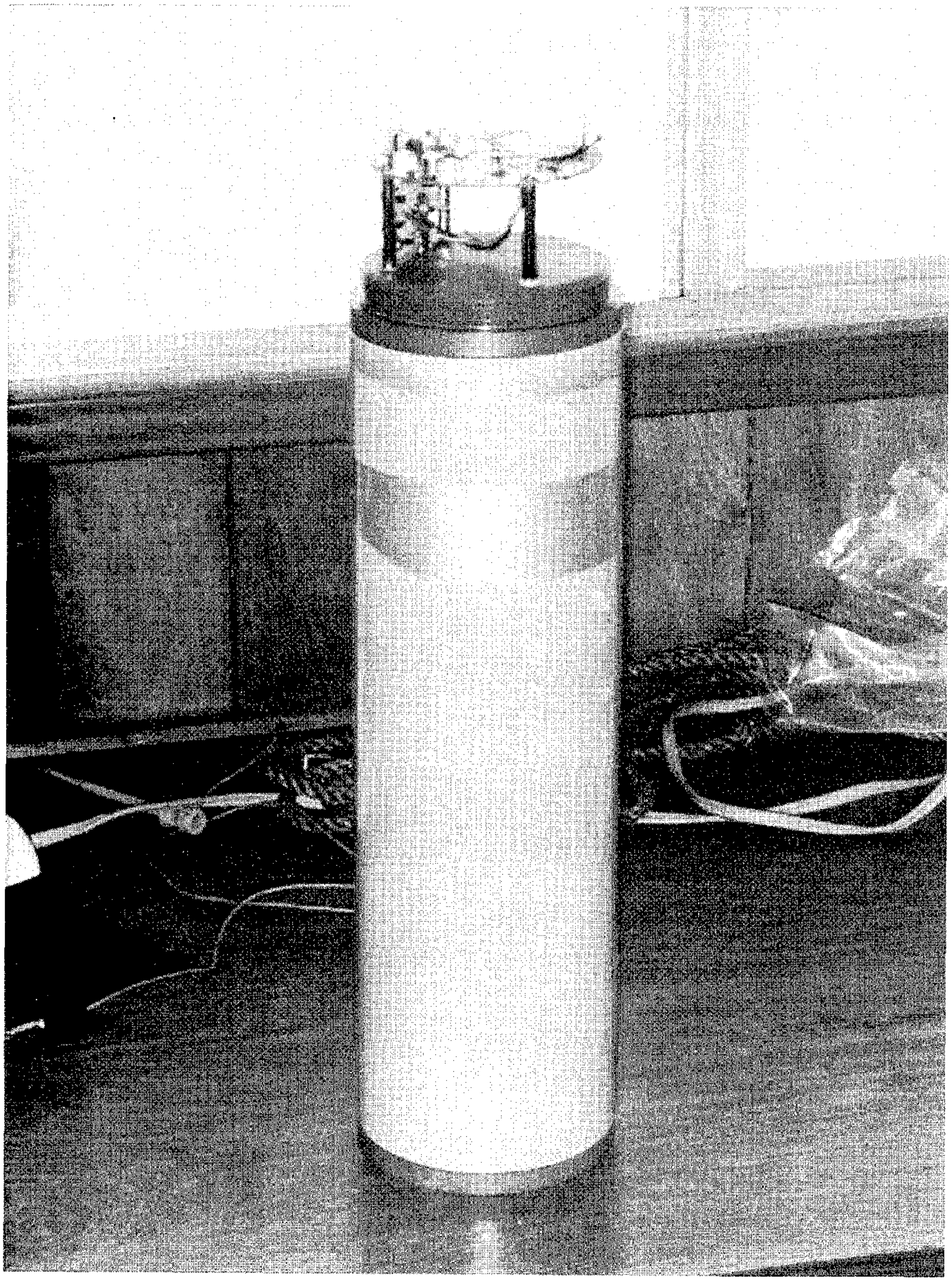


Figure 4-16. Self-Powered Vehicle Magnetometer Detector

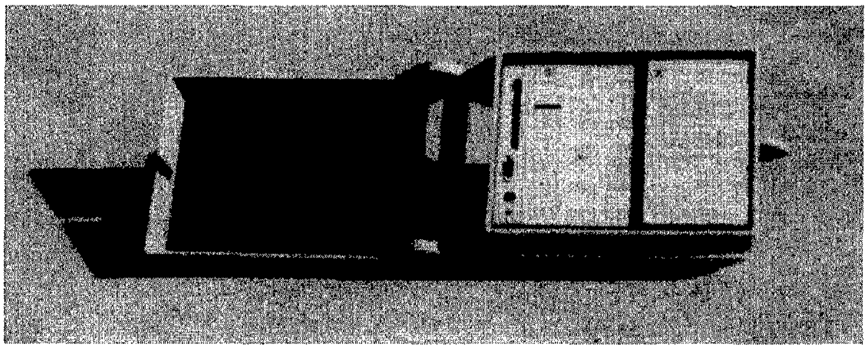


Figure 4-17. Delta I Vehicle Counter

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8. EVA 2000 Video Image Processor for Measuring Traffic Variables, Copyright 1993 by EVA, Inc.

5. THEORY OF OPERATION OF DETECTOR TECHNOLOGIES

The quest for a reliable and cost-effective vehicle detection and tracking system that can be installed and maintained with safety and minimal disruption of traffic, and can provide traffic data at least as accurate as the loop detector has been underway for some time.(1,2) Not only are detectors used to actuate traffic control devices and detect incidents, but they are also appearing in automatic vehicle identification applications associated with electronic toll and traffic management (ETTM) as discussed at the end of this section. Still other applications include sensing of vehicle presence, turning movements, and speed for advanced vehicle control systems.

This section reviews above-the-road and below-the-surface detector technologies. The above-the-road devices have the potential to replace inductive loop detectors for intersection control, traffic surveillance, and incident detection. Many of these technologies are in limited application in demonstration projects where their potential to supply accurate data is being evaluated.(3) The lessons learned are anticipated to lead to further enhancements. The section concludes with a discussion of automatic vehicle identification applications.

5.1 VIDEO IMAGE PROCESSORS

Video cameras were first introduced to provide roadway surveillance. They transmitted closed circuit television (CCTV) imagery to a human operator for interpretation. More advanced techniques now use video image processing to automatically analyze the scene of interest and extract information for traffic surveillance and control. Typically, the imagery is digitized in hardware that is hosted in a personal computer (PC) architecture. The PC also accommodates application-specific software used to calculate the desired traffic parameters. Video image processors (VIPs) can replace several in-ground inductive loops by a single above-the-road camera and signal processing that provide area-wide detection of vehicles and the promise of lower maintenance costs. Some VIP systems process data from more than one camera and thus increase the data collection area even further.

VIPs have the potential to classify vehicles and report vehicle presence, volume, occupancy, and speed for each class and for each lane observed. Other potentially available traffic parameters are density and link travel time.

5.1.1 Operation

Most current video image processors analyze imagery transmitted to them at full frame rates of 30 frames/s. Some can conserve transmission bandwidth by performing image processing in the camera or at the roadside controller and transmitting only low-bandwidth numerical traffic data to the operations center as shown in Figure 5-1. In addition to the traffic parameters, the detector interface module can transmit information that allows icons to be displayed on monitors in the traffic management center by using a combination of computer hardware and software located at the center. The icons represent the real-time traffic flow occurring on the freeway and the tracks of vehicles within the field-of-view of the camera. Different shaped and colored symbols can be created to represent automobiles, buses, trucks, motorcycles, etc. The icon representation of traffic flow, as compared to the display of full bandwidth video imagery, allows lower bandwidth transmission media to be used. The full bandwidth imagery is still available on demand for transmission to the operations center to verify and identify incidents and recurring congestion. By multiplexing video images from several cameras on one transmission line and sending the video only when requested, operating costs associated with leased transmission media are further reduced.

New generation VIPs are being developed to process high-resolution visible and infrared camera imagery with embedded algorithms

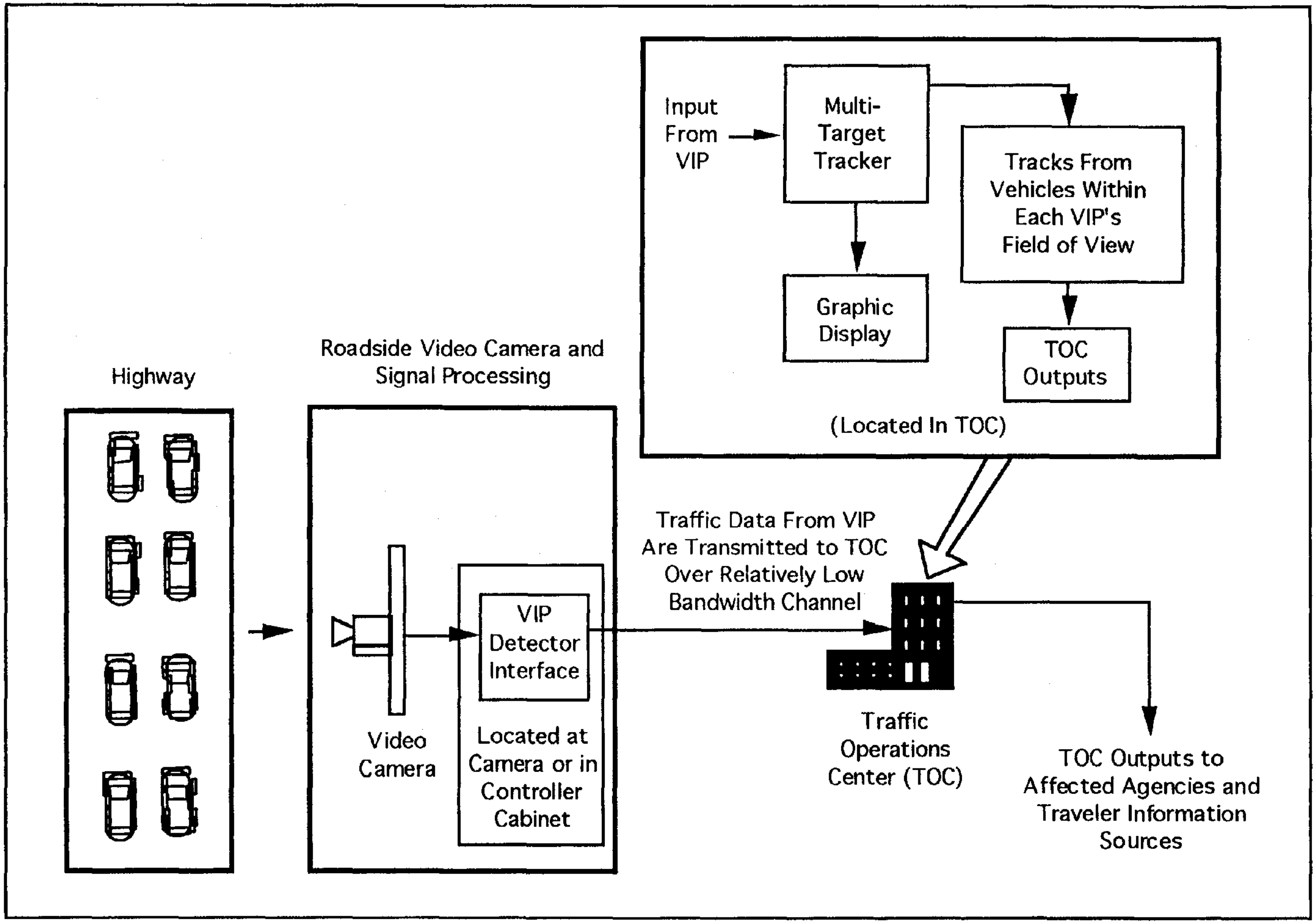


Figure 5-1. Modern Video Image Processor Incorporating Roadside Signal Processing

that are not susceptible to variations in ambient light, shadows, or other artifacts that can otherwise corrupt the traffic data. Several VIPs identify and track vehicles and then estimate the future position of the vehicle. These VIPs have the potential to transmit information to roadside displays and radios that alert drivers to factors that can lead to an incident. Other VIPs use information from a combination of sensors sensitive to visible, infrared, and ultraviolet wavelengths to detect vehicles and remove artifacts.

5.1.2 Mounting and Traffic Viewing Considerations

Table 5-1 shows how processing of upstream or downstream imagery influences VIP performance. The primary advantage of upstream viewing is that incidents are not blocked by the resulting traffic queues. However, tall trucks may block the line of sight and headlights may cause blooming of the imagery. Downstream viewing offers advantages of camera concealment so that driver behavior is not altered, easier identification and tracking of vehicles using information contained in the tail lights, and better acquisition of vehicle tracks because the vehicles are closer to the camera at track initiation.

Based on line-of-sight considerations, the detection distance at which a VIP can differentiate two closely spaced vehicles along the surface of a road is a function of camera mounting height, inter-vehicle distance or gap, and vehicle height as shown in Figure 5-2. The maximum detection distance D_{max} along a roadway without a grade is given by

$$D_{max} = h \frac{Veh_{gap}}{Veh_{height}} \qquad (5\text{-}1)$$

where

h = camera mounting height,

Veh_{gap} = inter-vehicle gap, and

Veh_{height} = vehicle height.

Other factors to be considered when installing cameras used in VIP systems include: (4)

- Vertical and lateral viewing angles,
- Number of lanes observed,
- Stability with respect to wind and vibration,

  and
- Image quality.

VIPs tolerate an oblique view of the highway if the mounting height is high, say 45 to 50 feet (13.7 to 15.2 m). For lower heights in the vicinity of 18 to 25 feet (5.5 to 7.6 m), a mounting location centered over the area of interest may be required. However, the lower the camera, the greater is the error in vehicle speed measurement, as the measurement error is proportional to the vehicle height divided by the camera mounting height.

The number of lanes of imagery analyzed by the VIP becomes important when the required field of view is larger than the VIP's capability. For example, if the VIP provides data from detection zones in three lanes, but five must be observed, that particular VIP may not be appropriate for the application.

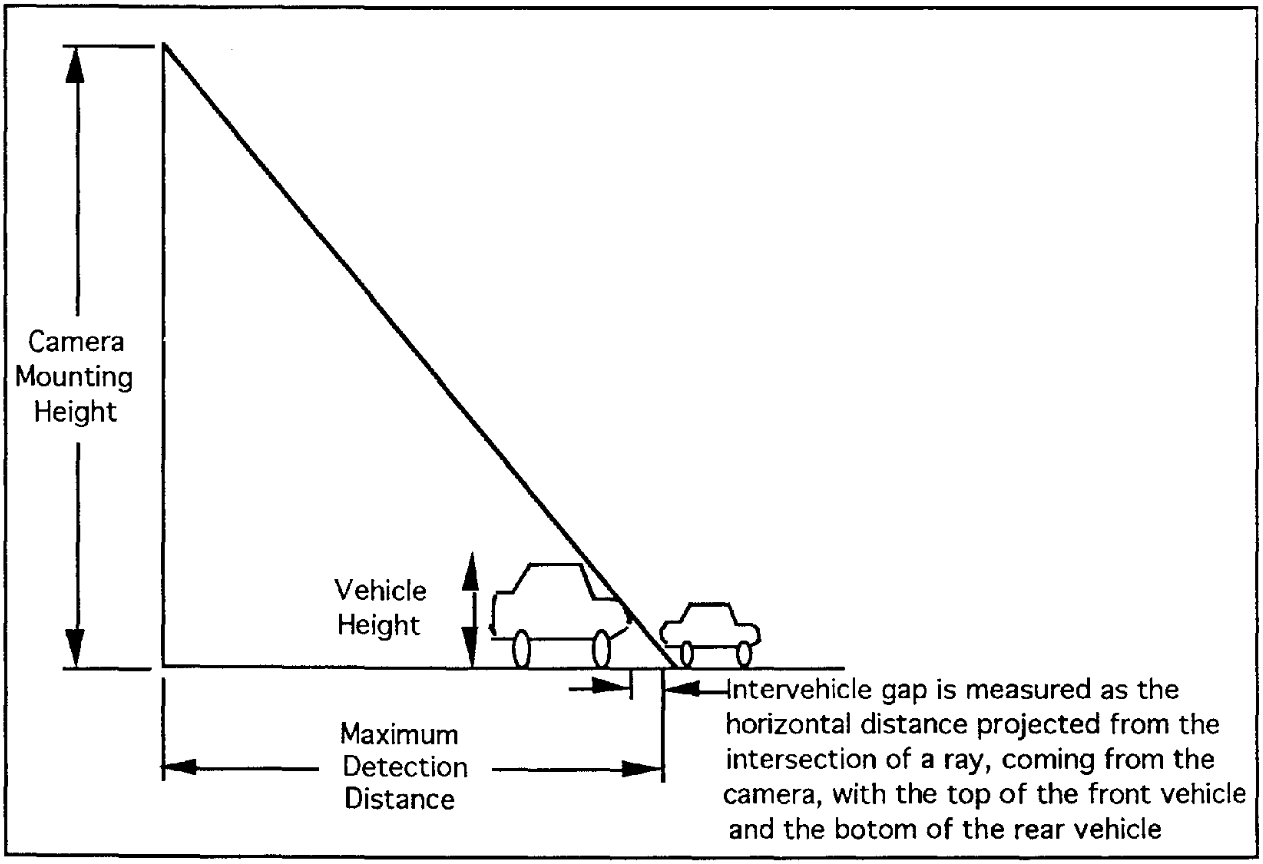
VIPs sensitive to large camera motion may be adversely affected by strong winds. Algorithms that predict the future path of a vehicle (such as a Kalman filter) and smooth its track may reduce sensitivity to camera motion.

Image quality and interpretation can be affected by cameras that have automatic iris and automatic gain control. In tests conducted by California Polytechnic Institute at San Luis Obispo, these systems were disabled.(4) In still other VIPs, the signal processing is tailored to take advantage of automatic light control systems.

Using the same camera for automatic vehicle detection with a VIP, and video surveillance with pan, tilt, and zoom features requires the camera to be repositioned for each application. If the field of view is not returned to the calibrated value for VIP operation, the performance of the VIP is adversely affected. It may be technically feasible, however, to reposition the camera at previously established VIP detection zones after it has been panned, tilted, or zoomed to view an incident location for verification and identification. In this case, one camera can be used for both applications. If the remote control of cameras and their return to calibrated fields of view is

Table 5-1. Video Image Processor Characteristics as Used in Upstream and Downstream Viewing

Upstream Viewing	Downstream Viewing
• Headlight blooming and glare from wet pavement	• Camera concealed from drivers
• More blockage from tall trucks	• More information from tail lights available for braking indication, vehicle classification, and turning movement identification
• With infrared imagery, there is no difference in information obtained from headlights or tail lights when a tracking algorithm is used	• With visible imagery, more information is available to a tracking algorithm from tail light viewing
• Traffic incidents are not blocked by resulting traffic queues	• Easier to acquire vehicles that are closer to the camera for the tracking algorithm application



Intervehicle gap is measured as the horizontal distance projected from the intersection of a ray, coming from the camera, with the top of the front vehicle and the botom of the rear vehicle

Figure 5-2. Video Image Processor Line-of-Sight Detection Geometry not feasible, then separate cameras may be required to performautomated traffic data collection and video surveillance. When two cameras are used, a lower cost camera system will generally suffice for the VIP mission as the pan, tilt, and zoom features are not required.

5.1.3 Signal Processing

The data reduction and image formatting are performed with firmware that allows the algorithms to run in real time. The data reduction hardware is commonly implemented on a single formatter card in a personal computer. Once the data are digitized and stored by the formatter, spatial and temporal features are extracted from the vehicles in each detection zone with a series of image processing algorithms as illustrated in Figure 5-3. A detection process that establishes one or more thresholds is used to limit and segregate data passed on to the rest of the algorithms. It is undesirable to severely limit the number of potential vehicles during detection, for once data are removed they cannot be recovered. Therefore, false vehicle detections are permitted at this stage since the declaration of actual vehicles is not made at the conclusion of detection processing. Rather, algorithms contained in the steps still to come are relied on to eliminate false vehicles and retain the real ones.(5) Image segmentation is used to divide the image area into smaller regions where features can be better recognized. The features are analyzed to generate vehicle presence, speed, and classification data. Alternatively, neural networks can be trained to recognize and count different classes of vehicles and detect incidents.(6) Once individual vehicles are identified, they can be tracked by applying Kalman filter techniques. Tracking offers the potential ability to warn of impending incidents due to abrupt lane changes or weaving.

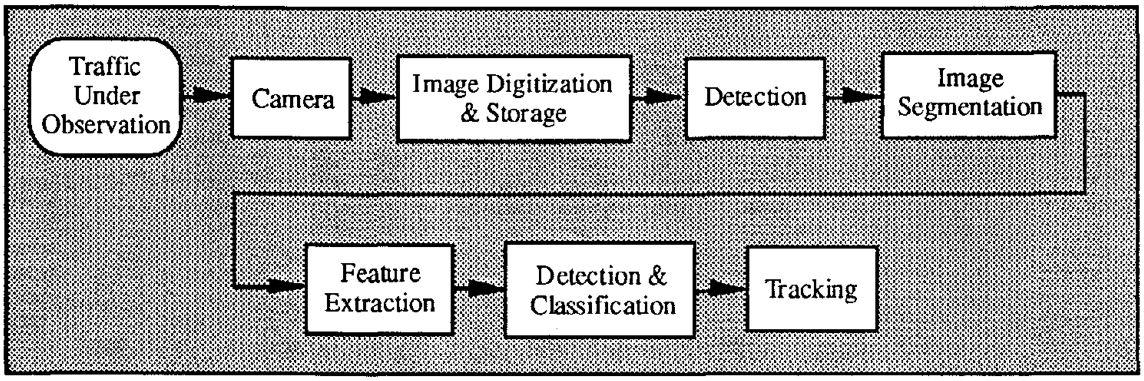


Figure 5-3. Conceptual Vehicle Detection, Classification, and Tracking System

There are two algorithmic approaches employed in image processors. In the first, VIPs detect vehicles at a number of fixed locations within the field of view of the camera by having the operator use interactive graphics to place the detection areas or zones. The zones can be oriented perpendicular, parallel, or at an oblique angle to the roadway lanes. Ideally, a signal is generated when a vehicle enters a detection zone. Some zone orientations, such as those parallel to a lane, were found to be less sensitive to vehicles than zones perpendicular to the travel direction. Newer software has apparently remedied this problem. Since a single camera and VIP can provide detection zones across several lanes, the VIP system can replace many loops and provide wide-area vehicle detection.

VIPs employing the second approach track vehicles continuously through the field of view of the camera. Multiple detections of the vehicle along a track are used to validate the detection. Once validated, the vehicle is counted and its speed is measured.(7)

The detection zone approach estimates vehicle speed by using relatively closely spaced pairs of zones to measure the time between the signals generated by a vehicle traversing the adjacent zones. This is similar in concept to speed traps implemented with two inductive loop detectors. The tracking algorithm associates a series of detections with a vehicle to predict its future position and to calculate link travel times. The more advanced VIPs that track individual vehicles can directly calculate speed from the algorithm that tracks the vehicles.

VIP algorithms have been improved to ignore artifacts produced by shadows, illumination changes, and reflections, and to minimize effects of adverse weather. In addition, the heavy congestion that degraded early VIPs does not appear to present a problem to more modern systems. Combined results for clear and inclement weather show vehicle volume, speed, and occupancy measurement accuracies in excess of 95 percent using a single detection zone.(8) VIPs with single detection zones in a lane are useful for monitoring traffic volumes on a freeway. For signalized intersection control, where vehicle detection accuracies of 100 percent are desired, the number of detection zones in the field of view is increased to between two and four, dependent on the camera mounting and road geometry.

5.2 MICROWAVE DETECTORS

The use of microwave radar for detecting objects had its beginnings before and during Word War II. In fact, the word *radar* was derived from the functions that it performs: *RA*dio *D*etection *A*nd *R*anging. The term *microwave* refers to the wavelength of the transmitted energy, usually between 1 and 30 cm corresponding to a frequency range of 1 GHz to 30 GHz. The prefix *giga* (G) represents 10^9. Radar operating at frequencies above 30 GHz is referred to as millimeter-wave radar, again corresponding to the wavelength of the transmitted energy.

Unlicensed operation of microwave detectors for traffic data collection and monitoring is limited to frequencies in bands near 10.5 GHz and 24.0 GHz under Part 15 of Federal Communications Commission (FCC) regulations for microwave devices. Part 15.245 of the FCC rules for Field Disturbance Sensors allows unlicensed operation at frequency bands between 10.500 and 10.550 GHz and 24.075 and 24.175 GHz if the electrical field strength 3 meters from the transmitting antenna is 2.5 V/m or less. The field strength of harmonics present in the transmitted signal must be no greater than 25 mV/m at 3 meters distance. The signal must also be at least 50 dB down from its in-band value outside this band. Field disturbance sensors cannot carry information in their transmitted signal.

Part 15.209 of the FCC rules for general radiation emissions allows transmission in the 1- to 40-GHz frequency range if the field strength is limited to 500×10^{-6} V/m at 3 meters.

Licensed transmission in the 33.4- to 36.0-GHz band is allowed under Part 90 FCC regulations for local government radio service. The output power is specified in the authorization. Transmission is secondary to U.S. government service. Both the manufacturer and the user need licenses. The telephone number for the Gettysburg, PA, FCC office that has jurisdiction for this service is (717) 337-1212.

As shown in Figure 5-4, microwave detectors transmit energy toward an area of roadway from an antenna mounted overhead that illuminates approaching or departing traffic, or in a side-looking configuration that views traffic across several lanes. When a vehicle passes through the beam, a portion of the transmitted energy is reflected back to the antenna. The energy then enters a receiver where the detection is made.

Microwave detectors currently used in traffic applications transmit two types of waveforms. The first is a continuous wave of electromagnetic energy whose frequency does not change with time. A detector that uses this waveform is capable of detecting only moving vehicles. It measures the speed of vehicles in its field of view using the Doppler principle. Here the frequency of the received signal differs from that of the transmitted signal f by an amount f_D equal to the Doppler frequency produced by the vehicle speed. The frequency shift thus denotes the passage of a vehicle. The relation between f_D, f, and vehicle speed v is

$$f_D = \frac{2v}{c} f \cos\theta \qquad (5\text{-}2)$$

where θ is the angle between the direction of propagation of radar energy and direction of travel of the vehicle, and c is the speed of light (3×10^8 m/s). If the vehicle is traveling directly toward the detector, the Doppler shift is maximum and positive in value. At 10 GHz, the Doppler frequency shift is approximately 30 Hz per statute mile per hour of vehicle radial speed, which is calculated as ($v \cos\theta$). Doppler detectors that do not also include range measuring capability cannot detect motionless vehicles.

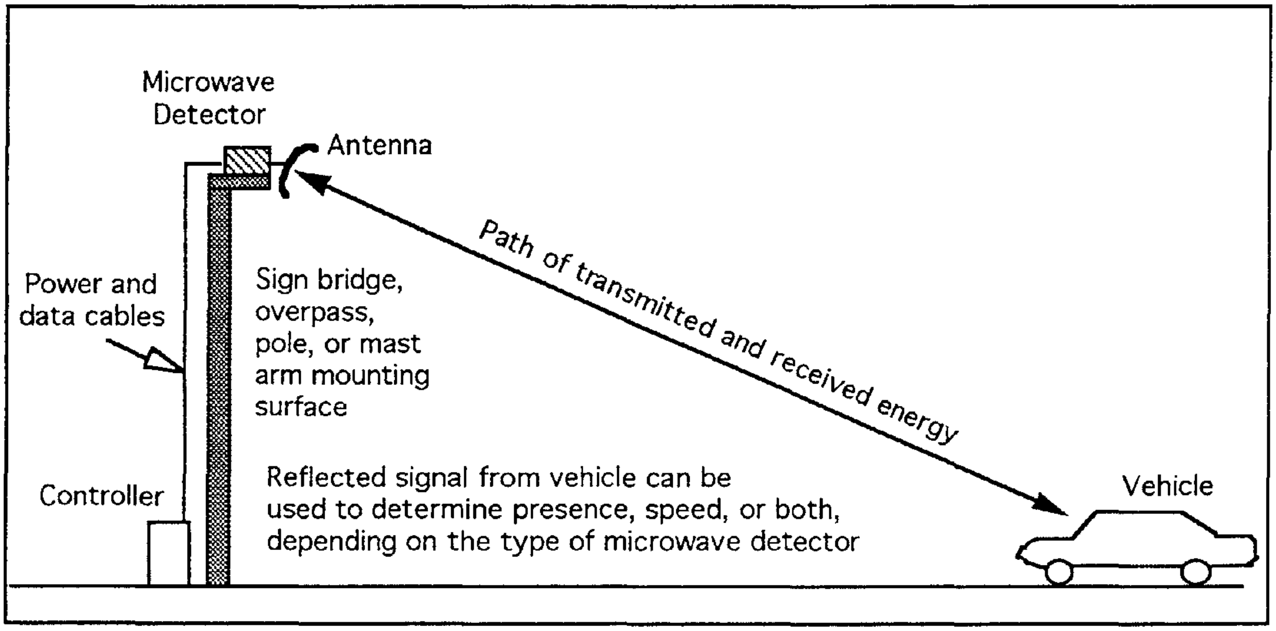


Figure 5-4. Microwave Detector

The second waveform is *sawtooth*, also called FMCW (frequency-modulated continuous wave), in which the transmitted frequency is constantly changing with respect to time, as shown in Figure 5-5.

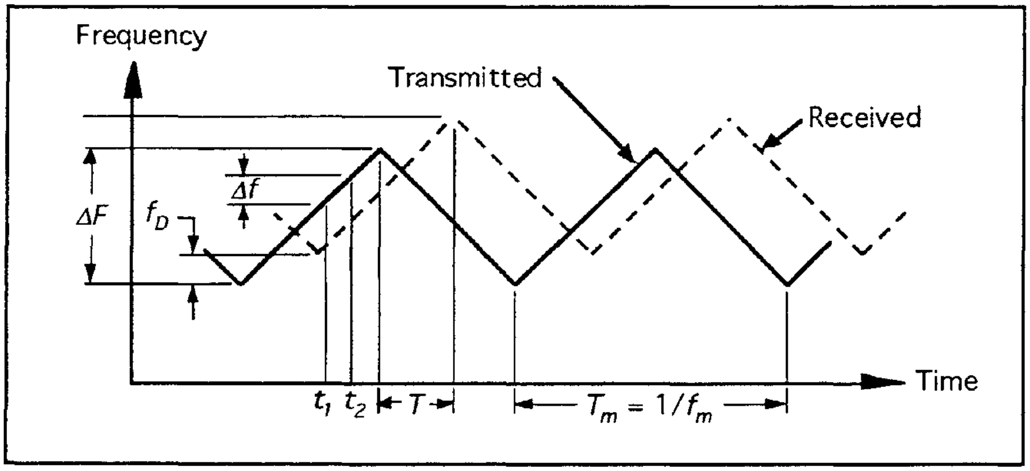


Figure 5-5. FMCW Waveform Parameters

Since the FMCW radar measures the range to the vehicle, it functions as a presence detector and can detect motionless vehicles. Range R is proportional to the difference in the frequency Δf of the transmitter at the time t_1 the signal is transmitted and the time t_2 at which it is received, as shown by

$$R = \frac{c\Delta f}{4\Delta F f_m} \qquad (5\text{-}3)$$

where

Δf = instantaneous difference in frequency, in Hz, of the transmitter at the times the signal is transmitted and received,

ΔF = RF modulation bandwidth in Hz,

and

f_m = RF modulation rate in Hz.

Alternatively, the range may be calculated by measuring the time difference T between consecutive peaks in the transmitted and received signals, as shown in Figure 5-5, such that

$$R = cT/2 \qquad (5\text{-}4)$$

when the transmitter and receiver are collocated.

The FMCW radar measures vehicle speed in two ways. The first method is used when the radar's field of view in the direction of vehicle travel is divided into range bins as shown in Figure 5-6(a). A range bin allows the reflected signal to be partitioned and identified from smaller regions than the entire antenna footprint.

Speed v is calculated from the time difference ΔT corresponding to the vehicle arriving at the leading edges of two range bins a known distance d apart as shown in Figure 5-6(b) and is given by

$$v = \frac{d}{\Delta T} \qquad (5\text{-}5)$$

where d = distance between leading edges of the two range bins and

ΔT = time difference corresponding to the vehicle arrival at the leading edge of each of the range bins.

The second method in which an FMCW radar measures speed is through the Doppler shift in frequency caused by the motion of a vehicle.$^{(9)}$ Referring to Figure 5-5, the instantaneous frequency difference between the two curves when they have positive slopes (upsweep) is given by

$$\delta f_u = \frac{4\Delta F f_m R}{c} - f_D \qquad (5\text{-}6)$$

and by

$$\delta f_d = \frac{4\Delta F f_m R}{c} + f_D \qquad (5\text{-}7)$$

when they have negative slopes (downsweep). Equation 5-3 is still valid when Doppler is present, as Δf in equation 5-3 represents the average frequency difference measured when the slopes are positive and negative. The radial vehicle speed v_R is

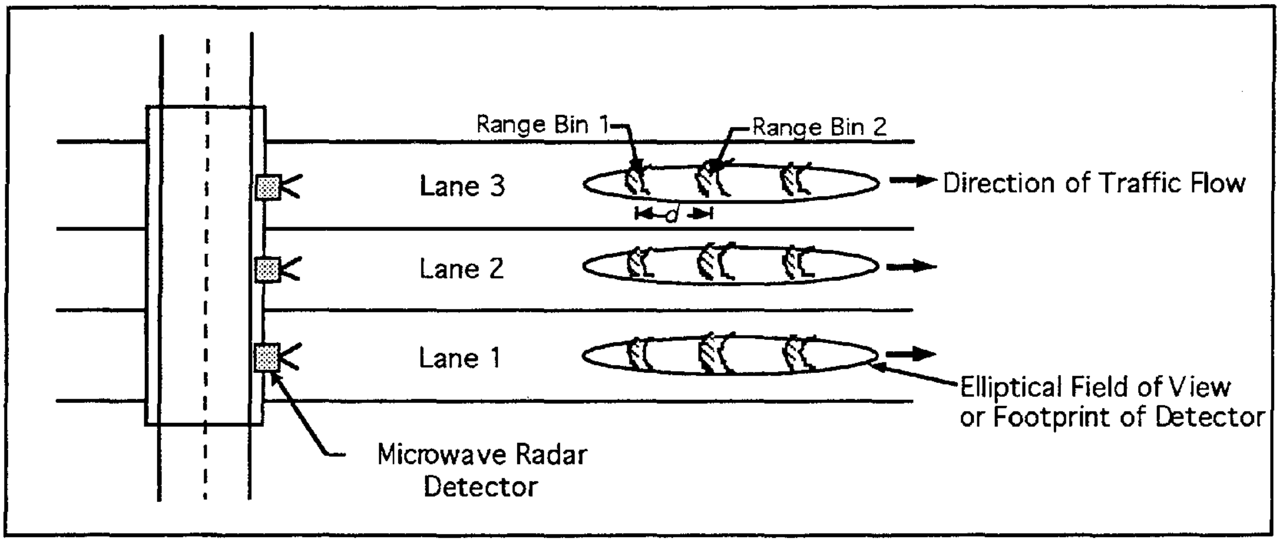
$$v_R = \frac{c}{4f}\,(\delta f_d - \delta f_u) \text{ or} \qquad (5\text{-}8a)$$

$$v_R = \frac{\lambda}{4}\,(\delta f_d - \delta f_u) \qquad (5\text{-}8b)$$

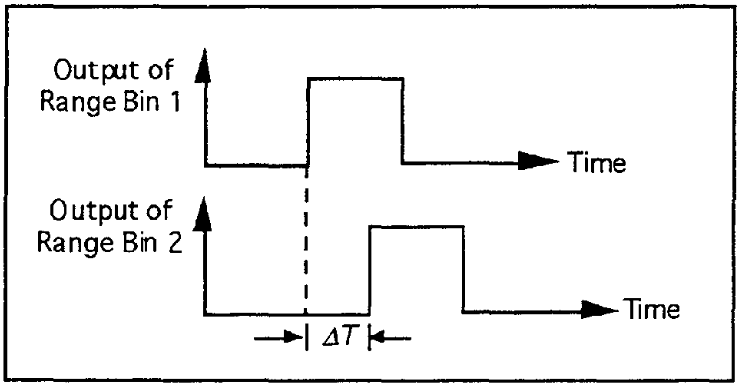
where $c = \lambda f$ and λ is the wavelength of the transmitted energy. If the radar is forward looking, radial speed is equal to the vehicle speed toward or away from the radar multiplied by the cosine of the angle between the direction of propagation of radar energy and direction of travel of the vehicle.

To differentiate between multiple vehicles in the radar footprint, an FMCW radar can be designed with a three-segment waveform such as the one in Figure 5-7. T_s represents the time duration of each segment.

An independent measure of radial speed v_R is produced by the unmodulated horizontal portion of the waveform where $df/dt = 0$. The remainder of the frequency versus time curve is identical to the linear FM discussed above. Therefore, the differences in frequencies, δf_u and δf_d, between the transmitted and received



(a) Range-Binned Footprints of Radar Detectors in Traffic Lanes



(b) Time-Phased Outputs of Range Bins

Figure 5-6. Range-Binned Radar Footprint

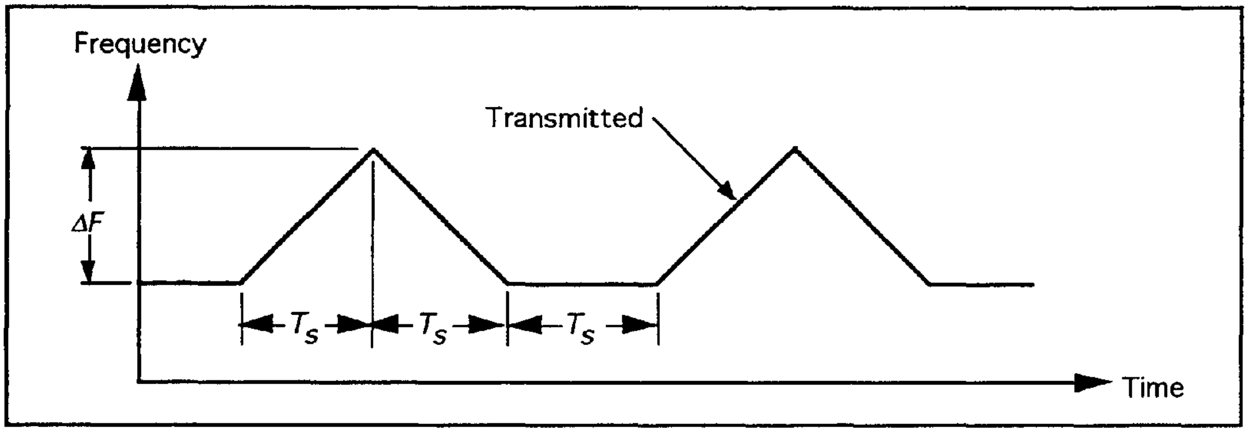


Figure 5-7. Segmented Linear FM Waveform

waveforms are identical to those given above. Since f_D has already been found from the unmodulated portion of the curve, δf_u and δf_d can be used to find the unambiguous range and speed of multiple vehicles that appear in the radar footprint as described in Appendix D.(10)

Range resolution δR of an FMCW radar is

$$dR = \frac{c}{2 \Delta F} \qquad (5\text{-}9)$$

Therefore, if the radar operates in the 10.500- to 10.550-GHz band where bandwidth is limited to perhaps 45 MHz to ensure that the field strength is down by 50 dB outside the band, the range resolution is, at best, 3.3 m (10.8 ft).

Speed or Doppler resolution is given by

$$\Delta f_D = 1/T_s \qquad (5\text{-}10)$$

Presence-measuring radars can be used to control left-turn signals and monitor traffic queues. Radars that detect only moving vehicles from their Doppler frequency can be used to measure vehicular speed on both city arterials and freeways.

5.3 INFRARED DETECTORS

Infrared detection devices currently marketed consist of both *active* and *passive* models. Detectors are available for overhead mounting to view approaching or departing traffic or traffic from a side-looking configuration. In the active system, detection zones are illuminated with low-power infrared energy supplied by light-emitting diodes (LEDs) or with higher levels of energy supplied by laser diodes. None of the LED type of infrared detector was available for this study. The infrared energy reflected from vehicles traveling through the detection zone is focused by an optical system onto a detector matrix mounted on the focal plane of the optics. With infrared devices, the word *detector* takes on a new meaning, namely the energy-sensitive element(s) that converts the reflected energy into electrical signals. Real-time signal processing is used to analyze the received signals and to determine the presence of a vehicle. Changes in received signal levels caused by environmental effects, such as weather and shadows, can be accounted for by the signal processing.

Active infrared detectors provide vehicle presence at traffic signals, vehicle counting, speed measurement, length assessment, and queue measurement. Active infrared detectors can be designed with different fields of view when required for stop-line presence detection and for presence detection in the intersection approach (e.g., a detection zone 68 to 100 feet (20.7 to 30.5 m) in advance of the stop line). The units accommodate mounting heights of between 15 and 30 feet (4.6 to 9.1 m). Multiple units can be installed at the same intersection without interference from transmitted or received signals.

Passive infrared detectors supply similar traffic parameters except for speed. They use an energy-sensitive element located at the optical focal plane to measure the thermal energy emitted by objects in the field of view of the detector and do not transmit energy of their own. The source of the emitted energy is gray-body radiation due to the non-zero temperature of emissive objects as illustrated in Figure 5-8. When a vehicle enters the field of view, the change in emitted energy from the scene is used to detect the vehicle.

An equation can be written for the difference in energy corresponding to a vehicle entering the detector's field of view. The emissivity of the vehicle and road surface in the wavelength region of interest are denoted by ε_V and ε_R, respectively, and their surface temperatures in degrees kelvin by T_V and T_R. The apparent temperature T_B of the vehicle, as sensed by the passive infrared detector, is

$$T_B(\theta,\phi) = \varepsilon_V T_V + (1 - \varepsilon_V)\, T_{Sky} \qquad (5\text{-}11)$$

T_{Sky} is a function of atmospheric and cosmic emission. θ and ϕ are the incident angle with respect to nadir and the angle in the plane of the road surface (the *x-y* plane), respectively.

One can write a similar expression for the apparent temperature of the road surface as

$$T_B(\theta,\phi) = \varepsilon_R T_R + (1 - \varepsilon_R)\ T_{Sky} \quad (5\text{-}12)$$

By subtracting the apparent temperature of the vehicle from that of the road, one gets an expression for the temperature difference $\Delta T_B(\theta,\phi)$ sensed by the passive infrared detector when a vehicle passes through its field of view. Thus,

$$\Delta T_B(\theta,\phi) = (e_R - e_V)\ (T_R - T_{Sky}) \quad (5\text{-}13)$$

when $T_R = T_V$.

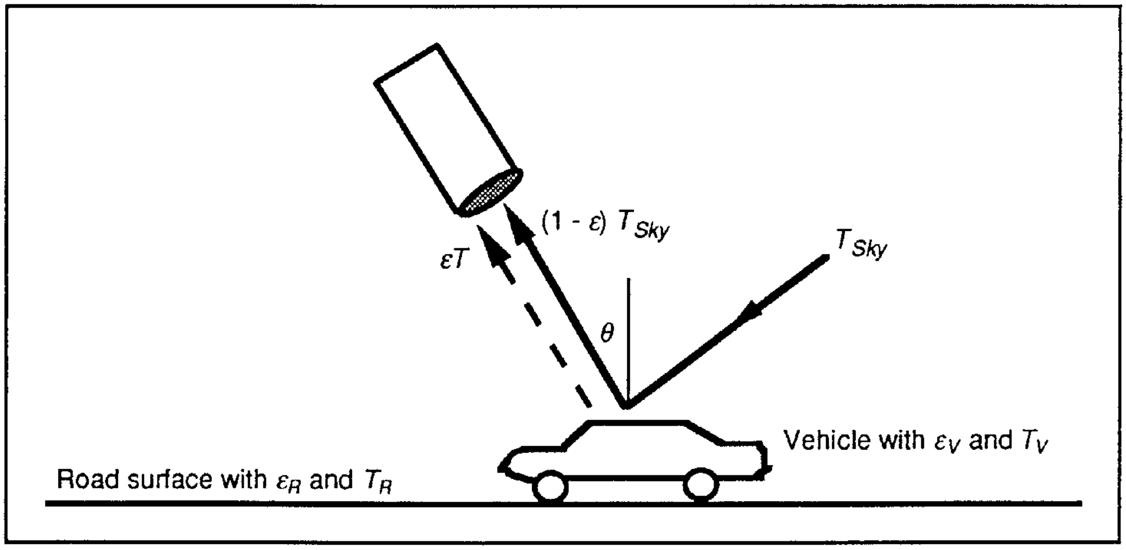


Figure 5-8. Emission of Energy by Vehicle and Road Surface

Hence, a vehicle generates a signal proportional to the product of the difference in emissivity between the road and the vehicle, and the difference between the absolute temperature of the road surface and the sky temperature. On overcast, high humidity, and rainy days, the sky temperature is greater than on clear days and the signal produced by a passing vehicle decreases. This, in itself, may not pose a problem to a properly designed passive infrared detector operating at the longer wavelengths of the infrared spectrum, especially at the relatively short operating ranges typical of traffic management applications.

Another attribute of infrared devices is their ability to image the scene of interest. Non-imaging infrared devices typically use one energy-sensitive detector on the focal plane to gather energy from the entire scene. Objects within the scene cannot be further divided into sub-objects or pixels (picture elements) with this device. Imaging sensors use staring two-dimensional arrays of detectors for traffic-monitoring applications, where each detector has a small instantaneous field of view. Here, more than one detector gathers energy from the scene, allowing details in the imaged area to be discerned. In an alternate method of obtaining imaging data, one-dimensional arrays can be scanned over the scene of interest.

Several disadvantages of infrared detectors are often cited. With active devices, atmospheric effects may cause scatter of the transmitted beam and received energy. Glint from sunlight may cause unwanted and confusing signals. With respect to weather, the amount of energy reaching the focal plane is sensitive to water from fog, haze, and rain, as well as to other obscurants such as smoke and dust. In addition to scattering, these environmental effects can absorb energy that would otherwise be detected by both active and passive infrared devices.

5.4 ULTRASONIC DETECTORS

Ultrasonic vehicle detectors can be designed to receive range and Doppler speed data, the same information used by the radar detectors. Ultrasonic detectors transmit sound waves, at a selected frequency between 20 and 65 kHz, from overhead transducers into an area defined by the transmitter's beamwidth pattern. A portion of the energy is backscattered or reflected from the road surface or a vehicle in the field of view. The preferred viewing configurations for range-measuring (presence) ultrasonic detectors are downward (at a nadir incidence angle) and side viewing. The speed-measuring ultrasonic detector is forward-looking, facing approaching traffic. The transducers in both the presence and speed-measuring ultrasonic devices convert the received sonic energy into electrical energy that is fed to signal processing electronics, either collocated with the transducer or located in a roadside controller.

The range-measuring detector transmits a series of pulses of width T_p (typical values range between 0.02 and 2.5 ms) and repetition period T_o (time between bursts of pulses), typically 33 to 100 ms, as shown in Figure 5-9. The detector measures the time it takes for the pulse to arrive at the vehicle and return to the transmitter. The receiver is gated on and off with a user-adjustable interval that helps to differentiate between pulses reflected from the road surface and those reflected from vehicles. The detection gate is usually set to allow detection of an object at a distance greater than approximately 0.5 m above the road surface. This is accomplished by closing the detection gate several milliseconds before the reflected signal from the road surface arrives at the detector. Automatic pulse repetition frequency control is used to reduce effects of multiple reflections and to improve the detection of high-speed vehicles. These goals are met by making the pulse repetition period as short as possible by transmitting the next pulse immediately after the reflected signal from the road is received.(11) A hold time T_h (composite values from manufacturers range from 115 ms to 10 s) is built into the detectors to enhance presence detection.

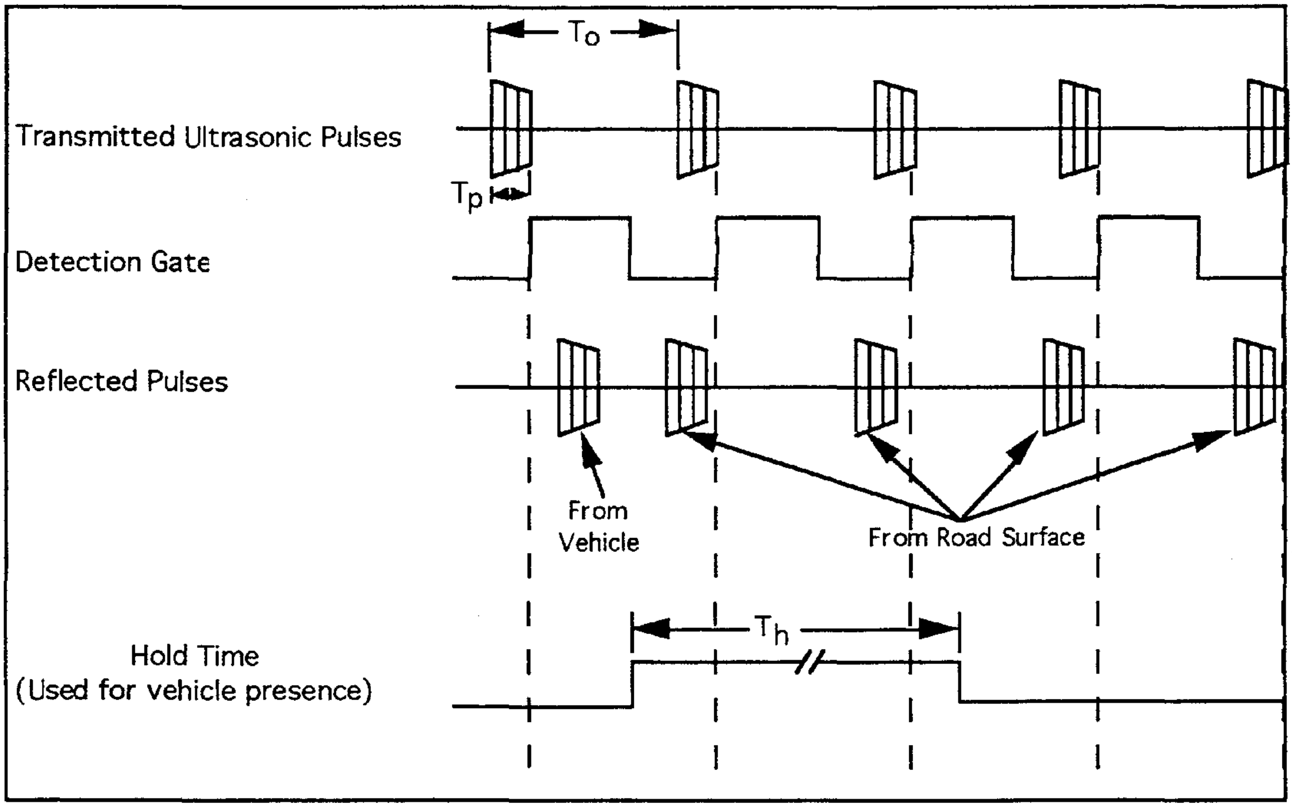


Figure 5-9. Operation of Range-Measuring Ultrasonic Detector

The speed (Doppler) measuring detector transmits a continuous wave of ultrasonic energy. It detects the passage of a vehicle by a shift in the frequency of the received signal. Vehicle speed can be calculated from the pulse width of an internal signal, generated by the detector's electronics, that is proportional to the speed of the detected vehicle.

5.5 PASSIVE ACOUSTIC DETECTOR ARRAYS

Vehicular traffic produces acoustic energy or audible sounds from a variety of sources within each vehicle and from the interaction of the vehicle's tires with the road. Although unintentional, the radiated sound acts as a beacon signal containing information that can be extracted by roadside acoustic energy detectors.

Arrays of passive acoustic microphones provide spatial directivity from which sounds are continuously detected and processed from a specific location along the highway. Sounds from locations outside the detection zone are rejected or attenuated. The size and shape of the detection zone are determined by the aperture size, processing frequency band, and installation geometry of the acoustic array.

When a vehicle passes through the detection zone, an increase in sound energy is detected by the signal processing algorithm and a vehicle presence signal is generated. When the vehicle leaves the detection zone, the sound energy level drops below the detection threshold and the vehicle presence signal is terminated. Passive acoustic arrays can replace magnetic induction loops by providing vehicle presence outputs in the form of contact closures. Using this input, a traffic signal controller can calculate various traffic flow measures, such as volume, occupancy, and average speed.

5.6 INDUCTIVE LOOP DETECTORS

The data supplied by inductive loop detectors are vehicle passage, presence, count, and occupancy. The principal components of an inductive loop detector are one or more turns of insulated wire buried in a shallow cutout in the roadway, a lead-in cable which runs from a roadside pull box to the controller, and an electronics unit located in the controller cabinet. The wire loop is excited with a signal ranging in frequency from 10 kHz to 200 kHz and functions as an inductive element in conjunction with the electronics unit. When a vehicle stops on or passes over the loop, its inductance is decreased. The decreased inductance increases the oscillation frequency and causes the electronics unit to send a pulse to the controller, indicating the presence or passage of a vehicle.

The introduction of digital signal processors has allowed more reliable, accurate, and precise measurement of the change in oscillation frequency or period associated with the loop output that is produced when a vehicle passes over the loop. The improved capability of the detector, in turn, has increased the accuracy of the presence, count, and occupancy measurements. The data processed in the electronics unit can be either the changes in frequency or period that are measured, or the ratio of the change to its initial value.(12) The processing techniques are called:

- Digital frequency shift,
- Digital ratio frequency shift,
- Digital period shift, and
- Digital ratio period shift.

The inductive loop detector represents a mature technology. Reliability of the loop has been improved through better packaging and installation techniques. These include delivery of loops already encased by the manufacturer in protective materials, more thorough cleaning of debris from the sawcut, and the use of better sealants in the installation process.

The output of most current inductive loop detectors is a simple relay or semiconductor closure, signifying the presence or absence of a vehicle. In advanced detector processing systems, some vehicle classification and fault detection can be performed by digitizing the detector output and feeding it to a microprocessor containing embedded signal processing algorithms. These match the detector output to stored signatures for specific vehicle types or fault conditions. Digital codes can be output to identify the type of vehicle detected or report detection faults to a central processing unit.

In the past two decades, loop detector technology has become the most widely used and accepted traffic detector technology in America today. The loop detector system, however, may still suffer from poor reliability, primarily from improper connections made in the pull boxes and in the application of sealants over the sawcut. These problems are accentuated when loops are installed in poor pavement or in areas where utilities frequently dig up the roadbed. Reliability can be improved by installing loops using newer procedures and loop wire protective enclosures developed by manufacturers and user agencies. Improved traffic system operation can be obtained by holding daily loop status meetings at which the malfunctioning loop detector locations are identified and repair teams are dispatched. Another disadvantage of loops is their inability to directly measure speed. If speed is required, then a two-loop speed trap is employed or an algorithm involving loop length, average vehicle length, time over the detector, and number of vehicles counted is used with a single loop detector.

5.7 MAGNETIC DETECTORS

Magnetic detectors indicate the presence of a metallic object by the disruption it causes in an induced or natural magnetic field. These detectors may be active devices, as with magnetometers, or passive devices, as with magnetic detectors. An example of a magnetometer is the 1-inch (25.4-mm) diameter by 4-inch (101.6-mm) long (approximate) detector that is buried about 12 to 18 inches (304.8 to 457.2 mm) below the surface of a road. Two types of passive magnetic detectors exist. One is subsurface-mounted and the other is mounted flush with the roadway. The primary use of magnetic anomaly detectors is to supplement or enhance data from other types of traffic detectors, although they are sometimes used in stand-alone applications.

5.7.1 Magnetometers

Magnetometers are active devices, excited with an electrical current in windings around a magnetic core material. They measure the passage of a vehicle when operated in the pulse output mode and give a continuous output as long as a vehicle occupies the zone of detection when operated in the presence mode. They are used where point or small-area location of a vehicle is required, such as on bridge decks and viaducts where inductive loops are disrupted by the steel support structure or can weaken the existing structure.

The Self-Powered Vehicle Detector (SPVD), developed with FHWA support, is a magnetometer detector with a self-contained battery and transmitter that broadcasts passage or presence information to a receiver that can be located remotely in a controller cabinet. A direct connection (lead-in cable) is not required. An antenna is built into the housing that encloses the magnetometer electronics and battery. The current SPVD model fits into a cylindrical hole 6 inches (152.4 mm) in diameter and 22 inches (558.8 mm) deep. Most of the volume is occupied by the battery. SPVDs have applications where temporary installations are needed or where they can be easily mounted under bridges or viaducts. Their suitability for permanent installation is a function of traffic volume and battery type. Telemetry-based traffic counters can also use spread-spectrum transmission to broadcast vehicle-count data to a receiver that can be located several miles away from the detector.

5.7.2 Passive Magnetic Detectors

Passive magnetic detectors sense perturbations in the Earth's magnetic flux produced when a vehicle passes over the detection zone. They require some minimum vehicle speed for detection, usually 3 to 5 mi/h (4.8 to 8.0 km/h) and, hence, cannot be used as a presence detector.

The two types of passive magnetic detectors differ only in their installation and size. One type is installed by tunneling under the roadway and inserting it into non-ferrous conduit. The other type is installed flush with the pavement. The first is 2 inches (50.8 mm) in diameter by 20 inches (508.0 mm) long. The second is approximately 3 inches by 5 inches by 20 inches long (76.2 mm by 127.0 mm by 508.0 mm long), encased in a cast aluminum housing and flush-mounted with the road surface. Passive magnetic detectors are responsive to flux changes over a large area, covering up to three lanes. If the lanes are considerably wider than 12 feet (3.7 m), several detectors may be required to get a response from small vehicles and motorcycles.

5.7.3 Selection Criteria and Future Trends

The criteria for selecting a magnetic sensor include the desired occupancy and traffic flow accuracy, detector sensitivity, output data rate, minimum required vehicle speed, and cost.

The infusion of new digital processing technology in the area of magnetic anomaly detection promises to significantly improve the performance of existing magnetic detectors, justifying a reassessment of their supplementary role in vehicle detection. In addition, the ability to assemble a group of magnetometers into an array sharing a common signal processor promises the ability to locate, track, and classify vehicles in a multilane scenario using a row of above-ground detectors.

5.8 RELATIVE COST OF DETECTORS

A satisfactory cost comparison between various detector technologies can only be made when the specific application is known. For example, a relatively inexpensive ultrasonic, microwave, or passive infrared detector may seem to be the low-cost choice at first glance for instrumenting a surface-street intersection if inductive loop detectors are not desired. But when the number of detectors needed is taken into account along with the limited amount of directly measured data that may be available (e.g., speed is not measured directly by a passive infrared detector), a more expensive detector such as a video image processor may be the better choice. For example, if it requires 12 to 16 conventional inductive loop detectors (or ultrasonic, microwave, or infrared, etc. detectors) to fully instrument an intersection, the cost becomes comparable to that of a VIP. Furthermore, the additional traffic data and visual information made available by the VIP may more than offset any remaining cost difference. In this example, the VIP is assumed to meet the other requirements of the application, such as the desired 100 percent detection of vehicles at the intersection.

Similar arguments can be made for freeway applications using multiple detectors and requiring information not always available from the less expensive detectors.

Still other applications, such as simple monitoring of multilane freeway or surface-street vehicle presence and speed, may be performed by two microwave radars mounted in a side-looking configuration. In this case, the radar detectors replace a greater number of loops that would otherwise need to be installed in the travel lanes. Furthermore, the radar poten-tially provides direct measurement of speed at a greater accuracy than provided by the loops.

Other factors that affect the cost and selection of detectors are the maturation of the designs and manufacturing processes for detectors that use the newer technologies, the attainment of reduced prices through quantity buys, and the availability of mounting locations and communications links at the application site.

5.9 AUTOMATIC VEHICLE IDENTIFICATION

Automatic vehicle identification (AVI) aids automated toll collection in many applications in North America, Europe, and Asia. Vehicles equipped with AVI transponders are used to determine travel times between fixed points as the vehicles move across a roadway network. As electronic toll collection continues to increase, the large universe of equipped vehicles will produce a secondary benefit by enabling automated measurements of travel time and congestion.

In the New York/New Jersey region, the TRANSCOM program uses AVI observations to track individual vehicles for real-time measurement of travel time. The transponder-equipped vehicles are identified by AVI readers along the roadway. The data are used to determine speed and travel times for incident and congestion management.

Merging this technology with a beacon system can provide true two-way communication with the vehicle. With this capability, real-time traffic data such as origin-destination pairs, travel time, and spot speeds can be collected from the vehicle, while the driver obtains motorist information such as congestion delays, parking availability, and alternative route choices. There are a number of projects being conducted in the Commercial Vehicle Operations sector of IVHS that anticipate the use of Automated Vehicle Identification, Automated Vehicle Location, and Automated Vehicle Classification for fleet operations and regulatory uses. These include the HELP (Heavy Electronic License Plate)/Crescent Project and the Advantage I-75 Project which promise reductions in the time it takes freight to move across the participating regions of the United States and Canada.

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6. TASK C SUMMARY
DEVELOP VEHICLE DETECTOR LABORATORY TEST SPECIFICATIONS AND LABORATORY TEST PLAN

6.1 LABORATORY TEST SPECIFICATIONS FOR VEHICLE DETECTORS

This section reviews the performance specifications and presents a test plan for state-of-the-art, above-the-road detectors that were evaluated in the laboratory tests conducted at the Hughes Aircraft Company, Fullerton, CA, facility and in the City of Los Angeles. These include ultrasonic, microwave, active infrared, passive infrared, and video image processors (VIPs). Although VIPs were not evaluated during the laboratory tests because they were not made available by the manufacturers at that time, they were later included in the field evaluations. The purposes of the laboratory tests were to have Hughes verify the performance of the detectors, with manufacturer assistance where needed, before field deployment and to train Hughes personnel in installing and operating the detectors.

6.1.1 Ultrasonic Detectors

Presence-only and speed-measuring ultrasonic detectors are currently manufactured. These enable direct measurements of vehicle presence, occupancy, and speed (depending on the detector type) to be made.

The following are the current performance characteristics of ultrasonic detectors.(1,2,3)

1. Detectable objects. Detect subcompact cars and larger vehicles. Future applications will require detection of motorcycles and bicycles as well.
2. Waveform. Presence-measuring ultrasonic detectors transmit a pulse waveform, while speed (Doppler)-measuring detectors use continuous wave (CW).
3. Frequency. The frequencies transmitted are between 25 kHz and 50 kHz, depending on the manufacturer and model.
4. Beamwidth. The beamwidth is designed to detect vehicles in single lanes. The upper limit to the beamwidth and sidelobe levels is driven by the requirement to reject vehicles in adjacent lanes. The lower limit is driven by the need to detect lane straddlers. The beamwidth is thus a function of vehicle width, lane width, transducer sidelobes, and mounting height. Typical beamwidths establish patterns on the road surface that are 4 feet (1.2 m) wide at the specified mounting height.
5. Speed measurement range. Speed-measuring ultrasonic detectors presently respond to vehicles traveling between 2.5 and 75 mi/h (4.0 and 120.7 km/h).
6. Speed measurement accuracy. Two types of vehicle speed are required: microscopic or spot vehicle speed and macroscopic or composite speed of a group of vehicles. Required accuracy for microscopic speed measurements is between 3 and 5 percent for signalized intersection applications and ±1 mi/h (1.6 km/h) for microscopic and macroscopic freeway incident detection applications.
7. Minimum distance between vehicles. Current detectors will detect two separate vehicles when they are 1.5 to 10 meters apart, depending on detector design and speed of the vehicle.
8. Detection Range. The required detection range is 8 to 20 meters for vehicle counting, occupancy, and speed measurements. Ultrasonic detectors may not be suitable for longer range surveillance applications as may be required for freeway incident detection.
9. Installation configuration. Both overhead and side-looking operations

are accommodated within the performance limits discussed above.

10. Power requirements. Must meet NEMA and Type 170 controller standards. These are 120 VAC, 60 Hz, with current draw not to exceed the capacity of the particular controller and installation. Some controllers have DC voltage available; however, the voltage and current availability vary and must be confirmed with the operating agency.

6.1.2 Microwave Detectors

By appropriate processing of the information in the received energy, direct measurements of vehicle presence, occupancy, and speed (depending on detector capability) can be obtained.

Current performance characteristics include:(4)

1. Detectable objects. Detectors sense subcompact cars and larger motorized vehicles. It is desirable to detect motorcycles and bicycles as well.

2. Detection pattern. The antenna pattern may be designed to illuminate single or multiple traffic lanes. Some multiple-lane applications, such as vehicle counting, require signal processing to differentiate between vehicles detected in the different lanes. If designed for intersection traffic management, single-lane coverage is required for measurement of left-turn lane occupancy. Multiple-lane coverage may be acceptable for detecting through-lane occupancy.

3. Detection angle. Microwave detector incidence angles can be adjusted in both the azimuth and elevation planes.

4. Response time. The response time is defined as the time for an input, generated by a vehicle in the field of regard, to be processed by the detector and registered as an output in the form of a presence, count, or other appropriate indication. A response time is also defined for the time required by the detector to drop an output when the vehicle leaves the field of regard. The response time of current models is <0.3 seconds. The upper limit may be unacceptable for counting high-speed vehicles in high-density traffic.

5. Hold time. Detector hold times are designed to eliminate dropout of vehicle detections as may occur when towing vehicles with long tongue couplings. A hold time retains vehicle presence during a potential dropout period until new data are received and averaged into the next vehicle presence or velocity calculation. Current detection hold times vary with the application, ranging from continuous for Doppler detectors to 1 second for detectors that respond to vehicle presence.

6. Mounting configuration. Microwave detectors are mounted above the roadway in forward-looking, rear-looking, and side-looking configurations.

7. Speed measurement range. The minimum vehicle speed measured is approximately 3 mi/h (4.8 km/h) for Doppler motion detectors and the maximum is 65 mi/h (104.6 km/h) to greater than 85 mi/h (136.8 km/h), depending on the model. True presence microwave detectors can detect stopped vehicles.

8. Speed measurement accuracy. Two types of vehicle speed measurement are required: microscopic or spot vehicle speed and macroscopic or composite speed of a group of vehicles. Required accuracy for microscopic speed measurements is ±3 to 5 percent for signalized intersection applications and ±1 mi/h (±1.6 km/h) for microscopic and macroscopic freeway incident detection applications. Current microwave Doppler detectors measure speed within ±2 to 3 mi/h (±3.2 to 4.8 km/h). One true presence microwave radar specifies

its speed measurement accuracy at ±10 percent.

9. Power requirements. Must meet NEMA and Type 170 controller standards. These are 120 VAC, 60 Hz, with current draw not to exceed the capacity of the particular controller and installation. Some controllers have DC voltage available; however, the voltage and current availability vary and must be confirmed with the operating agency.

10. FCC approval. The operator does not need FCC approval as the manufacturer has obtained this and has marked the radar with the proper identifier, e.g., meets requirements of FCC Rules, Part 15. These rules specify the center frequency, bandwidth, and output power of the radar.

6.1.3 Active Infrared Detectors

Active infrared (IR) detectors transmit a beam of light and detect a portion of it that is reflected back to the detector by the objects in the field of view. They provide presence, speed, count, and occupancy data in day and night operation. When a laser diode is used as the transmitting energy source, the detector can also provide vehicle profile and shape data, and, hence, be used for vehicle classification.

Specifications for the IR detector that uses a laser diode as the active transmitting element are:(5,6)

1. Detection indication. In addition to using LEDs as potential transmitters of infrared energy, high-intensity LEDs are also used as indicators of the output state of the detector, i.e., to alert the operator as to whether there is a vehicle in the field of view of the detector.

2. Detection pattern. The footprint on the road surface should emulate a 1.8-m x 1.8-m (6-ft x 6-ft) loop at a range of 9.2 m (30 ft) for signalized intersection control and freeway incident detection. It is also desirable to emulate a 4.3-m x 1.8-m (14-ft x 6-ft) loop and have a detection range of over 15.2 m (50 ft) for signalized intersection control and freeway ramp-metering applications.

3. Warmup time. The detector is operational within 10 seconds after application of power.

4. Stability. The detector must respond only to changes in scene reflectivity. Atmospheric effects, such as those caused by clouds shadowing the field of regard, shall not produce false vehicle detections in excess of those allowed for a particular IVHS application.

5. Response time. The response time is defined as the time for an input, generated by a vehicle in the field of regard, to be processed by the detector and registered as an output in the form of a presence, count, or other appropriate indication. A response time is also defined for the time required by the detector to drop an output when the vehicle leaves the field of regard. The response time of laser diode type IR detectors is ≈10 ms when a vehicle enters or leaves the field of regard.

6. Presence hold time. IR detectors using laser diode transmitters hold the presence for as long as a vehicle is in the field of view. This specification can be tailored, however, to meet individual operations requirements of the cognizant agency.

7. Speed measurement range. Currently available detectors measure speeds between 0 and >80 mi/h (128.7 km/h).

8. Speed measurement accuracy. The calculated accuracy for vehicle speed measurement is ±1 mi/h (±1.6 km/h) up to 70 mi/h (112.7 km/h).

9. Detection range. The vehicle detection range is 1.5 to 15 meters.

10. Power requirements. Must meet NEMA and Type 170 controller standards. These are 120 VAC, 60 Hz, with current draw not to exceed the capacity of the particular controller and installation. Some controllers have DC voltage available; however, the voltage and current availability vary and must be confirmed with the operating agency.

6.1.4 Passive Infrared Detectors

Passive infrared detectors sense objects through the energy that they emit. The detectors currently on the market usually have a single detector element that provides signals giving vehicle presence, occupancy, and count.

Characteristics of current passive infrared detectors include:(7)

1. Presence hold time. The presence signal is held as long as a vehicle remains in the field of view of the detector, up to 6 minutes maximum. This parameter can be designed to have other values as required.

2. Response time. Response times of current detectors are a maximum of 500 ms.

3. Speed measurement range. State-of-the-art passive infrared detectors detect stopped vehicles and those traveling at freeway speeds.

4. Stability. For the scene under observation, the detector must respond only to changes in the temperature and emissivity of the vehicles which are to be detected. Atmospheric effects, such as those caused by clouds shadowing the field of regard or rain-induced cooling of the background, shall not produce false vehicle detections in excess of those allowed for a particular IVHS application.

5. Sensitivity. An operator-controlled sensitivity adjustment may be required to give adequate dynamic range to detect vehicles under the anticipated weather conditions. The sensitivity must allow operation without continually changing settings to accommodate changing input levels due to varying climatic conditions.

6. Detection range. The vehicle detection range is 6.4 to 15 meters.

7. Power requirements. Must meet NEMA and Type 170 controller standards. These are 120 VAC, 60 Hz, with current draw not to exceed the capacity of the particular controller and installation. Some controllers have DC voltage available; however, the voltage and current availability vary and must be confirmed with the operating agency.

6.1.5 Video Image Processors

A video image processor is a combination of software and hardware components that extract desired information from the output of an imaging sensor, such as a conventional TV camera or an infrared camera. The combination of imaging hardware, processor, and software forms a VIP detector.

The following represent current VIP specifications.(8,9)

1. Detectable objects. Current VIPs sense motorcycles, subcompact cars, and larger motorized vehicles.

2. Number of lanes observed. Current systems provide vehicle data over at least three lanes. It is desirable to extend the coverage to the equivalent of five lanes in order to monitor emergency areas (such as highway shoulders), ramps for freeway applications, higher capacity freeways that have additional through-lanes, and multiple-lane surface-street intersections.

3. Speed measurement range. VIP detectors are capable of measuring speeds between 0 and 160 mi/h (257.5 km/h).

4. Speed measurement accuracy. Two types of vehicle speed measurement

are required: microscopic or spot vehicle speed, and macroscopic or composite speed of a group of vehicles. Required accuracy for microscopic speed measurements is ±3 to 5 percent for signalized intersection applications and ±1 mi/h (±1.6 km/h) for microscopic and macroscopic freeway incident detection applications.

5. Vehicle count accuracy. Counts are generally accurate to within ±5 percent.
6. Minimum distance between vehicles. VIP detectors are required to detect vehicles separated by 1/3 to 2/3 of a meter (1 to 2 feet) for the city arterial application. In freeway applications, the intervehicle spacing may be different (e.g., 10 to 30 m) depending on the comfort time of the driver (the time required or anticipated by the driver to stop the vehicle) and traffic congestion. In fact, in heavy congestion, the minimum vehicle separation may be the same as on an arterial. The maximum detection distance of a VIP along the surface of a road is a function of mounting height, intervehicle distance or gap, and vehicle height as described in Section 5.
7. Detection Range. The detection range is 8 meters to 20 meters for applications requiring traffic data close to the mounting location, and a minimum of 92 meters (300 feet) for adaptive, real-time signal control at city intersections and for freeway incident detection and traffic management.
8. Power requirements. Must meet NEMA and Type 170 controller standards. These are 120 VAC, 60 Hz, and current draw not to exceed the capacity of the particular controller and installation. Some controllers have DC voltage available; however, the voltage and current availability vary and must be confirmed with the operating agency.
9. Operator intervention requirements. The detector shall function without operator adjustments during setup or normal operation to account for:
    a. Day-night transitions.
    b. Shadows on the roadway.
    c. Reflections from vehicles or pavement during rain.
    d. Weather changes.

   The following conditions do require operator intervention:

    e. Repositioning the field of view.
    f. Initialization.
    g. Resetting the vehicle detection zone.

6.1.6 Inductive Loop Detectors

The specifications for the inductive loop detector amplifier models actually used in tests coordinated with the City of Los Angeles Department of Transportation and the state transportation departments supporting the field tests are included in Appendix G. Catalog pages were provided in the Task D Report.

6.1.7 Magnetometers

The specifications for the models actually used in tests coordinated with the City of Los Angeles Department of Transportation and the state transportation departments supporting the field tests are included in the Task D Report.

6.1.8 Interface, Cost, and Environmental Requirements

The following requirements apply to all of the detectors.

1. Communications data rates.

    a. Video imagery:

    A maximum of 128 KB/s (112 KB/s desirable) shall be used for imagery transmission with a VSAT communications link. Bandwidth may also be limited by the capacity of available leased lines or spread-spectrum radio channels.

b. Detector status data:

   (1) Urban application: 88 bytes/30 s from each intersection.

   (2) Freeways: 250 bytes/30 s from each site.

   (3) Identification and location of each vehicle equipped with a sensor/radio: 30 bytes/30 s.

2. Cost.

   a. Must be competitive with the life-cycle cost of multiple inductive loop detectors as used in the desired application.

   b. Periodic maintenance is acceptable. The time interval between maintenance operations should be as large as possible. A 2-month interval may be satisfactory for some applications. Maintenance requirements should be verified by consultation with the end customer.

3. Mounting configuration for city arterial application.

The following are preliminary guidelines for mounting detectors:

   a. Desirable to accommodate side mounting from a light pole or other utility pole. Detector should also be capable of being mounted at an intersection (on traffic light support pole) and looking 83 to 167 meters (250 to 500 feet) back toward oncoming traffic.

   b. Desirable for detectors to sense vehicles in multiple lanes to minimize the number of detectors needed to view the roadway. Utilization of a fish-eye lens to scan an intersection may help achieve this result with VIPs. (These comments also apply to freeway use of detectors.)

   c. Detector mounting height of 17 feet (5.2 m) is compatible with all utility poles.

   d. Traffic lanes are 10 to 12 feet (3.0 to 3.7 m) wide.

   e. Parking lane (lane nearest curb) is 17 feet (5.2 m) wide.

   f. Setback of traffic light from curb is 2 feet (0.6 m).

   g. Number of lanes to be monitored is one, two, or three.

4. Interfaces.

The interfaces depend on whether the test site uses a Type 170 or NEMA controller. The specific controller specification shall be used to define the interface between the detector, amplifier, and controller. General information about the amplifier/controller interface is given below.

   a. Type 170 controller:(10)

      (1) 6800 microprocessor-based.

      (2) Cards are 6-1/2 inches by 4 inches (165.1 mm by 101.6 mm).

      (3) Contact closure needed from detector.

      (4) Input/output lines typically available are: ±24 volts, reset, two pair field connections, two pair controller connections.

   b. NEMA controllers: Some use an 8085, 8-bit processor. Use NEMA Pub. TS-1 for detailed interface specifications.

5. Voltage.

Per Type 170 and NEMA controller specifications.

6. Temperature.

The outside temperature extremes for the detectors are determined from the following considerations:

The NEMA range for outside ambient temperature extremes is -30°F (-34°C) to +165°F (+74°C).(11) Some application sites may require the full military specification temperature range of -30°C to +125°C; however, colder states such as Minnesota may require designs that accommodate lower minimum outside operating temperatures. Heaters in weatherproof enclosures may be needed to control the operating environment of the electronic and mechanical components. Conversely, agencies operating in desert environments may require components capable of operating at higher outside temperatures. Here coolers or fans may be needed in the enclosures.

7. Humidity.

The detectors shall be designed to operate under conditions where the relative humidity complies with Table 2-1 of the NEMA Pub. TS-1 (1989) for Traffic Control Systems.

8. Lightning protection.

Lightning protection is recommended for all types of detectors.

9. Vibration and shock.

Vibration and shock hardening are needed to withstand swinging from poles during high winds and earthquakes. The following NEMA standards may have to be improved to meet these goals. Also, some detectors, such as nonimaging IR and ultrasound, work best when they do not swing.

a. The NEMA vibration standard [paragraph 2.2.5 of TS-1 (1989)] requires the detector to maintain all of its functions and physical integrity when subjected to a vibration of 5 to 30 cycles/s up to 0.5g applied in each of three mutually perpendicular planes.

b. The NEMA shock standard [paragraph 2.2.6 of TS-1 (1989)] specifies that the detector shall suffer neither permanent mechanical deformation nor any damage that renders the unit inoperable when subjected to a shock of 10g's ± 1g applied in each of three mutually perpendicular planes.

10. Electromagnetic energy health hazard.

The detector shall present no health hazard from emitted radiation. As a minimum, use current standards set by professional organizations and government agencies for safe levels of microwave and electromagnetic radiation power densities. The current standard is <1 mW/cm^2 (10 W/m^2) for indefinitely prolonged exposure. A factor of 10 less exposure may be desirable for large-scale public applications to further reduce anxiety in the public.

11. Other operating and storage conditions.

Use NEMA Publication TS-1 (1989) as a guide.

12. Vendor notification of extreme field test conditions.

The vendors will be notified of the anticipated outside temperature, humidity, wind, and vibration levels at each field test site, and will be required to make recommendations for proper operation of their detectors.

6.1.9 Summary

Table 6-1 compares the ability of the various overhead-mounted detector technologies to provide key traffic parameters such as presence, occupancy, flow, and speed on single and multilane roads. However, all detectors based on a given technology may not provide all of these parameters. The data available are a function of how the technology was implemented and the requirements set by the manufacturer or the transportation agency for measuring and transmitting particular data.

Table 6-1. General Qualitative Capabilities of Current Detector Technologies

Detector Technology	Presence	Occupancy	Volume	Speed	Multilane Coverage
Ultrasonic	Direct	Direct	Direct	Direct & Indirect	No
Microwave	Direct	Direct	Direct	Direct	Direct
Active Infrared	Direct	Direct	Direct	Direct & Indirect	Direct
Passive Infrared	Direct	Direct	Direct	Indirect	No
Video Image Processor	Direct	Direct	Direct	Direct	Direct
Key: Direct = Via direct measurement of data Indirect = Via calculations based on measured data					

6.2 LABORATORY TEST PLAN

The laboratory test plan and equipment were used to confirm the performance of the overhead-mounted traffic detectors described in Section 1. These detectors were previously tested by the manufacturer before delivery to Hughes. Therefore, the tests described below are in the nature of end-to-end system evaluation tests that confirm proper detector operation, rather than more detailed tests that evaluate the performance of subsystems within each detector.

The specific objectives of these tests were:

- ☐ Verify that detector operation conforms to vendor specifications.
  - The specifications measured under this objective are those that do not require the use of special manufacturer-specific test equipment, unless it is normally supplied with the detector.
  - The intent of these tests is not to confirm all manufacturer specifications, but rather to verify those most critical to detector operation for the state field tests. Those specifications not directly verified at Hughes will be confirmed using manufacturer test data and reports.
- ☐ Identify and measure other detector performance characteristics that affect traffic parameter values.

6.2.1 Ultrasonic Detectors

The ultrasonic detector test procedures for vehicle presence and speed detectors are based on information obtained from the detector vendors.

The first three tests and measurements below apply to Sumitomo detectors.(12)

1. Transmit frequency and output power of the presence detector.
   a. With the Sumitomo ultrasonic presence detector, the measurement of transmit frequency and output power is performed by connecting the transmitter-receiver to the input/output (I/O) terminal of the detector cabinet. Other manufacturers' equipment may require the use of transducers (i.e., special microphones) to convert the transmitted ultrasonic energy into electrical energy in order to perform these measurements.
   b. The ultrasonic transmit frequency and peak output power will be within the tolerances specified by the vendor.
2. Field of view (FOV) of the presence detector.
   a. The Sumitomo ultrasonic transmitter-receiver feeder will be connected to the I/O terminal of the detector cabinet. A cylinder will be placed in front of the transmitter-receiver as a standard reflection object, simulating a vehicle. The cylinder is approximately 0.2 m in diameter and 2 m in length. The distance between the cylinder and the transmitter-receiver is approximately 5 m.
   b. The measured FOV will be 1.2 m ±0.12 m (i.e., ±10 percent) and the detection lamp on the detector cabinet will be on when the cylinder is within the FOV of the detector.
3. Speed measurement accuracy of the speed detector.

   This test measures the Doppler frequency shift and the received signal amplitude using the transmitter-receiver of the ultrasonic speed detector.

   a. Connect the ultrasonic receiver cable to the input/output (I/O) terminal of the detector cabinet. A pinwheel type of reflector will be placed in front of the transmitter-receiver as a standard reflection object to simulate the return from a vehicle. The reflector's turning fins simulate vehicle movement. The distance between the reflector and the transmitter-receiver will be about 2 m.

b. The received amplitude and frequency of the Doppler signal will be measured at the detector unit and verified to be within the range prescribed by the vendor.

The following end-to-end operational test applies to the ultrasonic detectors built by Microwave Sensors.(13)

4. End-to-end operational test.

   a. Test equipment.

      (1) Square reflector target at least 6 inches (152.4 mm) on a side.

      (2) 10 to 24 VDC, 0.15-amp (min) power supply.

   b. Operational test.

      (1) Remove the enclosure cover.

      (2) Connect power supply.

      (3) Place square reflector 3 feet (0.9 m) from transmitter.

      (4) Turn transmitter on after equipment warm-up time has elapsed.

      (5) Verify that appropriate LED indicator is on.

5. Range test.

   a. Objectives. This test applies to all ultrasonic detectors. The objectives are to learn how to optimally install the detectors for the field tests and to examine their detection capabilities against real vehicles. Range testing will verify the detection range versus different size and shape motorized vehicles, speed (if the detector is designed to measure this parameter), and minimum spacing for differentiating between two vehicles in the same lane. The boresight direction of the ultrasonic speed and presence detectors will be determined before they are mounted on tower, light pole, and overhead sign structures used in these tests. A laser range finder may be used to aid in measuring the footprint on the ground.

   Video imagery of the tests will be recorded to help document the results. To aid in data evaluation, markers will be placed on the test track at regular intervals. Data sheets will be prepared in advance of the tests to ensure that all required data are recorded and test equipment identified. Test procedures may be expanded as needed to ensure test integrity and repeatability.

   b. Detection zone. The size of the detection zone will be measured by rolling a vehicle or moving the standard reflection object through the field of view and noting when the detector gives an output.

   c. Minimum spacing between vehicles. The minimum spacing for differentiating between vehicles will be found by parking a vehicle at one end of the detection zone and rolling another towards it from the other end. The distance recorded when the detector no longer distinguishes between the two vehicles is the minimum spacing. For detectors that respond to vehicles traveling above a minimum speed, a vehicle simulator, such as a metal plate, will be towed behind the first vehicle. The spacing between the vehicle and the plate will gradually be decreased from run to run to determine the minimum spacing required for vehicle differentiation. Alternatively, a second vehicle may be towed behind the first at a preset distance.

d. Detection range. To characterize detection range versus vehicle type and speed, tests will be performed at the minimum and maximum operating ranges of the detectors. Automobiles and pickup trucks will be driven through the field of view of the detectors at speeds between 5 and 55 mi/h (8.0 and 88.5 km/h), in 10-mi/h (16.1-km/h) increments.

e. Sensitivity to vehicle density. As time permits, the performance of the detectors will be verified against low-density (<800 vehicles per hour per lane) and high-density (>1800 vehicles per hour per lane) traffic flows. These data will aid in establishing optimal use of the detectors during field testing. The speed measurement accuracy of applicable detectors will be verified during these tests by using speed surveys performed by the host agency, e.g., the City of Los Angeles Department of Transportation. Techniques to be used include radar speed guns, infrared speed guns, and vehicles traveling at predetermined speeds through the detection zones.

6.2.2 Microwave Detectors

These tests for microwave vehicle presence and speed detectors supplement the signal-to-noise, speed calibration, and output level adjustment tests performed by the vendors. The end-to-end operational test applies to microwave detectors built by Microwave Sensors.(14) Microwave radar detectors built by other vendors may require modifications to this test.

1. End-to-end operational test.
    a. Test equipment.
        (1) Square reflector target at least 6 inches (152.4 mm) on a side.
        (2) 10 to 24 VDC, 0.25-amp (min) power supply.
    b. Operational test.
        (1) Remove the enclosure cover.
        (2) Connect power supply.
        (3) Place square reflector 3 feet (0.9 m) from transmitter.
        (4) Turn transmitter on after equipment warm-up time has elapsed.
        (5) Verify that appropriate LED indicator is on.
2. Minimum and maximum detectable radar cross section.

    Calibrated corner reflectors (CRs) will be inserted into the FOV of the true presence detectors to determine the minimum detectable target size and the maximum target size that can be detected without saturating the detector. The latter result is not expected to affect detector operation for traffic management applications. An approximate range of CR sizes is from 5 m^2 to 100 m^2. Several reflectors in this range will be selected. Since the transmitted and received waveforms are linear and like polarized, trihedral (odd bounce) reflectors will be used.

3. Range test.

   a. Objectives. This test applies to all microwave detectors. The objectives and testing techniques are the same as those discussed earlier for the ultrasonic detectors. The tests will verify boresight, detection range, sensitivity to intervehicle spacing, and beam patterns. If the detector measures speed, then its capability to measure speeds of individual and groups of vehicles will be verified.

   b. Detection zone. The size of the detection zone will be measured by rolling a vehicle or inserting a corner reflector through the field of view and noting when the detector gives an output.

   c. Minimum spacing between vehicles. The minimum spacing for differentiating between vehicles will be found by parking a vehicle at one end of the detection zone and rolling another towards it from the other end. The distance recorded when the detector no longer distinguishes between the two vehicles is the minimum spacing. For detectors that respond to vehicles traveling above a minimum speed, a vehicle simulator, such as a metal plate, will be towed behind the first vehicle. The spacing between the vehicle and the plate will gradually be decreased from run to run to determine the minimum spacing required for vehicle differentiation. Alternatively, a second vehicle may be towed behind the first at a preset distance.

   d. Detection range. To characterize detection range versus vehicle type and speed, tests will be performed at the minimum and maximum operating ranges of the detectors, some of which extend out to 300 feet (91.4 m). Automobiles and pickup trucks will be driven through the field of view of the detectors at speeds between 5 and 55 mi/h (8.0 and 88.5 km/h), in 10-mi/h (16.1-km/h) increments.

   e. Sensitivity to vehicle density. As time permits, the performance of the detectors will be verified against low-density (<800 vehicles per hour per lane) and high-density (>1800 vehicles per hour per lane) traffic volume. These data will aid in establishing optimal use of the detectors during field testing. The speed measurement accuracy of applicable detectors will be verified during these tests by using speed surveys performed by the host agency, e.g., the City of Los Angeles Department of Transportation. Techniques to be used include radar speed guns, infrared speed guns, and vehicles traveling at predetermined speeds through the detection zones.

6.2.3 Active Infrared Detectors

The following laboratory procedures are for testing Schwartz Electro-Optics active IR detectors that use a laser diode as the transmitting energy source.(15) This detector generates two beams to count and measure the speed of vehicles. Active IR detectors manufactured by other vendors may require modifications to the tests described below.

1. Setup.

   The equipment for these tests consists of a sighting scope, IBM personal computer (PC), vendor-supplied test software, a black target having low reflectance, and a white target having high reflectance.

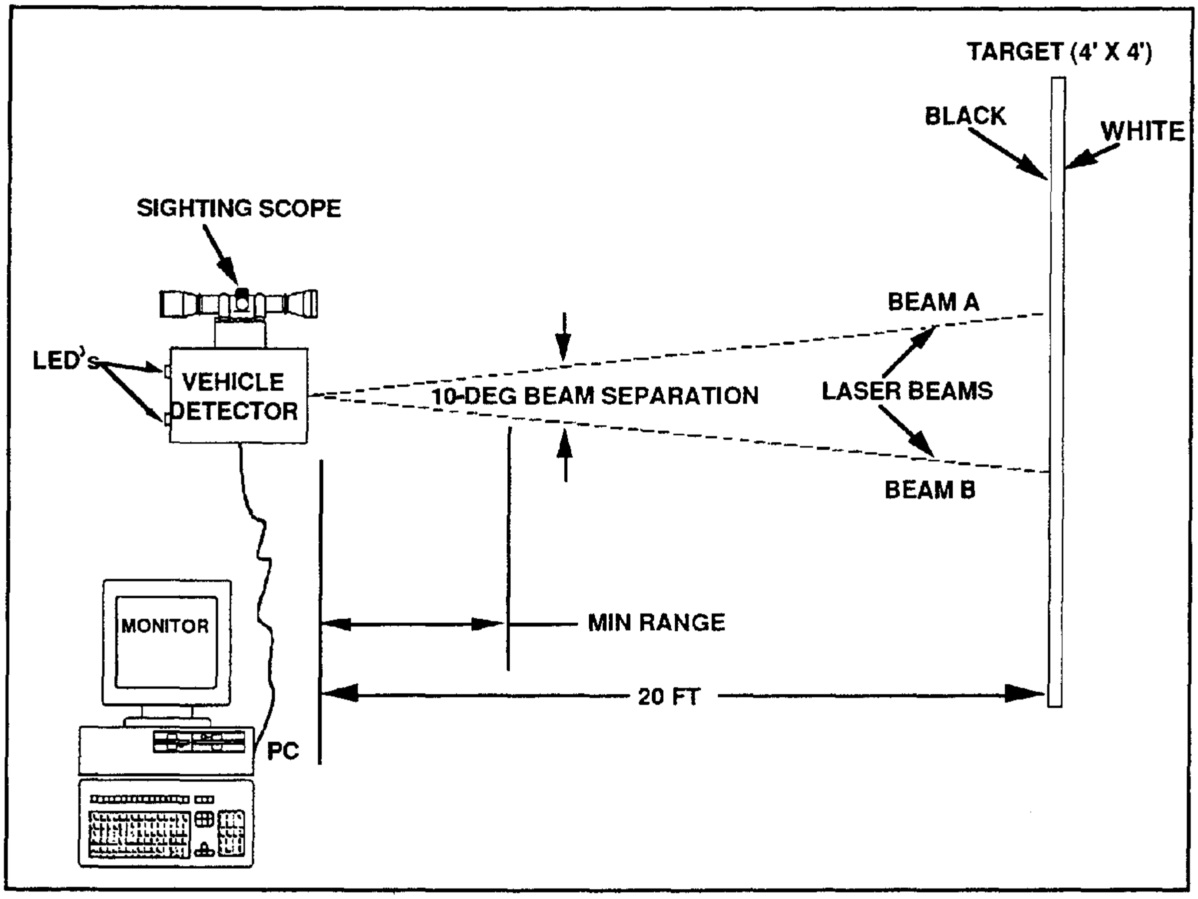
The layout for the laser radar IR detector functional tests is shown in Figure 6-1. The detector is oriented so that the cross hairs of the sighting scope are centered on the black target at a distance of 20 feet (6.1 m). A PC is connected to the vehicle detector's serial interface. Initially, an opaque screen is used to block the laser transmitter beam at a distance less than the detector's minimum range (as specified by the vendor).

2. Self-test.

   After the detector is warmed up, the manufacturer-supplied test software will initiate a series of five self-tests.

   In the first, the integrity of the operating software in read-only memory (ROM) will be verified by calculating an 8-bit checksum. Each byte in ROM will be accumulated, ignoring overflow, to form an 8-bit value that will be compared with the checksum that is stored in ROM. The second self-test verifies proper functioning of the RAM through a non-destructive read/write test that toggles each bit in memory from on to off. The third self-test uses the microprocessor to measure the laser's pulse repetition frequency (PRF). The last two tests measure the power supply voltages and the detector's temperature using the microprocessor's A/D (analog-to-digital) converter.

   If the traffic detector passes all five self-tests, the green LED will flash for about 2 seconds and then remain on continuously. If the red LED flashes and then remains on continuously, the detector has failed one or more of the self-tests.



1 ft = 0.305 m

Figure 6-1. Setup Used to Verify Functioning of Active IR Detector with Laser Diode Transmitter

3. Initialization.

   With the laser beams blocked, the red LED indicator will glow continuously, indicating that the range is beyond the minimum/maximum limits. Upon removing the opaque screen, the red LED will turn off, indicating that the detector is measuring a range within its minimum/maximum limits.

   If the screen is inserted in the beam at a range greater than the minimum range, but less than the range to the target minus 1 foot (0.3 m), the green LED will turn off. This corresponds to a vehicle-presence indication. When these tests are complete, turn on the PC and load the test software.

4. Return-signal strength.

   With the vehicle detector viewing the black target at a distance of 20 feet (6.1 m), the return signal is displayed as a percent of full scale. If properly operating, the return signal will be within ±10 percent of the baseline value supplied with the detector (for a given ambient temperature).

5. Range measurement.

   If the laser power is within vendor specifications, the 20-foot (6.1-m) range to the black target is displayed on the monitor to within the ±0.25-foot (76.2-mm) accuracy of the detector. When the target is reversed so that range measurements are made to the white surface, the range value displayed is the same as that for the black target to within the detector's accuracy.

6. Speed measurement function.

   This test confirms that the detector's speed measurement circuit is functioning, but does not calibrate the speed measuring function. Pass the screen rapidly through the laser beams at a distance of 2 feet (0.6 m) from the target. The PC monitor should indicate vehicle count and speed. The vehicle count should be increased in increments of one each time the procedure is repeated.

7. Range test.

   a. Objectives. The objectives and test techniques for these range tests are the same as those for the ultrasonic detectors. The tests verify boresight, detection range, sensitivity to intervehicle spacing, and beam patterns. If the detector measures speed, then its capability to measure individual and group vehicle velocities is also verified.

   b. Viewing angle. The detectors are installed on the tower or overhead structure at viewing angles that are a function of the manufacturer-specified mounting height.

   c. Detection zone. The size of the detection zone is measured by rolling a vehicle or moving a reflector through the field of view and noting when the detector gives an output.

   d. Minimum spacing between vehicles. The minimum spacing for differentiating between vehicles is found by parking a vehicle at one end of the detection zone and rolling another towards it from the other end. The distance recorded when the detector no longer distinguishes between the two vehicles is the minimum spacing.

   e. Detection range. Detection range versus vehicle type and speed are measured to determine the minimum and maximum operating ranges of the detectors. Automobiles and pickup trucks are driven through the field of view of the detectors at speeds between 5 and 55 mi/h (8.0 and 88.5 km/h) in 10-mi/h (16.1-km/h) increments.

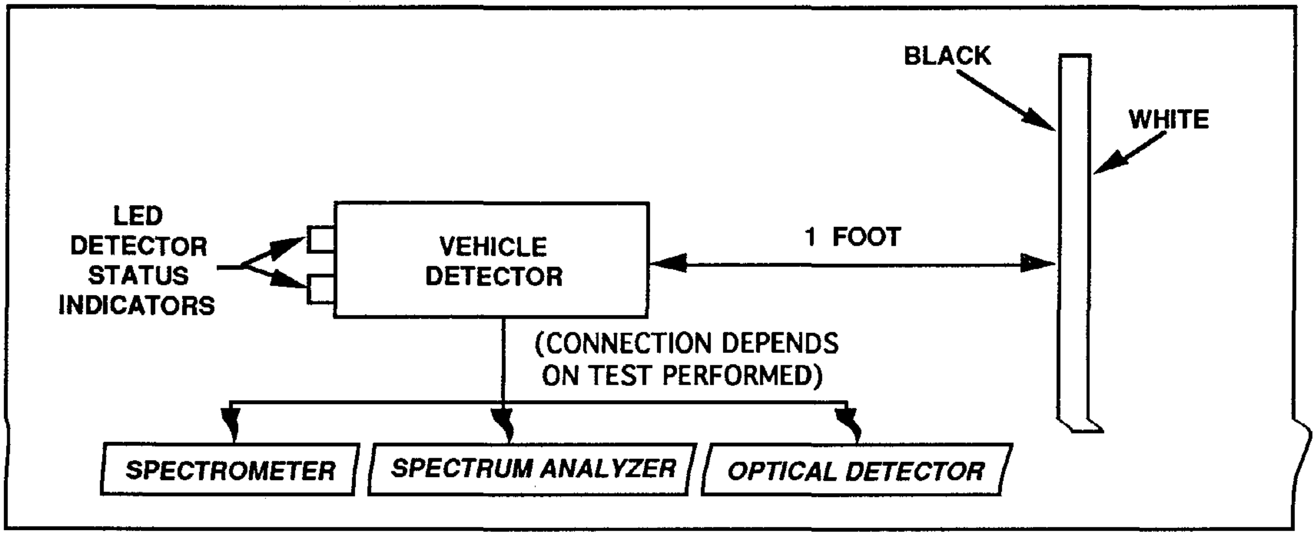
f. Sensitivity to vehicle density. The performance of the detectors are verified in low-density (<800 vehicles per hour per lane) and high-density (>1800 vehicles per hour per lane) traffic flows. These data aid in establishing optimal use of the detectors during field testing. The speed measurement accuracy of the laser radar is verified by using speed surveys performed by the host agency. Truth data are obtained from radar speed guns, infrared speed guns, and vehicles traveling at predeter-mined speeds in the detection zones.

6.2.4 Passive Infrared Detectors

The indoor tests of the passive IR detectors are designed to measure frequency response, sensitivity, boresight, and effects of temperature changes on performance. The plans and equipment for testing passive infrared detectors are described below.(16)

1. Indoor test setup.

   The passive infrared detector is mounted such that its field of view is focused on a calibrated "blackbody radiator" target as shown in Figure 6-2. After power is applied and the detector has stabilized, the blackbody emission source, whose temperature corresponds to that of an operating vehicle, is used to characterize the detector. The blackbody is located at a relatively short distance (e.g., 1 foot [0.3 m]) from the detector to obtain an accurate reading that is not degraded by background objects.



1 ft = 0.305 m

Figure 6-2. Indoor Test Setup for Passive IR Detector Frequency Response, Sensitivity, and Detection Pattern Tests

2. Indoor test.

   a. Frequency response. A frequency spectrometer is used to measure the response of the detector to different wavelengths of radiation.

   b. Detector sensitivity. Distance between detector and calibration source, size of the calibration source, its temperature, and its emissivity are variables that are parametrically varied for this measurement. The gain of the detector is adjusted to prevent saturation at maximum signal strength. The distance between the blackbody and the detector is increased until the radiance signal-to-noise ratio (S/N) drops below the level sufficient for detection. A spectrum analyzer is used to check the specific detector detectivity D* value (which is proportional to S/N).

c. Detection pattern. The detection pattern is measured by plotting the output of the detector as a function of the range and azimuth position of a blackbody. An optical transducer is used to convert the output of the passive IR detector under test into units of volts that are then plotted against azimuth angle. The test is repeated at several ranges within the operational limits.

3. Range test.

a. Objectives. The objectives and test techniques for the range test are the same as those discussed earlier for the ultrasonic detectors. The tests provide vehicle tracking data as a function of vehicle speed (although the actual speed cannot be measured by the passive IR detectors), number of vehicles in the FOV, vehicle separation distance, and vehicle color. The tests verify boresight, detection range, and beam pattern.

b. Viewing angle. The detectors are installed at a viewing angle commensurate with the mounting height as specified by the vendor. Overhead and side-mounting operation are characterized.

c. Detection zone. The size of the detection zone is measured by rolling a vehicle or moving an emissive object through the field of view and noting when the detector gives an output.

d. Minimum spacing between vehicles. The minimum spacing for differentiating between vehicles is established by parking a vehicle at one end of the detection zone and rolling another towards it from the other end. The distance recorded when the detector no longer distinguishes between the two vehicles is the minimum spacing. These tests are performed for light- and dark-colored vehicles.

e. Detection range. To characterize detection range versus vehicle type and speed, tests are performed at the minimum and maximum operating ranges of the detectors. Automobiles and pick-up trucks are driven through the field of view of the detectors at speeds between 5 and 55 mi/h (8.0 and 88.5 km/h), in 10-mi/h (16.1-km/h) increments.

f. Sensitivity to vehicle density. The performance of the detectors is verified against low-density (<800 vehicles per hour per lane) and high-density (>1800 vehicles per hour per lane) traffic flows. These data aid in establishing optimal use of the detectors during field testing.

6.2.5 Video Image Processors

The VIP described below is typical of those that function as ILD replacements in that they provide vehicle count, presence, occupancy, and speed. Additional data that can be provided by more advanced VIP systems in development include vehicle classification and tracking from lane to lane. The VIP illustrated in Figure 6-3 contains four representative subsystems.

The camera subsystem consists of an infrared or a visible-spectrum camera with an externally controllable and automatic iris mode, luminance/chrominance (Y/C) (when a color camera is configured) and National Television Standards Committee (NTSC) video outputs, and a fixed focal length lens. Additional items may include a filter, lens shade, zoom lens, and a remotely controlled rotatable pan/tilt camera mount.

The camera enclosure subsystem consists of a reinforced, environmentally controlled enclosure; transparent window; camera mount; and mounting brackets.

The processor subsystem contains the circuit boards and software that detect vehicles in the camera's field of view and calculate vehicle count, velocity, and length. This subsystem may be rack-mountable in a 19-inch (482.6-mm) chassis, but may be substantially smaller as well. In fact, some systems in development will perform the processing within the camera enclosure. The output data are transmitted through a communications interface (I/F) to a traffic management center. NTSC video can be made available on demand for surveillance or can be continuously transmitted over suitable bandwidth channels. Locally, data can be accessed on an RS-232 serial interface and video accessed from a standard BNC connector.

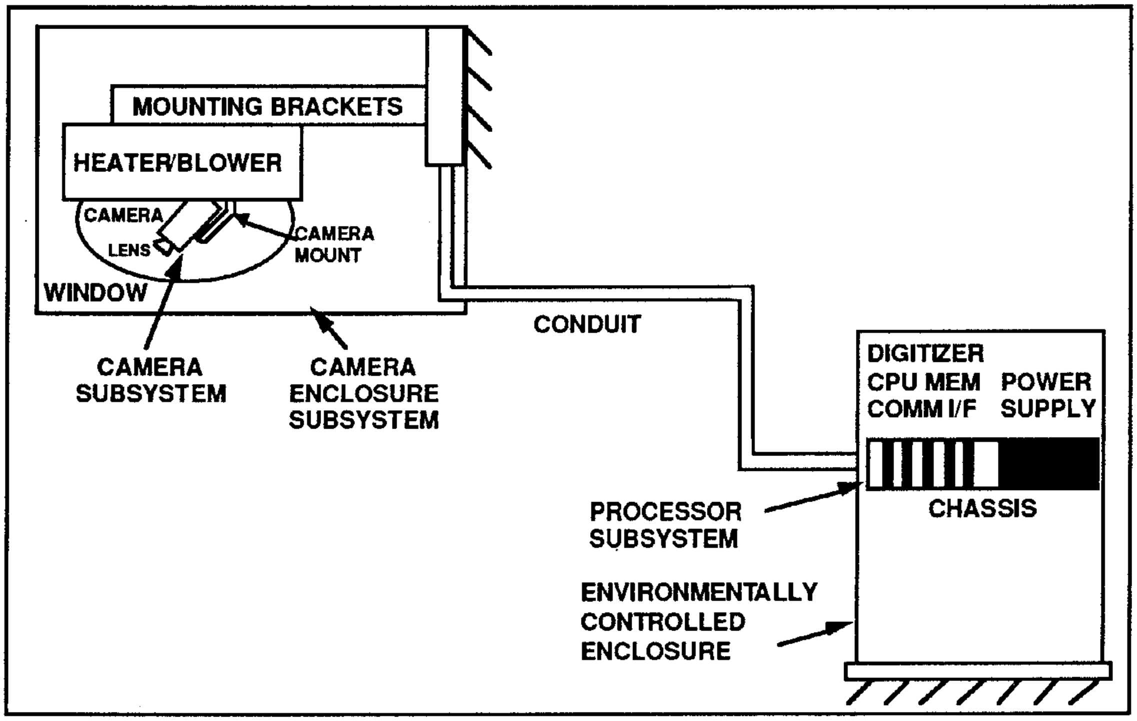


Figure 6-3. Representative Video Image Processor System

The cable subsystem consists of the video cable that transmits video from the camera to the processor subsystem, and the power and control cables that transmit all power, environmental, and operational control signals for the camera and enclosure from the processor subsystem to the camera.

The installation and test procedures for the VIPs consist of:

1. Installation.

   The camera enclosure and subsystems are mounted over the traffic lanes to be monitored. The viewing angle is adjusted to give the camera an unobstructed view of the traffic lanes, while excluding the sky from the field of view of the camera.

The processor subsystem is housed in an environmentally controlled enclosure to maintain the required temperature range, with relative humidity 0 to 90 percent, non-condensing. The enclosure supplies standard 120 VAC, 60 Hz, 200 watts power with surge protection to the processor chassis. The processor is typically installed within 150 feet (45.7 m) of the mounted camera subsystem (the maximum length of the standard cables). However, video supplied over longer dedicated lines is also accept-able. If cable installation requires weatherproof or underground conduit, appropriate arrangements are to be made with local traffic engineers.

2. Test station.

   Portable setup/test equipment is required for some VIP systems. The setup equipment can typically include a keyboard, two monitors, and a joystick. In this example, the user follows the procedures for the indoor tests and for detector placement in the video scene and initiation of the VIP functions specified in the range test.

3. Indoor test.

   This test verifies basic operation of the detector algorithms using pre-recorded imagery data.

   Required equipment includes an optical disc player and the portable setup/test station described above. The preferred input for the recorded video is through the Red-Green-Blue (RGB) or Y/C connectors to the processor, although standard NTSC video can be used if necessary. The user performs the following setup procedure as though the data were from a live source:

   a. Connect the recorded video to the vehicle detector.
   b. View the video on the set up station monitor.
   c. Use the keyboard and joystick to place the detectors in the traffic lanes as seen on the monitor.
   d. Start vehicle detector operation using the keyboard.

   The number of vehicles detected by the VIP and their speeds are compared to the truth data set for the environmental and traffic conditions on the recorded video. Typical conditions that are evaluated include variations in the number of lanes, shadows, rain, and day/night transitions.

4. Range test.

   a. Objectives. The objectives of these tests are to verify the detection range and zone boundaries, verify the ability of the detector to measure vehicle speed and vehicle count, and verify the resistance of the detector to artifacts such as shadows.

   b. Mounting. The VIP camera is installed in an overhead-mounted configuration above the test track. If the detector is mounted between 18 and 24 feet (5.5 and 7.3 m) above the track, it is generally placed over the center of the traffic lanes to be monitored. With mounting heights of 40 to 50 feet (12.2 to 15.2 m), the camera may be located off to the side of the traffic flow. Higher mounting generally produces more accurate speed measurement.

   c. Detection range and speed. The test vehicle is driven from a range of 300 feet (91.4 m) towards the camera to verify the detection-range boundaries and speed outputs of the VIP. The speed accuracy is checked at one or more specific speeds.

   d. Multiple-vehicle detection. Single-lane traffic consisting of two or more vehicles separated by 10 feet (3.0 m) verifies the ability of the VIP to detect multiple vehicles.

e. Resistance to artifacts. Opposing traffic is used to verify the ability of the VIP to detect a vehicle and measure its velocity in the presence of an opposite-moving shadow in its lane.

f. Truth data. Parameters (such as vehicle counts per lane, average vehicle speed, and vehicle lengths) obtained from the imagery using human analysts are used as "truth" data. Such data are gathered for various camera positions, traffic conditions, weather variations, and over a 24-hour period representative of various lighting conditions.

The speed measurement accuracy of the detectors is verified during these tests by using speed surveys performed by the host agency. Techniques used include radar speed guns, infrared speed guns, and vehicles traveling at predetermined speeds through the detection zones.

Effects of stationary and moving shadows from both man-made and natural objects, such as buildings, bridges, trees moving in the wind, and other vehicles are studied as they are available. Vehicle-length data probably cannot be generated in darkness when the vehicles themselves are not visible. Under these conditions, most present-day algorithms use vehicle lights to provide an indication of vehicle presence.

6.2.6 Summary

Detector specifications and a test plan have been developed to perform the required laboratory tests. These tests help ensure adequate testing at a minimum cost before subjecting the detectors to the more rigorous field trials. The detector manufacturers have provided detector specifications and selected laboratory test procedures. These procedures can be used to further understand the strengths and weaknesses of each type of detector.

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7. TASK E SUMMARY

CONDUCT LABORATORY DETECTOR TESTS

The Task E reports update the laboratory test plans and describe the results obtained from evaluation of above-the-road vehicle detectors conducted at Hughes Aircraft Company in Fullerton, CA and in the City of Los Angeles. Part I of the report describes the results obtained at the Munson test track at Hughes-Fullerton where vehicles were driven through the field of view of the detectors at low speed. Parameters such as power consumption, detection range, delay time, ground illumination pattern, and detection sensitivity with respect to vehicle type were characterized. Passive infrared detectors, originally scheduled for evaluation on the test track and in the laboratory, were not available for these tests. Part II describes indoor bench tests and results for the microwave detectors. Here, output power and frequency, input power consumption, minimum detectable signal, response time, and antenna patterns were measured. Part III describes the results from tests performed by the City of Los Angeles Department of Transportation at their Exposition Boulevard test site under real traffic flow conditions. Here the performance of the above-the-road detectors were compared with those of inductive loops and magnetometers. Video image processors were not evaluated during any of the laboratory tests because they were not available at the time.

7.1 SCOPE

Tests conducted at Hughes Aircraft Company in Fullerton, CA evaluated:

- Detector outputs in response to motor vehicles traveling on a test track.
- Power consumption, detection range, and delay time.
- Detector beam patterns and sensitivity to different types of vehicles.

7.2 DETECTORS EVALUATED

The following detectors were evaluated during the laboratory tests:

Microwave Detectors

- Microwave Sensors Model TC-20
- Microwave Sensors Model TC-26
- Whelen Engineering Model TDN-30

Ultrasonic Detectors

- Microwave Sensors Model TC-30C
- Sumitomo Electric Industries Model SDU-200
- Sumitomo Electric Industries Model SDU-300

Laser Radar Detectors

- Schwartz Electro-Optics Model 780D1000

Passive Infrared Detectors

- Eltec Model 842 (Los Angeles only)

Inductive Loop Detectors

(Los Angeles only)

Magnetometers

(Los Angeles only)

Two of each detector were furnished by the manufacturers, with the exception of the Sumitomo SDU-200, where one was supplied. We later learned that the correct model number for the SDU-200 is the RDU-101. However, since the SDU-200 nomenclature was already in use for this detector, we kept it as the designation for the Sumitomo Doppler ultrasound detector.

7.3 MUNSON TRACK FACILITIES

A scissors lift, shown in Figure 7-1, was used at the Munson track to support the overhead detectors and adjust their heights.

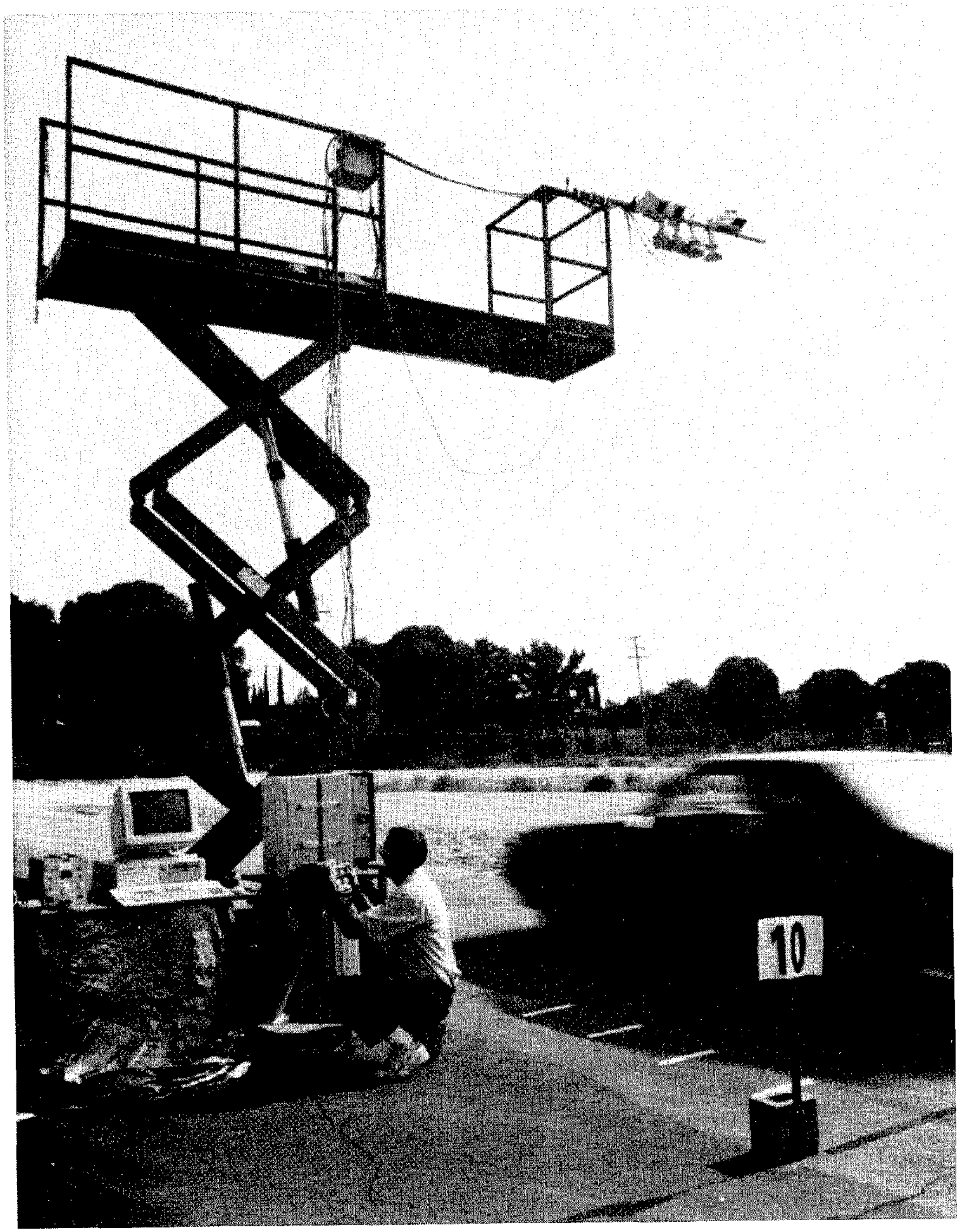


Figure 7-1. Munson Test Track
Shown are the scissors lift upon which the detectors are mounted, power supplies and meters, and a passing target vehicle.

7.3.1 Test Track

The portion of the track composed of a 350-foot (106.7-m) straight section of conventional single-lane road was used during the test. The paved road had a 2-degree incline approaching the detector mounting location that was accounted for when adjusting the incidence angle of the detectors.

Marking the location of the scissors lift (i.e., the detector mounting location) as 0 feet, 150 feet (45.7 m) of the track was striped at 10-foot (3.0-m) intervals and the distance was marked along the edge. Additional markings were placed at 50-foot (15.2-m) intervals through 250 feet (76.2 m). These markers were used for estimating distances between the detector being evaluated and the vehicle when an event occurred. Additional markers were added at 5-foot (1.5-m) intervals in critical detection areas to more accurately measure detection ranges.

7.3.2 Detector Mounting

A scissors maintenance lift was used as the detector mounting platform. Attached to and protruding from the lift was a length of 1-inch (25.4-mm) galvanized pipe upon which the detectors were mounted as shown in Figure 7-2. The lift was elevated to the appropriate height for the detector performance measurements.

7.3.3 Target Vehicle Descriptions

Three vehicle types were used as targets.

Vehicle 1: 1985 Ford Mustang two-door sedan, representing a medium-sized automobile. Its external dimensions were:

Length = 180 inches (4.6 m);
Width = 68 inches (1.7 m);
Height = 45 inches (1.1 m).

Vehicle 2: 1986 Honda Goldwing 1200 motorcycle, representing the class of large motorcycles. Its external dimensions were:

Length = 98 inches (2.5 m);
Width = 38 inches (0.97 m);
Height = 59 inches (1.5 m).

Vehicle 3: 1986 Honda Rebel 450 motorcycle, representing the class of small motorcycles. Its external dimensions were:

Length = 89 inches (2.3 m);
Width = 34 inches (0.86 m);
Height = 49 inches (1.2 m).

7.3.4 Detector Evaluation Procedure

Different procedures were established for detectors that relied on vehicle motion to produce an output and for those that were true presence detectors, capable of detecting stopped vehicles.

7.3.4.1 Speed/Motion-Sensing Detectors

Performance data for motion detectors were collected in one of two ways: (1) an observer located on the elevated scissors lift recorded the approaching vehicle with a camcorder, producing a record to be evaluated at a later time, or (2) a roadside observer, located at the range where vehicle detection was anticipated, recorded the vehicle position at the time an alarm sounded, signifying detection by the detector under test.

7.3.4.2 Presence-Sensing Detectors

The presence-sensing detectors available for these tests gave an output when a vehicle entered its field of view, but did not provide speed information. These detectors were evaluated for their presence-sensing consistency and beam-pattern size.

7.3.4.3 Detector Output Monitor

A detector output monitor was attached to the camcorder. Housed in a small plastic enclosure, it consisted of a battery, piezoelectric alarm, and a light-emitting diode (LED). The LED was mounted at the end of the enclosure on an arm that positioned the LED in the lower part of the field of view of the camcorder. When connected to an appropriate detector output, the LED was turned on and the piezoelectric alarm sounded when a vehicle was detected. The camcorder captured both the LED and audible signals during the recording process and helped identify the correct detection range.

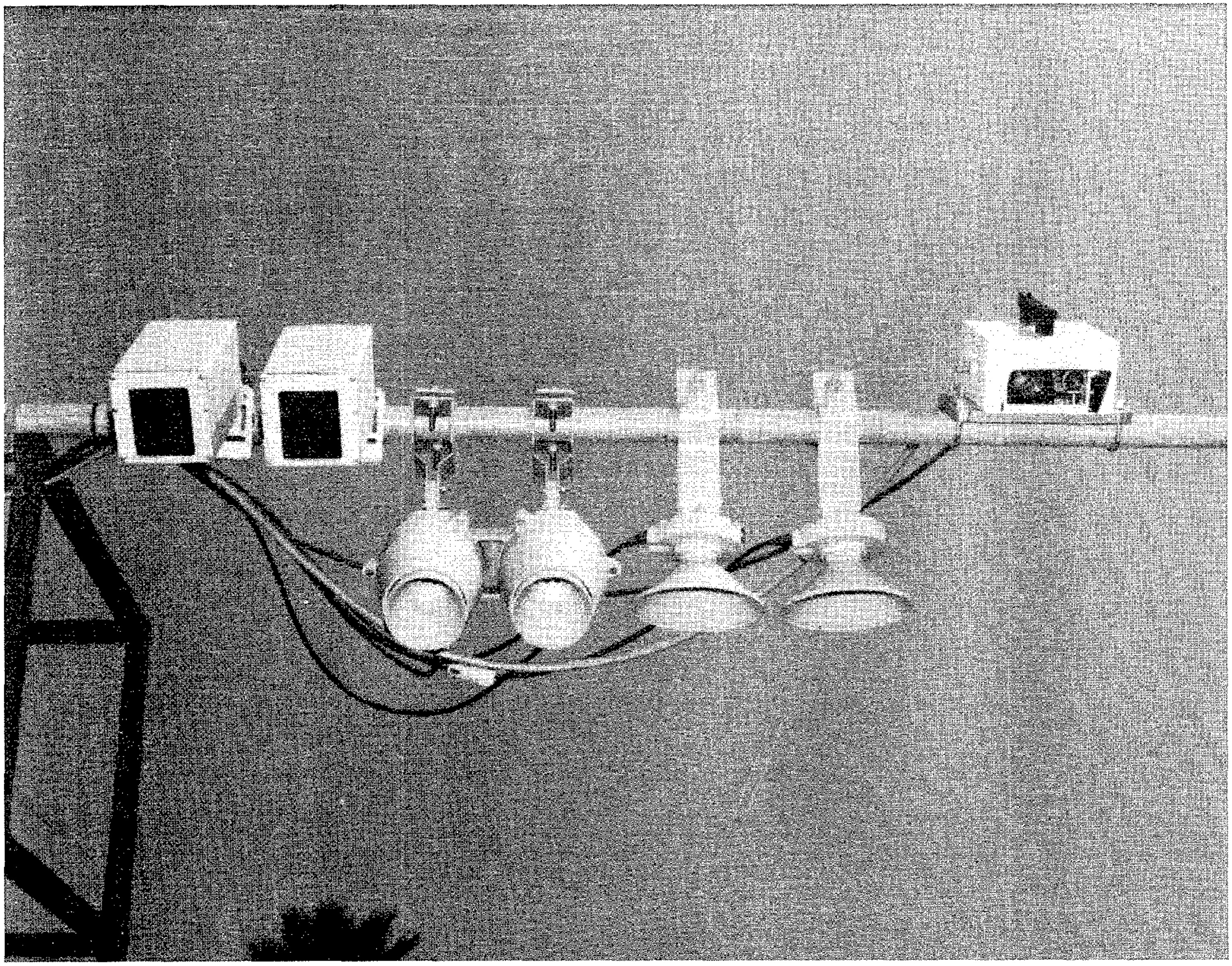


Figure 7-2. TC-30C, SDU-200, SDU-300, and 780D1000 Detectors (From Left to Right) Mounted On the Scissors Lift

7.3.4.4 Measurements

The sequence shown in Figure 7-3 illustrates the test event sequence.

Power:

The applied voltage was adjusted to the manufacturer's low and high limits and the current draw was measured at each voltage.

Delay Time:

Several detectors have adjustable delay times that maintain the detection signal after the vehicle passes through the detector's field of view. The minimum and maximum values were measured.

Detection Range:

The detection range was variable on several of the speed/motion and presence detectors through a sensitivity adjustment. The detection ranges for minimum and maximum sensitivity settings were recorded when this adjustment was available.

Incidence Angle:

The incidence angle of most of the speed/motion and presence detectors can be varied to change the engagement range. The exception is the presence-type ultrasonic detectors that operate at a nadir (0 degree or straight down) incidence angle. As detector design and operation permitted, incidence angles of 45 and 70 degrees were used to measure detection range.

Inbound/Outbound Vehicle Detection:

This feature was evaluated if the detector had the capability of detecting both inbound and outbound vehicles.

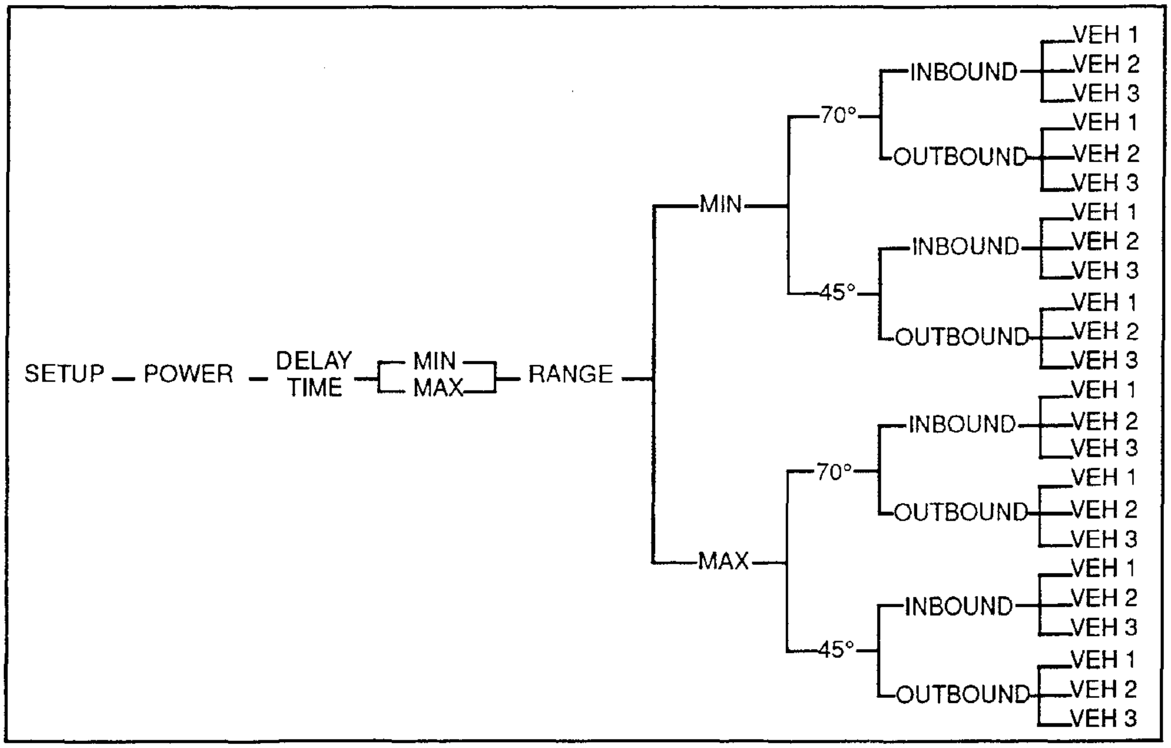


Figure 7-3. Munson Test Track Event Sequence

7.4 LESSONS LEARNED FROM TEST TRACK DETECTOR EVALUATION

Hughes tested seven vehicle detectors during June through July 1992 on the Munson test track. The detectors included three ultrasonic (SDU-200, SDU-300, TC-30C), three microwave (TC-20, TC-26, TDN-30), and an infrared laser radar (780D1000).

7.4.1 Microwave Detectors

The three microwave detectors, Microwave Sensors TC-20 and TC-26 and Whelen Engineering TDN-30, operated at an X-band frequency of 10.54 GHz.

7.4.1.1 TC-20

The TC-20 detector was raised to 17 feet (5.2 m) above the road surface with incidence angles of 70° and 45° with respect to nadir. Although only one traffic lane was used in the test, the wide-beam (16°) antenna should detect multiple lanes of traffic in a real traffic flow environment, since it has a 14-foot (4.3-m) diameter 3-dB footprint approximately 60 feet (18.3 m) downstream when mounted at a 70° incidence angle. The potential to detect traffic outside the lane of interest is reduced by decreasing the detection range by turning the range adjust screw counterclockwise (CCW). The minimum hold time (hold time screw fully CCW) was 0.5 second.

7.4.1.2 TC-26

The TC-26 was operated at a height of 17 feet (5.2 m) with both inbound and outbound vehicles, at incidence angles of 70° and 45° with respect to nadir, and at high and low sensitivity settings. The detector can be operated with the low-range setting to minimize detection of adjacent-lane vehicles. In the low-range mode the footprint on the road surface is narrowed. However, even in this mode, the 15-foot-long (4.6-m-long) Ford Mustang was detected at a range of 200 feet (61.0 m).

7.4.1.3 TDN-30

The TDN-30 detector was configured for the freeway traffic management mode to demonstrate its detection-range envelope. The TDN-30 has a narrow-beam antenna, requiring jumper JP8 to be installed on the electronics board in the housing. Jumper JP2 was installed to detect approaching vehicles or removed to detect departing vehicles. Other jumpers specify the serial communications data transmission rate and mode, dwell time, and application. When the detector is mounted parallel to the roadway surface, the antenna boresight is 45 degrees with respect to nadir.

The ability of the narrow-beam antenna to discriminate between two vehicles traveling at the same speed, one behind the other, was evaluated. In the first run, the Ford Mustang and a small Toyota pickup truck were driven at 10 mi/h (16.1 km/h) with 15 feet (4.6 m) separation. The detector indicated constant presence when the vehicles were driven into the detection zone. In the following run, the same two vehicles were driven at 15 mi/h (24.1 km/h) with an estimated separation distance of 20 feet (6.1 m). This time a momentary break in the tone from the detector output monitor was heard, indicating separate detection of both vehicles as they were driven through the detection zone.

7.4.2 Ultrasonic Detectors

Microwave Sensors' TC-30C and Sumitomo's SDU-200 and SDU-300 were the ultrasonic detectors evaluated. The TC-30C and the SDU-300 are presence detectors that mount directly over a lane and look straight down at the road surface at an incidence angle of 0 degrees. The SDU-200 (RDU-101) is a Doppler device that operates at an incidence angle of 45 degrees.

7.4.2.1 TC-30C

Operator adjustments on the TC-30C were the detection-range control and the relay hold time. The range control was set so that the receiver didn't trigger on the road surface, but instead detected the tops of vehicles 2 to 3 feet (0.6 to 0.9 m) above the road surface. The detection range was established by first turning the range-control screw clockwise until the detector detected the road surface and then turning the screw counterclockwise until the detection was dropped. The relay hold time was adjusted for minimum hold (0.25

seconds) by turning the appropriate screw fully counterclockwise. If vehicle detection did not occur, the receiver gain was adjusted.

7.4.2.2 SDU-200 (RDU-101)

The SDU-200 was evaluated for vehicle detection and speed-measuring capability.

Accurate speed measurements are dependent on the speed correction switch, DSW1, that controls the reading on the digital speed display. When the spring-loaded three-position Display/Operate/Test switch is momentarily placed in the Test (down) position, the display should read between 92 and 96 km/h.

The digital display read 98 km/h when the three-position switch was placed in Test during the first run. Since this value was too high, DSW1 was adjusted from 9 (normal) to 8, corresponding to a 3 percent reduction in the displayed value. When the digital display was interrogated again, it showed 96 km/h, a reading within specifications.

The small vehicle/large vehicle discrimination value was adjusted next. It enables vehicle counts to be made in each of two vehicle size classes. A value is normally chosen to differentiate between vehicles below and above 6.0 m in length. Since the largest vehicle in these tests was 15 feet (4.6 m) long, SW1 was set to the minimum value of 4.4 m.

The VR2 sensitivity adjustment is used to specify whether vehicles in one or more lanes are detected. Since the test was designed to detect vehicles in one lane only, VR2 was set near the full clockwise or minimum sensitivity position.

7.4.2.3 SDU-300

The three switches located in the right corner behind the front panel of the SDU-300 control unit are set at the factory for normal operation. The detector functioned properly during the tests using these settings.

7.4.3 Infrared Laser Radar Detector

The Schwartz Electro-Optics 780D1000 active infrared laser radar was operated at incidence angles of 0° (nadir), 45°, and 60°. It was designed to function with approaching traffic only at the time of these tests.

Detector data were evaluated by connecting the RS-232 connector to a personal computer that runs a setup and data acquisition program supplied by Schwartz. The detector functioned properly at 45° and 60° incidence angles. If the backscattered laser signal is too weak to be detected at 60°, as may happen with some reflecting surface shapes, the incidence angle must be reduced to increase the magnitude of the returned signal. Generally, in a normal installation, the incidence angle is 45° or less. Zero-degree incidence is beyond the normal operational design limit of the detector.

7.5 DETECTOR PERFORMANCE RESULTS FROM TEST TRACK MEASUREMENTS

The detectors were evaluated with respect to:

- Test vehicle,
- Operating current,
- Delay time,
- Engagement range,
- Disengagement range,
- Beam pattern, and
- Operational and functional anomalies.

7.5.1 TC-20 Microwave Detector

The TC-20 was evaluated at incidence angles of 45° and 70°.

7.5.1.1 Operating Current

The operating voltages for the TC-20 are 10 to 24 VAC or 12 VDC at 250 mA. During the Munson tests, the voltages ranged from 18 to 24 VAC. Additional power consumption measurements for the microwave detectors are given in Section 6 of this chapter.

Table 7-1. Input Power for TC-20

VOLTAGE	CURRENT
18 VAC	223 mA
24 VAC	225 mA

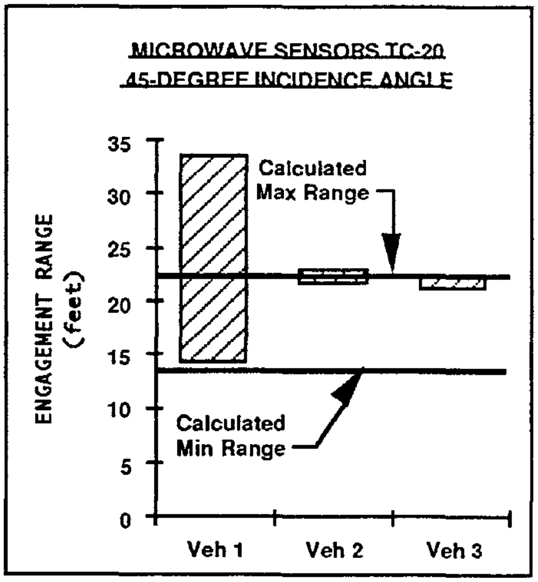
7.5.1.2 Delay Time Measurement

Table 7-2. Delay Time For TC-20

DELAY TIME
270 ms minimum
9.6 s maximum

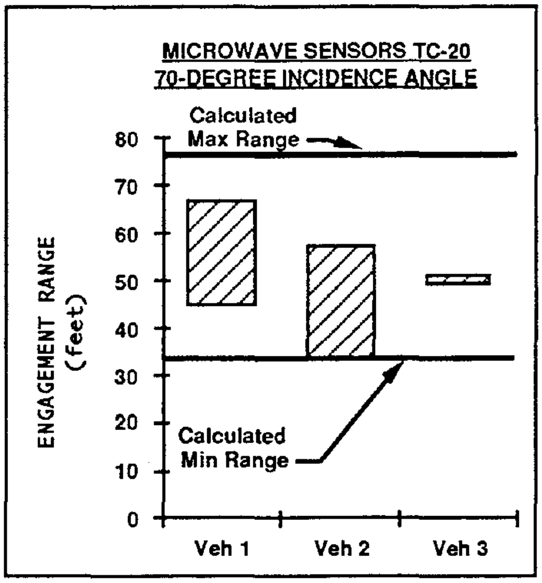
7.5.1.3 Detection Range

Figures 7-4 and 7-5 show the TC-20 engagement range using the detector's maximum range setting and 45° and 70° incidence angles, respectively, compared to the calculated engagement range. The calculated engagement range is based on geometrical factors that include mounting height, beamwidths, and incidence angle as tabulated in Appendix C of Part I of the Task E Report and Appendix F of this Final Report. It assumes that receiver output power, sensitivity, and target radar cross section are adequate to receive the signal at the detector. Vehicle 1 is the Ford Mustang, vehicle 2 is the large motorcycle, and vehicle 3 is the small motorcycle.



1 ft = 0.305 m

Figure 7-4. Detection Range of TC-20 at 45-Degree Incidence Angle



1 ft = 0.305 m

Figure 7-5. Detection Range of TC-20 at 70-Degree Incidence Angle

7.5.2 TC-26 Microwave Detector

The TC-26 was evaluated at incidence angles of 45° and 70°.

7.5.2.1 Operating Current

The operating voltages for the TC-26 are specified at 12 to 24 VAC or VDC with a current of 350 mA.

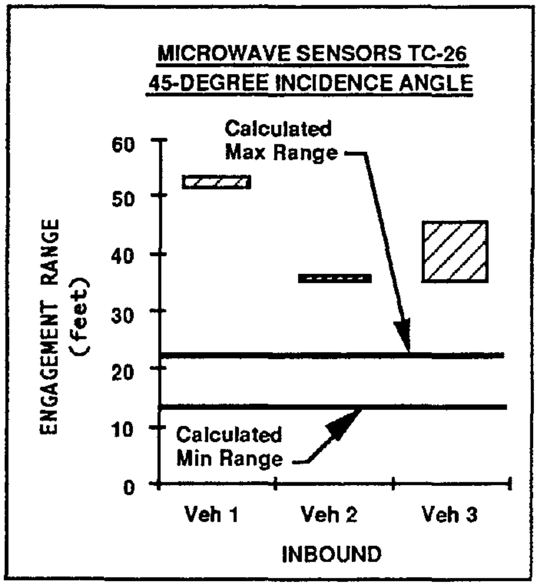
Table 7-3. Input Power for TC-26

VOLTAGE	CURRENT
18 VAC	505 mA
24 VAC	518 mA

7.5.2.2 Detection Range

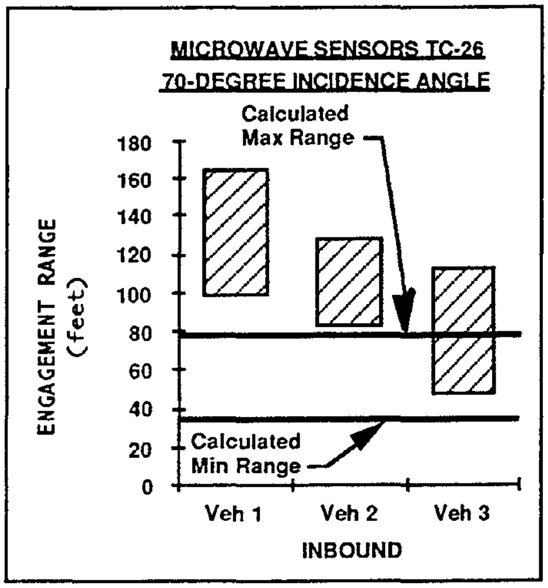
Figures 7-6 and 7-7 show the engagement range of the TC-26 at the maximum range setting and 45° and 70° incidence angles, respectively, for inbound vehicles as compared to the calculated engagement range.

Figures 7-8 and 7-9 show the engagement range at the maximum range setting and 45° and 70° incidence angles, respectively, for outbound vehicles as compared to the calculated engagement range. Vehicle 1 is the Ford Mustang, vehicle 2 is the large motorcycle, and vehicle 3 is the small motorcycle.



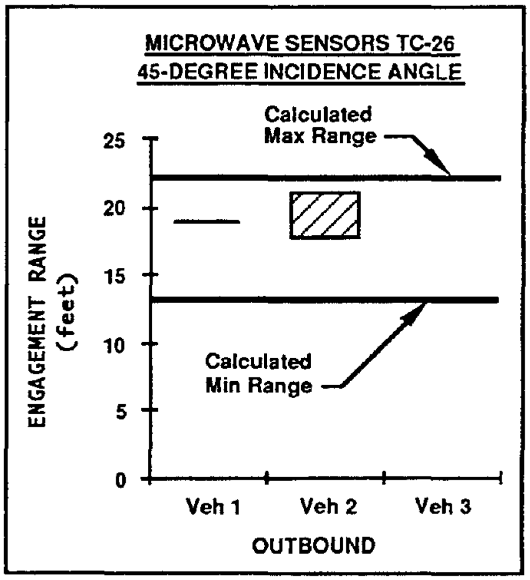
1 ft = 0.305 m

Figure 7-6. Detection Range of TC-26 at 45-Degree Incidence Angle, Vehicles Inbound



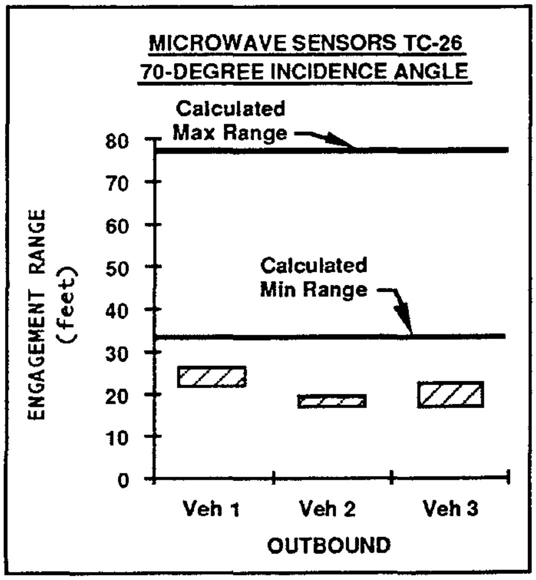
1 ft = 0.305 m

Figure 7-7. Detection Range of TC-26 at 70-Degree Incidence Angle, Vehicles Inbound



1 ft = 0.305 m

Figure 7-8. Detection Range of TC-26 at 45-Degree Incidence Angle, Vehicles Outbound



1 ft = 0.305 m

Figure 7-9. Detection Range of TC-26 at 70-Degree Incidence Angle, Vehicles Outbound

7.5.3 TDN-30 Microwave Detector

The TDN-30 operates at an incidence angle of 45° when the bottom of the detector housing is parallel to the road surface.

7.5.3.1 Operating Current

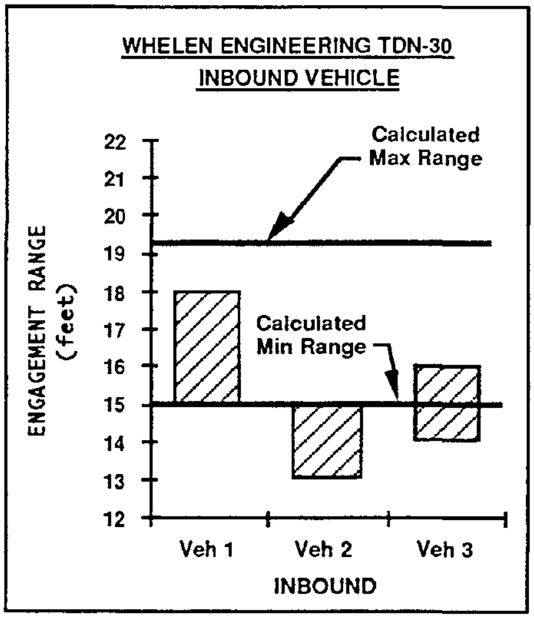
The specified operating voltages for the TDN-30 are 11 to 15 VDC at 200 mA.

Table 7-4. Input Power for TDN-30

VOLTAGE	CURRENT
11 VDC	150 mA
15 VDC	155 mA

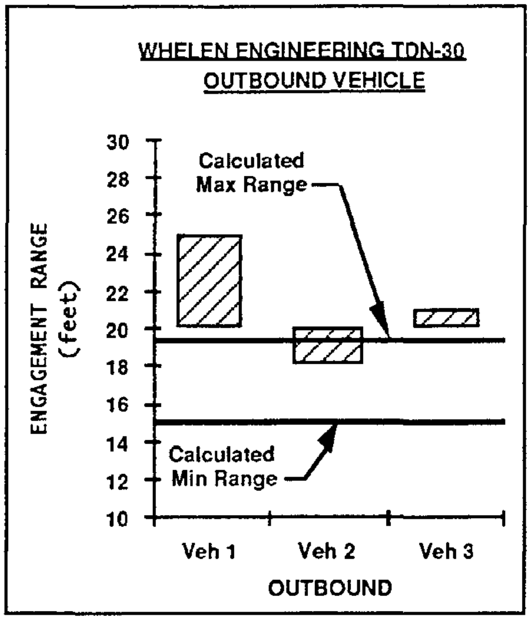
7.5.3.2 Detection Range

Figures 7-10 and 7-11 show the measured engagement range of the TDN-30 compared to the calculated range for inbound and outbound vehicles, respectively. The calculated range is based on geometrical factors that include mounting height, beamwidths, and incidence angle. Vehicle 1 is the Ford Mustang, vehicle 2 the large motorcycle, and vehicle 3 the small motorcycle.



1 ft = 0.305 m

Figure 7-10. Inbound Vehicle Detection Range of TDN-30 at 45-Degree Incidence Angle



1 ft = 0.305 m

Figure 7-11. Outbound Vehicle Detection Range of TDN-30 at 45-Degree Incidence Angle

7.5.4 TC-30C Ultrasonic Detector

The TC-30C operates at 0° incidence angle.

7.5.4.1 Operating Current

The specified operating voltages for the TC-30C are 6 to 12 VDC or 12 to 24 VAC at 150 mA.

Table 7-5. Input Power for TC-30C

VOLTAGE	CURRENT
12 VAC	332 mA*
24 VAC	268 mA*

*With no vehicle in detection zone.

7.5.4.2 Delay Time Measurement

The delay time measurements compare favorably with the manufacturer's specification of 0.25-s minimum to 10-s maximum.

Table 7-6. Delay Time for TC-30C

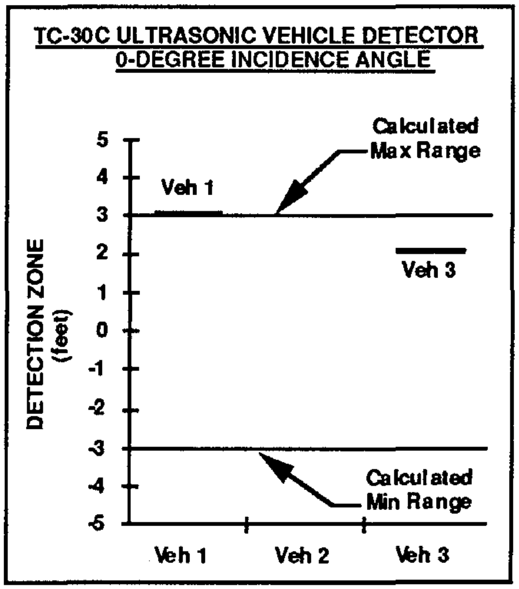
DELAY TIME
270-ms minimum
9.6-s maximum

7.5.4.3 Detection Zone

Since the TC-30C operates at nadir, the range measurement nomenclature was changed to "detection zone" from "detection range."

Figure 7-12 shows the measured detection zone of the TC-30C at a 0° incidence angle as compared to the calculated zone. The calculated zone is based on geometrical factors that include mounting height, beamwidths, and incidence angle. It assumes that receiver output, sensitivity, and target reflective properties are adequate to receive the signal at the detector. Vehicle 1 is the Ford Mustang and vehicle 3 the small motorcycle.

The detection zone starts at the engagement range where the vehicles enter the beam. The nonzero nature of the minimum delay time affects the disengagement range measurement (i.e., the range at which the vehicle presence signal is dropped by the detector). Because of this, distances at which the vehicle presence was dropped were not measured. Vehicle 2 was not available when the TC-30C engagement range was measured.

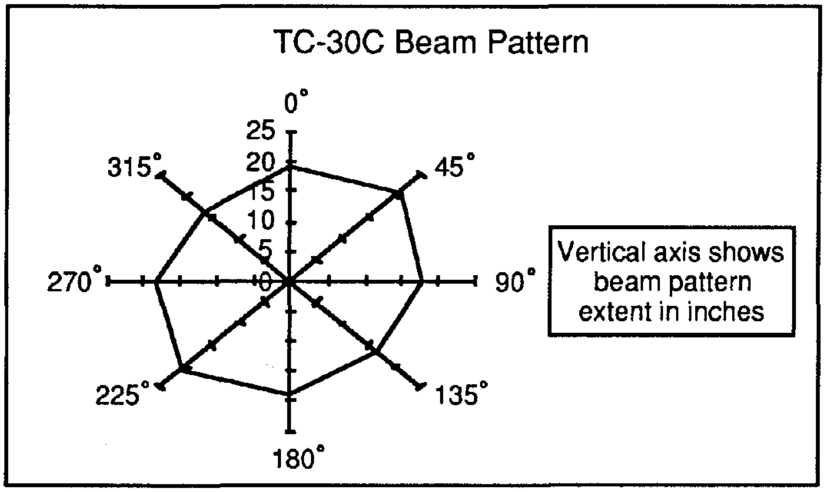


1 ft = 0.305 m

Figure 7-12. Detection Zone of TC-30C at 0-Degree Incidence Angle

7.5.4.4 Beam Pattern

The TC-30C beam pattern is shown in Figure 7-13. The measurements were taken at approximately 15 feet (4.6 m) below the detector.



1 in = 25.4 mm

Figure 7-13. Beam Illumination Pattern of TC-30C Ultrasonic Detector

7.5.5 SDU-200 Ultrasonic Detector

The SDU-200 Doppler detector has a transmitting horn transducer and a receiving horn transducer that are mounted at 45° with respect to nadir. The horn furthest from a wall or other barrier is used as the transmitter.

7.5.5.1 Operating Current

The detector operates at a nominal voltage of 100 VAC. Its power consumption was measured at the minimum and maximum specified operating voltages.

Table 7-7. Input Power for SDU-200

VOLTAGE	CURRENT
80 VAC	102 mA
110 VAC	102 mA

7.5.5.2 Detection Range

Since the incidence angle of the detector must be at 45°, detection range measurements as a function of angle were not made, other than to confirm that the detector did sense the vehicles as they passed through its field of view.

7.5.6 SDU-300 Ultrasonic Detector

The SDU-300 is mounted at a nadir incidence angle.

7.5.6.1 Operating Current

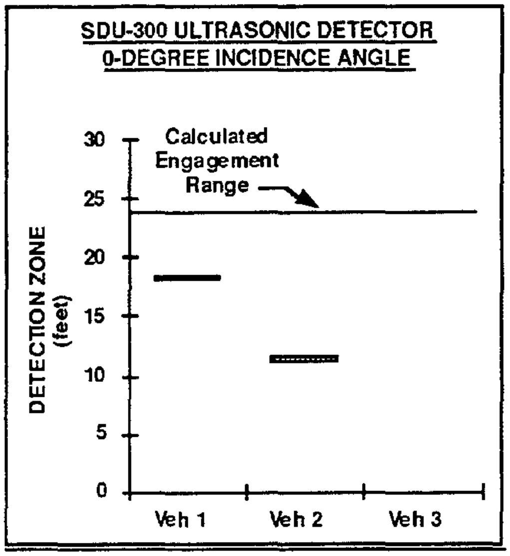
This presence detector operates at a nominal voltage of 100 VAC. Once again, its power consumption was measured at the minimum and maximum specified operating voltages.

Table 7-8. Input Power for SDU-300

VOLTAGE	CURRENT
80 VAC	54 mA
110 VAC	69 mA

7.5.6.2 Detection Zone

Figure 7-14 shows the measured detection zone of the SDU-300 at a 0° incidence angle as compared to the calculated zone.



1 ft = 0.305 m

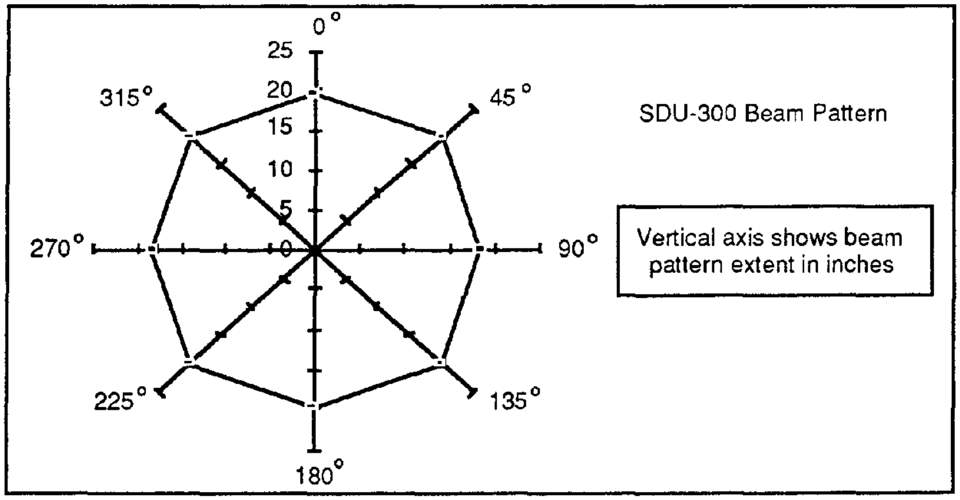
Figure 7-14. Detection Zone of SDU-300 at 0-Degree Incidence Angle

The calculated zone is based on the beamwidth, mounting height, and incidence angle of the detector. It assumes adequate receiver sensitivity and target reflective properties to detect a vehicle at the range calculated from the geometrical factors. Vehicle 1 is the Ford Mustang and vehicle 2 the large motorcycle. Vehicle 3, the small motorcycle, was not available for this test.

The detection point used in the measurements for vehicles 1 and 2 was the distance at which they entered the beam. The nonzero hold time affects the measurement of the distance at which the presence call is dropped when vehicles leave the beam. Because of this, the distance at which presence was dropped was not measured.

7.5.6.3 Beam Pattern

The beam pattern, shown in Figure 7-15, was measured at nadir from a height of approximately 13 feet (4.0 m) above the road surface.



1 in = 25.4 mm

Figure 7-15. Beam Pattern of SDU-300 Ultrasonic Detector

7.5.7 780D1000 Laser Radar Detector

The 780D1000 laser radar detector is normally mounted at incidence angles of less than 45°. However, in these tests, the incidence angle envelope was stretched to measure the performance limits of the detector.

7.5.7.1 Operating Current

The nominal operating voltage for the laser radar detector is 115 VAC.

Table 7-9. Input Power for 780D1000

VOLTAGE	CURRENT
90 VAC	44 mA
130 VAC	34 mA

7.5.7.2 Vehicle Speed

Table 7-10 compares the speed measured by the 780D1000 to the speed recorded from the speedometer on vehicle 1. The vehicle speedometer was not calibrated by an independent source for this evaluation.

Table 7-10. Measurement of Vehicle 1 (1985 Ford Mustang) Speed With Laser Radar Detector

Incidence Angle (degrees)	Speedometer (mi/h)	780D1000 Measured Speed (mi/h)
45	8	7
45	15	15
45	20	21
45	20	19
60	11	12
60	8	7
60	8	8

1 mi/h = 1.61 km/h

7.6. DETECTOR PERFORMANCE RESULTS FROM BENCH TEST MEASUREMENTS

Bench tests were performed to measure radio frequency (RF) output power, output frequency, minimum detectable signal, input power consumption, and response time of the microwave traffic detectors (Microwave Sensors TC-20 and TC-26 and Whelen TDN-30). A photograph of the measurement equipment is shown in Figure 7-16 with the Whelen TDN-30 as the detector under test.

The instrumentation horn was used to capture the radiated energy from the detector under test and transmit it to other equipment. The connections made to the instrumentation horn for various measurements are shown in Table 7-11. Volt meters and current meters were used to measure the input power to the detector. The response time was found by measuring the time difference between the injected RF signal and the closure of a relay.

Table 7-11. Device Connected to Instrumentation Horn for Measuring Various Detector Characteristics

Measurement	Device Used
Output power	Power meter
Frequency	Spectrum analyzer
Minimum detectable signal	Sweep oscillator

A summary of the bench test measurements and the manufacturers specifications is shown in Table 7-12. A comparison of the input power consumption of the detectors as measured during the Munson track tests and the bench tests is given in Table 7-13.

Table 7-12. Microwave Detector Bench Test Results

Parameter	Whelen TDN-30 SN 00109 *Specified*	Whelen TDN-30 SN 00109 *Measured*	Microwave Sensors TC-20 SN 234242 *Specified*	Microwave Sensors TC-20 SN 234242 *Measured*	Microwave Sensors TC-26 SN 234326 *Specified*	Microwave Sensors TC-26 SN 234326 *Measured*
Output power	Not specified	4.6 dBm or 2.9 milliwatts	10 dBm or 10 milliwatts	10.2 dBm or 10.5 milliwatts	10 dBm or 10 milliwatts	11.9 dBm or 15.5 milliwatts
Output frequency	10.525 GHz	10.520 GHz	10.525 GHz	10.520 GHz	10.525 GHz	10.519 GHz
Minimum detectable signal	Not specified	Not able to perform test	Not specified	-54 dBm or 4 microwatts	Not specified	-60.7 dBm or 0.9 microwatts
Input power consumption	1.8 watts typical	2.2 watts	3.0 watts	2.8 watts	8.5 watts maximum	3.9 watts
Response time	Not specified	Not able to perform test	165 ms	8.4 ms average	250 ms	11.5 ms average

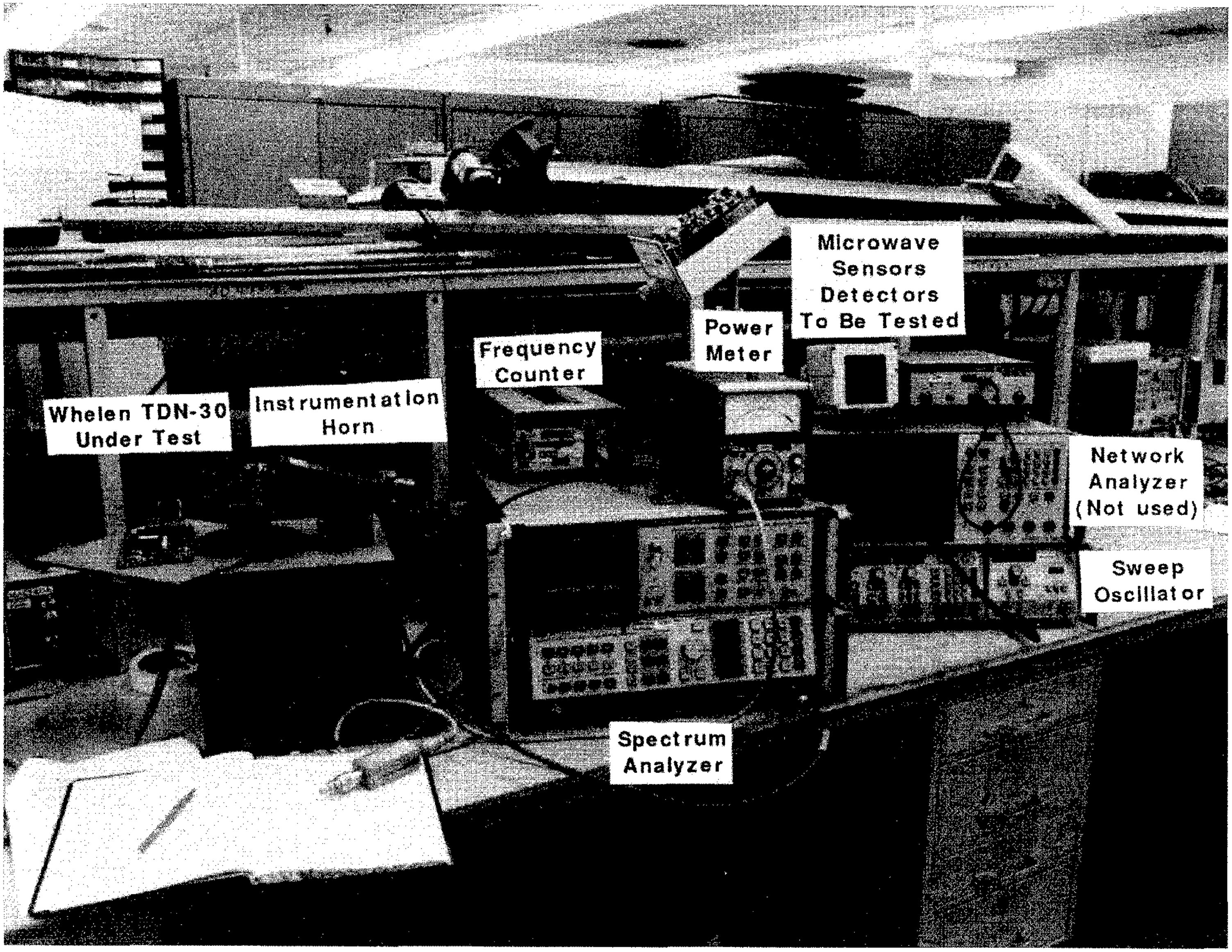


Figure 7-16. Bench Test Setup

Table 7-13. Munson Track and Bench Measurements of Input Power Consumption With Different Voltage Sources

Data Source	Whelen TDN-30	Microwave Sensors TC-20	Microwave Sensors TC-26
Manufacturer's Specification	1.8 (nominal) to 2.8 Watts (maximum) using 12 VDC and 14 VDC, respectively	6.0 Watts (maximum) using 10 to 24 VAC or 12 VDC	8.5 Watts (maximum) using 12 to 24 VAC/DC
Munson Test	1.65 to 2.3 Watts using 11 VDC and 15 VDC inputs, respectively	4.0 to 5.4 Watts using 18 VAC and 24 VAC inputs, respectively	9.1 to 12.4 Watts using 18 VAC and 24 VAC inputs, respectively
Bench Test	2.2 Watts using 13.5 VDC input	2.8 Watts using 13.5 VDC input	3.9 Watts using 13.5 VDC input

7.7 DETECTOR PERFORMANCE RESULTS FROM TESTS IN THE CITY OF LOS ANGELES

Beginning in August 1992, the City of Los Angeles Department of Transportation, in conjunction with Hughes Aircraft Company, evaluated the effectiveness and operating characteristics of various overhead vehicle detection systems. Eleven detectors comprising six different technologies were used: passive infrared, ultrasound, microwave, laser radar, inductive loop, and magnetometer. The inductive loops and magnetometers were already installed in the Exposition Boulevard test area. Their performance was compared with those of the overhead technologies. The first set of data was collected from August 25 to October 19, 1992. Computer data files were analyzed beginning with September 29 and continuing through October 19, 1992.

7.7.1 Test Site Description

The detector test site was located on Exposition Boulevard, near University Avenue, in the City of Los Angeles. Three eastbound lanes, shown in Figure 7-17, were already instrumented with inductive loops, magnetometers, passive IR, and ultrasonic detectors. The TC-30C, TC-26, 780D1000, and TDN-30 were mounted on the pole closest to the foreground. The middle pole contained the 842s. The pole farthest in the background supported the TC-20 and SDU-300. The traffic lanes monitored by each detector are shown in Table 7-14. Lane 1 is the leftmost lane.

7.7.2 Data Analysis Methods and Results

The count accuracy of the inductive loop detectors was 99.4 percent ±0.6 percent as computed from the recorded imagery that provided visual verification of the count. Inductive loop volume data collected in the lanes monitored by the in-ground and aboveground detectors under test were used to determine the relative accuracy of the other detectors. Fifteen-minute data increments were used in the analysis.

7.7.2.1 Accuracy

The base accuracy for each detector in each 15-min period is expressed as a ratio of the count from the detector under test to the count from the calibrated loop detector. This detector accuracy ratio (DAR) is given by

$$\mathrm{DAR} = \frac{\textit{Test Detector Count}}{\textit{Calibrated Loop Detector Count}} \qquad (7\text{-}1)$$

Table 7-15 gives the accuracy ratios of the detectors. A ratio of unity indicates a 100-percent correlation between the detector under test and the calibrated loop detector. An accuracy ratio greater than unity indicates a tendency for the detector under test to overcount, while an accuracy ratio less than

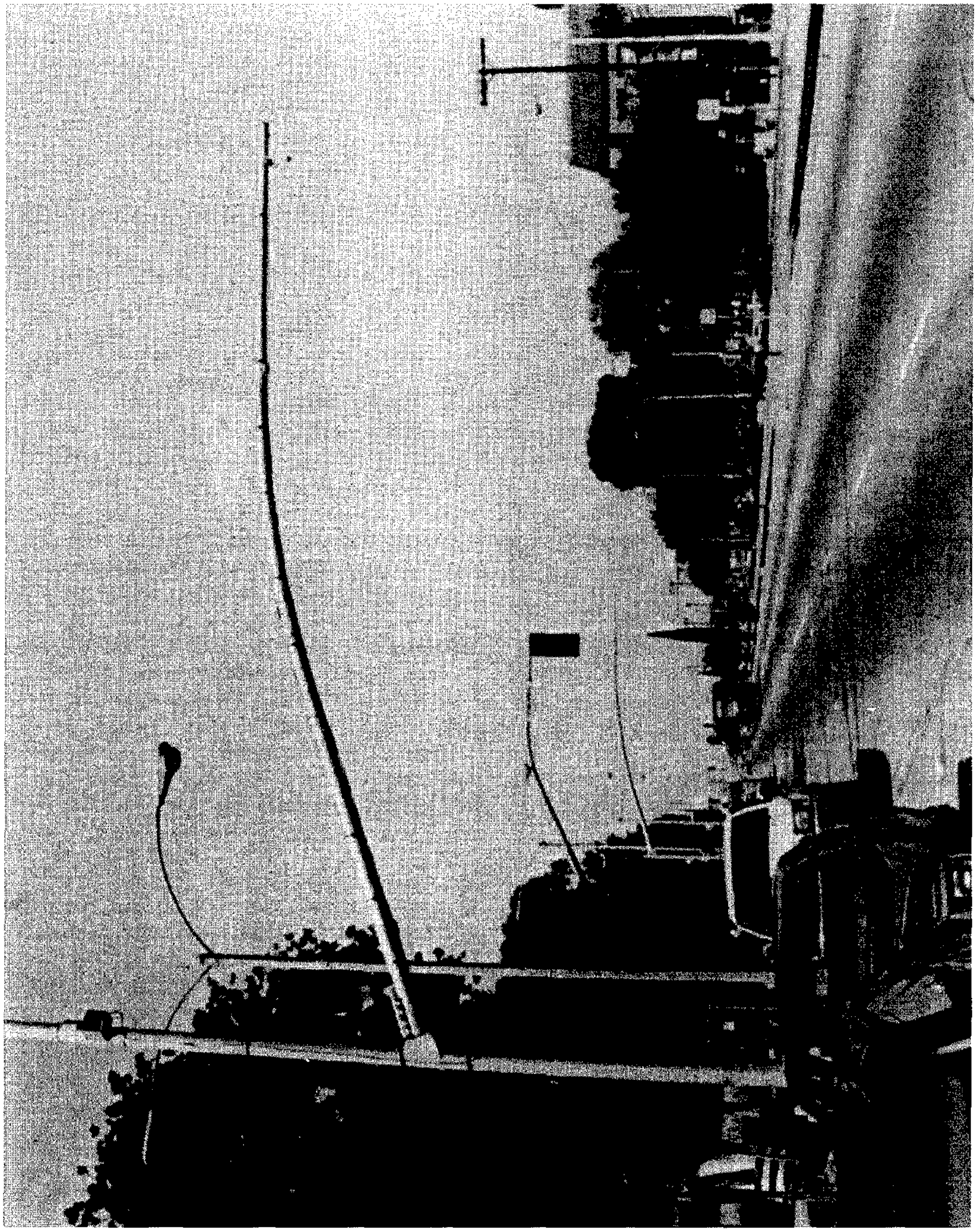


Figure 7-17. Eastbound Lanes on Exposition Boulevard Test Site

Table 7-14. Detector Mounting Locations

Detector	Lane Location
Inductive Loops	1, 2, and 3
Magnetometers	1, 2, and 3
Sumitomo SDU-300 (Ultrasound)	3
Eltec 842 (Passive Infrared)	3
Microwave Sensors TC-20 (Microwave Detector)	2
Microwave Sensors TC-30C (Ultrasound)	1
Microwave Sensors TC-26 (Microwave Detector)	2
Schwartz Electro-Optics 780D1000 (Laser Radar)	3
Whelen TDN-30 (Microwave Detector)	3

Table 7-15. Accuracy of Detectors Under Test

Detectors Listed in Descending Order of Overall Accuracy	Accuracy Ratio
SEO 780D1000 Laser Radar Detector	0.996
Whelen TDN-30 Microwave Detector	1.020
Eltec 842 Infrared Detector (#430)	0.955
Microwave Sensors TC-20 Microwave Detector	0.954
Eltec 842 Infrared Detector (#429)	0.952
Magnetometer Lane #3	1.055
Sumitomo SDU-300 Ultrasonic Detector	0.944
Magnetometer Lane #1	1.102
Microwave Sensors TC-30C Ultrasonic Detector	1.113
Magnetometer Lane #2	0.774
Microwave Sensors TC-26 Microwave Detector	2.711

unity indicates a tendency for the detector under test to undercount.

Some of the tested detectors show a low accuracy ratio because of the long hold time built into the detector by the manufacturer. When there is a high frequency of occurrence of closely spaced, high-speed vehicle traffic, a short detector hold time is needed to obtain accurate volume measurements. Other applications may require a high resistance to multiple counts provided by the long hold time, as when detecting long wheelbase vehicles.

7.7.2.2 Reliability

The periods in which vehicle counts did not meet Chauvenet's criterion (i.e., those periods where readings were greater than 2.81 times the standard deviation of the mean daily counts) were treated as a failure of the detector under test to provide accurate data. This was in addition to any detector data dropout times recorded by the Los Angeles Department of Transportation's Automated Traffic Surveillance and Control (ATSAC) computers. The ATSAC analysis computation returns a zero accuracy value if the detector under test returns a zero volume when the inductive loop detector returns a non-zero volume. Thus, any 15-min period in which the test detector accuracy was zero was considered to be an undercount failure. An analysis algorithm also tested for ghost signals generated by the detector under test in the absence of vehicles detected by the calibrated loops.

As a measure of the reliability of detector data output, the detector data dropout ratio (D^3R) shown in Table 7-16 was computed as

$$D^3R = 96/(\text{Number of Zero Accuracy Results} + \text{Number of Ghost Signals}) \quad (7-2)$$

where 96 is the number of 15-min periods per day.

Table 7-16. Detector Data Dropout Ratio for Detectors Under Test

Detectors Listed in Descending Order of Detector Data Dropout Ratio	D^3R in Hours*
Whelen TDN-30 Microwave Detector	74.67
Microwave Sensors TC-20 Microwave Detector	69.52
Sumitomo SDU-300 Ultrasonic Detector	59.29
Eltec Infrared Detector (#430)	51.69
Microwave Sensors TC-30C Ultrasonic Detector	42.89
Eltec Infrared Detector (#429)	42.00
Microwave Sensors TC-26 Microwave Detector	41.14
Magnetometer Lane #3	38.77
SEO 780D1000 Laser Radar Detector	36.08
Magnetometer Lane #1	27.24
Magnetometer Lane #2	19.02

*Detector data dropout ratio accounts for the number of 15-minute intervals in which: (1) the test detector returns a zero volume and the inductive loop detector returns a non-zero and (2) the test detector returns a non-zero volume and the inductive loop detector returns a zero.

The laser radar dropout ratio calculated from the April to June 1993 data (shown in the table) was degraded by a 2.25-h interval on June 23 (survey day 16) during which no data were output by the laser radar. The problem was at the detector site and did not apparently involve the local signal controller or existing communication network. Whether the data dropout was due to the detector itself or to the detector's power supply could not be determined from the available information. However, even with this outage, the performance of the laser radar was comparable to that of the other detectors.

Sumitomo raised other issues that may have affected the accuracies reported in Table 7-15 with respect to undercounting of vehicles. They pointed out that vehicle lane changing may have occurred in the region between the overhead detectors and the calibrated loops, although this did not appear to be a significant problem.

The measures of data output reliability used in the Los Angeles evaluation (namely, daily percent downtime and detector data dropout ratio) are not meant to be absolute measures of the detector's hardware reliability. The data dropout ratios simply provide a comparison between the various detectors as they operate with the current California Type 170 Traffic Signal Controllers, and their ability to cope with the traffic conditions encountered during the tests. Therefore, some of the dropouts or gross inaccuracies in the detectors under test may be caused by either compatibility problems with local equipment or unusual traffic conditions. Hard reliability figures for the inductive loop detectors are not available. Hence, the numbers shown in Table 7-16 should be used only as relative values for comparing the data dropouts from the detectors during this test.

8. TASK F SUMMARY

DEVELOP VEHICLE DETECTOR FIELD TEST SPECIFICATIONS AND FIELD TEST PLAN

8.1 TEST OBJECTIVES

The primary objective of the field tests was to quantify the performance of traffic detector technologies with respect to the types and accuracy of the data they provide for the IVHS applications identified in the Task A report.(1) The detectors were evaluated in freeway and arterial street traffic. The video recording of the traffic flow in the detectors' field of view provided truth data for vehicle count and presence against which to compare detector output data from the technologies under test. Speed guns and probe vehicles were also used to supply truth data.

A second objective was to expose the detector technologies to a variety of weather conditions. This required the selection of geographically diverse test sites and seasons in which to conduct the tests and the capability to not only measure the accuracy of the traffic data supplied by the detectors, but also to monitor and record the environmental conditions prevailing throughout the tests.

The third objective was to compare the performance of the new detector technologies with that of current inductive loop detectors (ILDs) and magnetometers.

The fourth objective was to engage diverse vehicle and driver populations in different regions of the United States in the detector technology performance evaluation and, thus, enhance the national applicability of the test results.

8.2 DETECTOR TECHNOLOGIES EVALUATED

Table 8-1 lists the detectors and the technologies they represent that were evaluated in the field test program. Inductive loop detectors were also included in the test matrix, although they are not listed in the table. A list of detector manufacturers is provided in Appendix B.

8.3 TRAFFIC PARAMETERS MEASURED

Flow rate, speed, and density, or its surrogate occupancy, are an interrelated set of traffic parameters used to describe the quality of traffic flow on a highway. To measure flow rate accurately, detectors need to discriminate between vehicles where there are gaps on the order of 25 feet (7.6 m) and time headways of 1 to 2 seconds. Speeds can be measured using ILDs in speed traps composed of two closely spaced (15 to 20 feet [4.6 to 6.1 m] apart) loops excited by oscillators that are continuously dedicated to each loop in the pair, or less accurately with a single loop and an assumed vehicle length. Some microwave detectors, such as the device that transmitted a frequency modulated continuous wave (FMCW) and the laser radar evaluated in this project, measure speed by noting the time it takes for the vehicle to arrive at two points a known distance apart. Microwave Doppler and ultrasound detectors measure speed using the Doppler effect.

Density (vehicles per mile per lane) is difficult to measure directly, except with some type of picture format, such as video imaging or aerial photography. Consequently, lane occupancy (the percent of time the detection zone of a detector is occupied by a vehicle) has been used as a surrogate measure for density. In this case, the requirement to discern the boundaries of vehicles is much more stringent than for counting. Accurate occupancy measures require discriminating between vehicles and gaps to within 1 to 5 percent of their true values, as discussed in the Task A report.(1)

Other traffic parameters important for traffic management are presence, queue length, travel time, intersection turning movements, and vehicle classification. Presence needs to be measured, even if the vehicle is stationary, for applications that include intersection control and ramp metering. Therefore, detectors which require motion in order to be

Table 8-1. Detectors and Technologies Evaluated During Field Tests

Symbol	Technology	Manufacturer	Model	Quantity
U-1	Ultrasonic Doppler	Sumitomo	SDU-200 (RDU-101)	1
U-2	Ultrasonic Presence	Sumitomo	SDU-300	2 heads, 1 controller
U-3	Ultrasonic Presence	Microwave Sensors	TC-30C	2
M-1	Microwave Detector Motion Medium Beamwidth	Microwave Sensors	TC-20	2
M-2	Microwave Detector Doppler Medium Beamwidth	Microwave Sensors	TC-26	2
M-4[a]	Microwave Detector Doppler Narrow Beamwidth	Whelen	TDN-30	2
M-5	Microwave Detector Doppler Wide Beamwidth	Whelen	TDW-10	2
M-6	Microwave Radar Presence Narrow Beamwidth	Electronic Integrated Systems	RTMS-X1	2
IR-1	Active IR Laser Radar	Schwartz Electro-Optics	780D1000 (Autosense I)	1
IR-2	Passive IR Presence	Eltec	842	1
IR-3	Passive IR Pulse Output	Eltec	833	1
IR-4[b]	Imaging IR	Grumman	Traffic Sensor	1
VIP-1	Video Image Processor	Econolite	Autoscope 2003	1
VIP-2	Video Image Processor	Computer Recognition Systems	Traffic Analysis System	1
VIP-3[c]	Video Image Processor	Traficon	CCATS-VIP 2	1
VIP-4[b]	Video Image Processor	Sumitomo	IDET-100	1
VIP-5[d]	Video Image Processor	EVA	2000	1
A-1[e]	Passive Acoustic Array	AT&T	SmartSonic TSS-1	1
MA-1	Magnetometer	Midian Electronics	Self-Powered Vehicle Detector	2
L-1[b]	Microloop	3M	701	4
T-1[b]	Tube-Type Counter	Timemark	Delta 1	1

a. M-3 was designated for a microwave radar detector that was not received.

b. Used at Tucson, Arizona test site only.

c. Used at all Arizona test sites.

d. Used in Phoenix, Arizona 7/94 test only.

e. Used in Phoenix 11/93 and Tucson tests.

activated, such as passive magnetic detectors and others that transmit continuous wave energy, cannot perform this task. Queue length, as density, requires wide-area detection to be measured directly.

Travel time is inversely proportional to average speed. For travel time to be measured directly, the same vehicle has to be identified at several points along a highway using either (1) a roadside-mounted detector or (2) a vehicle identification device mounted on the vehicle that is interrogated by readers deployed along the highway system. Thus, travel time could be a side benefit of instituting an automatic vehicle identification (AVI) system in which the vehicles act as "probes." Vehicle classification could also be an offshoot of AVI if it was widely deployed. However, AVI systems are considered beyond the scope of the field testing portion of this project. Imaging systems, high-resolution ranging systems such as active infrared and some ultrasonic systems, and ILDs coupled with special vehicle transmitters and receiver amplifiers also have vehicle classification ability.

8.4 ENVIRONMENTAL FACTORS

The environmental factors considered during the field tests were precipitation, wind, temperature, barometric pressure, acoustic noise, electromagnetic interference, shadows, and vibration.

8.4.1 Precipitation

Precipitation in the form of rain and snow affects the operation of visible, infrared, and ultrasonic detectors. In addition, fog and mist have a detrimental effect on those detectors using the visible and infrared spectrum.

8.4.2 Wind

Wind is a factor in ultrasonic detector operation as it causes turbulence that can distort the ultrasonic waveform. The Sumitomo SDU-200 ultrasonic speed detector is designed to operate at wind speeds up to 56 mi/h (25 m/s). Wind is also a cause of detector movement, discussed further in the section on vibration.

8.4.3 Barometric Pressure

Barometric pressure changes may affect the speed of propagation of ultrasonic waves and thus the accuracy of range measurements. An automatic calibration feature on some ultrasonic detectors, such as those from Sumitomo, eliminates most weather-related effects.

8.4.4 Acoustic Noise

Acoustic noise in the audible or ultrasonic ranges could conceivably interfere with the operation of passive acoustic arrays and ultrasonic detectors. However, the relatively small and focused field of view used by the overhead detectors makes this event unlikely.

8.4.5 Electromagnetic Interference

Electromagnetic interference has the potential to affect the operation of all types of traffic detectors, as it can enter through the aperture of the detector or through the enclosure that protects the electronics that process the data. Broad-spectrum electromagnetic interference can thus insert noise into the signal and data processing hardware. For the special case of microwave detectors, interference may occur when the detector is operated in the vicinity of high-power radars transmitting at nearby frequencies. The use of radars for speed enforcement by local police did not interfere with the operation of the microwave detectors during the field tests. Computers and video monitors produced interference that degraded the operation of the SPVD magnetometer receiver when the receiver was not isolated on its own AC circuit.

8.4.6 Shadows

Shadows can affect the operation of video image processors. During cloudless midday operation, the contrast between shadow and sunlit areas can be great, perhaps leading to false declarations of shadows as vehicles. In addition, low-angle direct sunlight and glint from the reflection of sunlight off other surfaces can produce glare in the scene or on the detector lenses. These effects can be eliminated or reduced through advanced signal processing and proper mounting of the VIP camera.

8.4.7 Vibration

Vibration can pose a problem both for the image processing detectors and possibly for some of the other detectors mounted above ground. This is most likely to occur when the detectors are mounted on high poles, or when video images are obtained with a long focal-length lens. Wind is likely to be a common cause of vibration; but for detectors located on structures, vibration could also develop from heavy trucks moving across or below the structure.

8.5 GROUND TRUTH

Accurate data against which to evaluate state-of-the-art detector technologies were obtained from the recorded video of the traffic flow. A video home system (VHS) format video camera and computer-controlled video cassette recorder (VCR) with stop-motion capability were used to manually sample the recorded video to obtain count, volume, and presence truth data. A data logger system that automatically records, time tags, and displays the vehicle detections from all the detectors under test was developed to simplify the data analysis process. The data logger is described later in this section and in Appendix C.

In addition to serving as a database from which traffic parameter truth data are obtained, the video provides a visual record of environmental conditions encountered during testing and a visual record to aid in resolving anomalies that may arise during data analysis.

By analyzing the video record off-line, manual counts were made to verify the real-time data collected by the detectors. The following comments illustrate how the video imagery was used to obtain ground truth data for selected traffic parameters.

8.5.1 Volume

Volume data were obtained manually by replaying the video to count the required vehicle types and movements, such as lane crossings. The time stamp of detector output events provided by the data logger, along with the recorded video tape index number, allowed correlation of video imagery with detector data.

8.5.2 Speed

Speed ground truth data were obtained by driving a marked probe vehicle through the detection zone during data collection periods. The driver recorded vehicle speed, lane, and approximate time for each run. The exact time was obtained from the corresponding time stamps supplied by the data logger. The probe vehicle was identified by hanging a flag from the radio antenna or the truck lid, by inserting a traffic cone through the window of the probe, by driving with the trunk open, or by waving a hat or other object from the window of the vehicle while driving through the field of view of the camera. Beginning with the Tucson runs, a Detector Systems vehicle-mounted transducer was used to emit a vehicle identification code that was picked up by the inductive loops and recorded by the data logger. Speed truth data were also manually recorded from a police radar during the evaluations at the Orlando freeway site.

8.5.3 Occupancy and Presence

Occupancy and presence data were verified by superimposing the detector relay closure event on the video whenever the detector sensed a vehicle within its capture zone. This procedure is controlled by the application-specific Phase II software written for the data analysis process.

8.5.4 Queue Length, Turning Movements, and Vehicle Classification

When available as outputs from detectors, these parameters can be manually verified from the video.

8.6 TRAFFIC DATA COLLECTION REQUIREMENTS

The data collection requirements differ slightly for the freeway and surface arterial test locations.

8.6.1 Freeway Test Locations

For the freeway test sites, count, flow rate, speed, and occupancy were measured by the detectors under test and compared with simultaneous data obtained from inductive loop detectors and video during peak and off-peak hours.

8.6.2 Surface Arterial Test Locations

Data to calculate presence, flow rate, speed, and occupancy were recorded for the signalized intersection environment on a signal cycle-by-cycle basis and categorized signal cycle-by-cycle basis and categorized for peak and off-peak periods. Queue length and turning movements were not output by any of the detectors evaluated.

8.7 TEST SITE LOCATIONS

The detector technology evaluation sites were located in Minneapolis, MN; Orlando, FL; Phoenix, AZ, and Tucson, AZ as shown in Table 8-2. The expected weather conditions are listed. Detailed descriptions are provided in the Task B report.(2)

Table 8-2. Test Sites

City	Freeway	Surface Arterial	Weather	Test Period
Minneapolis	I-394 at Penn Avenue	Olson Highway at Lyndale Avenue	Cold, snow, sleet, fog	Winter 1992-1993
Orlando	I-4 at SR 436	SR 436 at I-4	Hot, heavy rain, lightning	Summer 1993
Phoenix	I-10 at 13th Street	Not applicable	Warm, heavy rain, lightning	Autumn 1993
Tucson	Not applicable	Oracle Road at Auto Mall Drive	Cool to warm, heavy rain, lightning	Winter-Spring 1994
Phoenix	I-10 at 13th Street	Not applicable	Hot, heat waves, heavy rain, lightning	Summer 1994

8.8 DETECTOR INSTALLATION

8.8.1 Site Preparation

Site preparation included arranging for the housing and installation of data recording equipment in a portable trailer, installing sufficient data and power cables to connect the detectors with the data recording apparatus and power supplies, painting of calibration marker distances on the roadway surface, and obtaining descriptions of each of the ILDs that were installed for the tests.

Calibration distance markers were painted across each lane or on the shoulder of the test section of roadway, where possible, to aid in measuring the distance of vehicles from the above-the-road detector mounting location and for VIP calibration. The stripes were painted at 5- to 25-foot (1.5- to 7.6-m) intervals (depending on the requirements for VIP setup and calibration) out to approximately 300 feet (91.4 m), with the zero-foot mark located at the detector mounting location.

8.8.2 Overhead Detector Mounting

In order to have space to mount and operate all the overhead detectors at the same time, they were attached to two or more grids constructed of 1.5-inch (38.1-mm) galvanized pipe and secured with various types of pipe clamps or manufacturer-supplied mounting hardware. When the mounting of the detectors on the pipe grids was not practical, they were attached directly to the overhead structure.

The pipe grid was connected to a central ground in the trailer at the equipment rack to minimize ground currents that affect some detectors. An uninterruptable power supply and lightning protection devices on all input data lines were used to help protect data recording equipment.

8.8.3 Overhead Detector Layouts

The overhead detectors were configured into arrays at each evaluation site. Specific conditions, such as the number of active traffic lanes and the existing structures available on which to mount detectors, influenced the specific configuration and array mounting technique.

8.8.4 In-Ground Detectors

The detector evaluation site layout accommodated the requirement to compare ILD and magnetometer technology performance with that of the above-ground detectors. The location of the buried detectors were indicated by temporary pavement markings, sealants used in the installation process, or traffic cones on the shoulders when snow was present. These markings appear in the video record of the tests.

8.8.5 Cable Requirements

Detailed information about detector operation, mounting, power requirements, and output data are found in the detector manufacturers operations manuals and the Task D report that were supplied to the state agencies hosting the field tests.(3) Summaries of the installation requirements to accommodate detector size, weight, data transmission, and power are given in Table 8-3. Input power sources included 115 VAC, 100 VAC,12 VAC, 12 VDC, and 24 VDC. Wind-shear loads on the bolts that attach poles to the subground support structure were taken into account. About 200 lines were required for input power and data output. Detector output data and 115-VAC input power were not transmitted in the same cable to lessen the likelihood of data corruption by the power lines.

8.9 TEST PROCEDURES

8.9.1 Run Times

The detectors were operated for several multi-hour time intervals during a 24-h period to obtain data for various levels of traffic flow and different light levels and lighting transition periods throughout the day and night. Shadows and daylight-to-darkness transitions were encountered with this test regime. Typical runs started at predawn and continued through the end of the morning rush hours. A second run was made each day beginning at about 3:30 in the afternoon and continuing well into nighttime darkness. As these two runs spanned light and heavy traffic and various lighting conditions, a midday run was unnecessary most of the time. They were made, however, when traffic or weather conditions dictated.

8.9.2 Weather Data

Temperature and wind speed and direction were recorded on the data logger. Temperature sensors were generally placed in two locations, one on the detector mounting structure and another near the ground surface. The wind sensors were placed on an 8- to 15-foot (2.4- to 4.6-m) high pole near the trailer or the side of the road. When available, daily hour-by-hour weather records were obtained from local newspapers. A record of any visible precipitation was made on the video tapes recorded for each run. The official weather observations at each field test site were obtained from the National Climatic Data Center (NCDC) in Asheville, NC after the tests were completed as contained in Appendix J.

8.9.3 Equipment Checkout Runs

Once the detectors were installed, checkout tests were performed to ensure that the equipment was functioning in a manner consistent with the laboratory tests described in the Task C and E reports and the specifications of the detector manufacturers.(4,5) In the checkout tests, marked vehicles traveling at known speeds traveled through the detector test area. Normal traffic was also used to verify that the detectors are responding to vehicles passing through their fields of view.

Table 8-3. Detector Installation Requirements

Detector Symbol	Manufacturer and Model Number	Input Power	Detection Range (feet)	Discrete Detector Outputs	Serial Detector Outputs
U-1	Sumitomo SDU-200	80-110 VAC 6 Watts	26 max	Relay Contacts: 2 amp max 500 V max 100 VA max	Detection by vehicle length: 1 bit; Speed (binary): 8 bits; Speed (in terms of pulse width): 1 bit
U-2	Sumitomo SDU-300	80-110 VAC 6 Watts	5 to 26	Relay Contacts: 2 amp max 500 V max 100 VA max	
U-3	Microwave Sensors TC-30C	6-12 VDC 12-24 VAC 150 mA	3 to 22	Relay Contacts: Form C, 5 A @ 24 VDC	
M-1	Microwave Sensors TC-20	10-24 VAC 12 VDC 250 mA	3 to 100	Relay Contacts: Form C, 2 A	
M-2	Microwave Sensors TC-26	12-24 V AC or DC 350 mA	200 max (autos)	Relay Contacts: Form C, 5 A @ 24 VDC & 5-5V logic level outputs	
M-4	Whelen TDN-30	11-15 VDC 200 mA	100 max	Two opto-isolator outputs: 40 V holdoff, ON <1 V @ 50 mA	RS-232 @ 1200 or 2400 baud
M-5	Whelen TDW-10	11-15 VDC 200 mA	100 max	Two opto-isolator outputs: 40 V holdoff, ON <1 V @ 50 mA	RS-232 @ 1200 or 2400 baud
M-6	Electronic Integrated Systems RTMS-X1	95-135 VAC 150 mA	200 max	12 isolated o.c. contact pairs (1 pr/ln) rated for 50 mA @ 30 V	RS-232 data bus @ 9600 baud
IR-1	Schwartz Electro-Optics 780D1000	115 VAC 20 Watts	5 to 50	Presence Relay	RS-232 for speed, count, and range
IR-2	Eltec 842	95-135 VAC 10 watts max	21 to 54	Relay Output: 3.5 A, 250 VAC 300 W	
IR-3	Eltec 833 M2	100-130 VAC 22 mA	16 to 98	Relay Output: 3.5 A, 120 VAC 200 VA	
IR-4	Grumman IIR Traffic Sensor	115 VAC	up to 1000		RS-232 data @ 9600 baud
VIP-1	Econolite/ Autoscope 2003	115 VAC 100 Watts	up to 300	RS-170 Video	RS-232 data @ 2400 or 9600 baud
VIP-2	Computer Recognition Systems Traffic Analysis System	95-132 VAC 400 VA	up to 300	CCIR standard or RS-170 Video. Also VME bus	RS-422, RS-232 Opto 22 Relays 16-bit parallel
VIP-3	Traficon CCATS-VIP 2	115 VAC	up to 300	RS-170 Video	RS-232C data @ 9600 baud
VIP-4	Sumitomo IDET-100	100 VAC ≤ 200 VA		RS-170 Video	RS-232 data @ 9600 baud
VIP-5	EVA 2000	41 VAC ± 15% 48 VDC ± 15% 25 to 35 Watts	up to 300	RS-170 Video or CCIR PAL	RS-232 data up to 19200 baud; RS-422 to 64k baud
A-1	AT&T TSS-1	24 VDC 250 mA		Two opto-isolator outputs	170/NEMA interface

1 ft = 0.305 m

Table 8-3. Detector Installation Requirements (continued)

Detector Symbol	Depth (inches)	Width (inches)	Height (inches)	Weight (pounds)	Height Above Roadway (feet)	Angle From Vertical (degrees)	Beam-width (degrees)	Look Up-Stream?	Look Down-Stream?
U-1	6.6	11.8	7.2	Not available	16.4 to 18.0	34 to 55	15	Yes	No
U-2	6.3	6.3	5.1	Not available		0	13	Nadir	Nadir
U-3	7.0	4.5	4.0	3.0	12 to 18	0	20	Nadir	Nadir
M-1	7.5	4.5	4.5	4.0	12 to 18	20 to 70	16 Az 15 El	Yes	Yes
M-2	7.0	4.0	4.0	3.0	14 to 18	20 to 70	16 Az 15 El	Yes	Yes
M-4	10.0	12.0	10.0	10.5	16 to 32	Incidence angle is 45 deg when properly mounted	7	Yes	Yes
M-5	10.0	12.0	10.0	10.5	12 to 40	Incidence angle is ≈70 deg when properly mounted	25	Yes	Yes
M-6	6.0	11.0	9.0	10.0	16 to 32		15 Az ≈50 El	Yes	Yes
IR-1	6.3	6.3	3.5	6.0	15 to 20	0 to 45	1 mrad (El) x 9.4° (Az)	Yes	No
IR-2	8.7	4.7	3.1	6.0	15 to 20	45 to 68	4	Yes	Yes
IR-3	8.3	4.7	3.2	3.0	13 to 20	14 to 43		Yes	Yes
IR-4	30	9.0	7.9	25.0			HFOV = 27° 320 (H) x 240 (V) pixels	Yes	Yes
VIP-1	10	17.5	5.75					Yes	Yes
VIP-2								Yes	Yes
VIP-3	9.0	3.0	7.0					Yes	Yes
VIP-4				14.0				Yes	Yes
VIP-5	9.3	12.4	10.7	6.6	33 to >59			Yes	Yes
A-1	3.5	22.0	22.0	25.0	20 to 35		6 (3 dB) 20 (10 dB)	Yes	Yes

1 in = 25.4 mm
1 ft = 0.305 m
1 lb = 0.454 kg

8.9.4. Video Feed to Image Processors

At most sites, black-and-white video imagery was supplied by a common camera and a video distribution amplifier to the VIPs, monitors, and VCR. The Autoscope system, however, used a separate camera designed specifically for its processor, except in Minnesota where a Burle camera supplied by MnDOT was used.

8.10 DATA RECORDING AND ANALYSIS

A PC-based data logger, shown in Figure 8-1, automatically recorded and time-tagged data and assisted in their analysis. Application-specific software run by the 386 PC formatted the VCR video tapes and issued stop and start commands to the VCR. Video tape index numbers were recorded by the data logger to correlate with the time tags and detector output events.

The data logger is capable of recording 8 analog signals, such as Doppler frequency, air temperature, and wind speed and direction; 16 relay-based detector output transitions; 40 optically isolated detector output transitions; and 16 RS-232 serial inputs. Since the protocols for reading the serial data are unique to each detector, the detector's serial output was connected to a specific RS-232 input port on the data logger as identified in Figure 8-1. Further description of the data logger is given in Appendix C.

The Phase II software developed for the data logger converts the raw input data into comma-delimited format, and Paradox software converts that into a database from which a direct comparison of speeds, counts, occupancies, etc. can be made across the detectors. The database values can be plotted as a function of time or green-phase cycle length using a program such as Mathcad to simultaneously display parameters from the selected detectors. Statistics such as means and standard deviations can also be computed to assess the accuracies of the detectors.

In Tucson, data produced by high-frequency sampling of the change in inductance produced by the passage of a vehicle over inductive loops were recorded on a dedicated personal computer and hard drive along with time stamps supplied by the data logger computer. The high sampling rate needed to reproduce the frequencies of interest required a separate computer and hard drive to prevent overloading of the drive on which the other detector output data are recorded. Waveforms associated with the passage of vehicles through the magnetic field produced by an array of magnetometers were recorded on a Metrum recorder located in the field trailer. These were transcribed onto suitable magnetic media that are compatible with the data analysis system.

8.11 SECURITY FOR THE EVALUATION SITE

Provisions were made to secure the trailer and equipment from burglary. These measures included the installation of extra locks and a cellular-phone-based security system that automatically notified appropriate authorities in the event of unauthorized access to the trailer or a fire. Land-line telephone service was installed in the trailer as well when it was available. When a possibility existed for the public to interfere with the operation of the overhead detectors, measures such as fencing off the detectors from public access were employed.

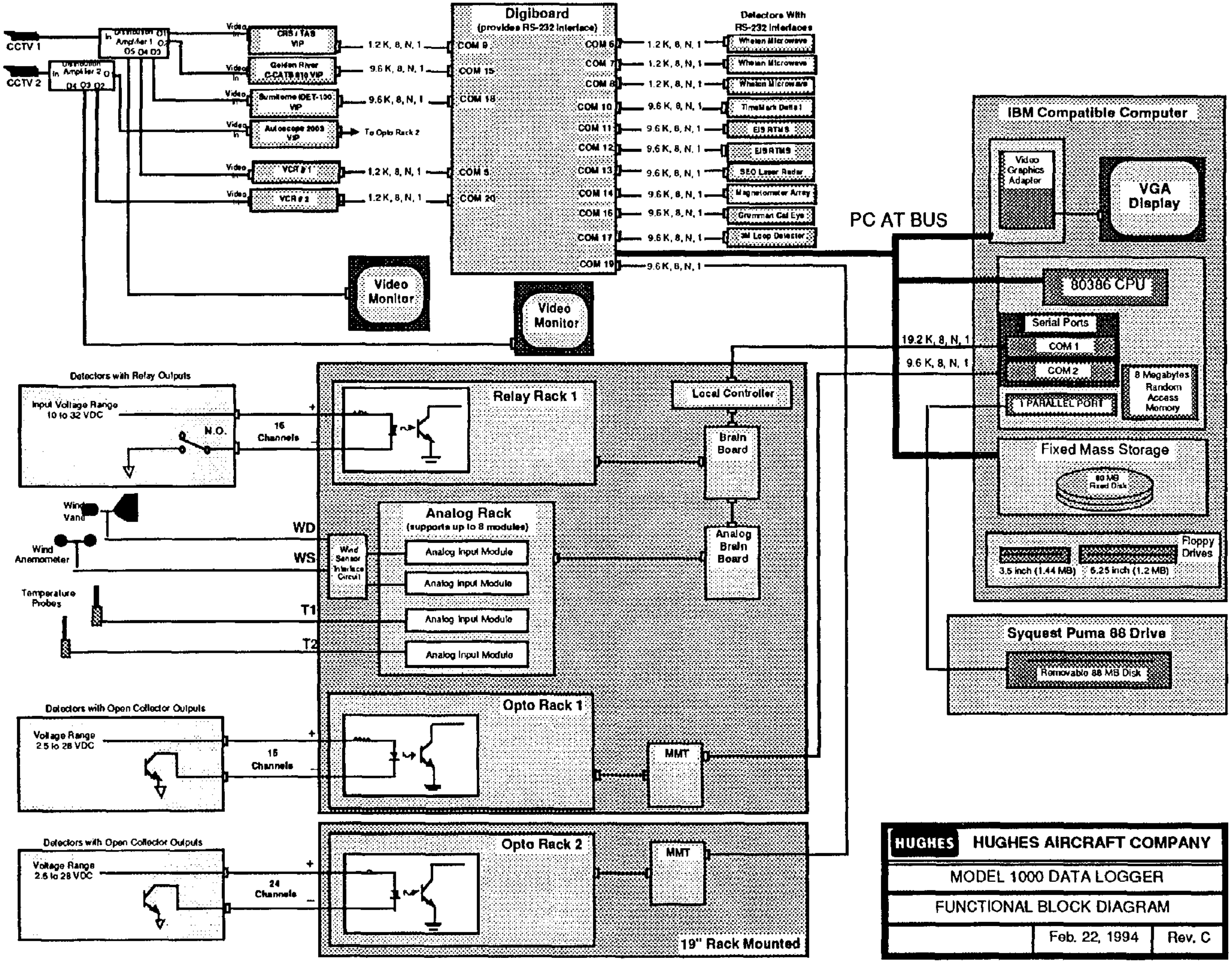


Figure 8-1. Data Logger

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4. Detection Technology for IVHS: Task C Report - Laboratory Test Specifications and Test Plan, Federal Highway Administration Contract DTFH61-91-C-00076, U.S. Department of Transportation, Washington, D.C. (1994).

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9. TASK G

INSTALL VEHICLE DETECTORS AT FIELD SITES AND COLLECT FIELD TEST DATA

Six field sites were selected in which to evaluate modern detector technologies suitable for traffic management on freeways and surface streets. Table 9-1 summarizes the location, evaluation period, weather, and traffic flow direction at each site. The Phoenix freeway site was visited twice in order to obtain hot weather data that were not gathered during the first visit. The detectors installed at the sites and the technologies they represent are listed in Table 9-2.

Table 9-1. Descriptions of Detector Technology Evaluation Sites

Location	Evaluation Period	Weather	Traffic Direction
Minneapolis freeway: I-394 at Penn Avenue	Winter 1993	Cold, snow, sleet, fog	Departing (AM); Departing and approaching (PM)
Minneapolis surface street: Olson Highway at East Lyndale Avenue North	Winter 1993	Cold, snow, sleet, fog	Departing
Orlando freeway: I-4 at SR 436	Summer 1993	Hot, humid, heavy rain, lightning	Approaching
Orlando surface street: SR 436 at I-4	Summer 1993	Hot, humid, heavy rain, lightning	Departing
Phoenix freeway: I-10 at 13th Street	Autumn 1993	Warm, rain	Approaching
Tucson surface street: Oracle Road at Auto Mall Drive	Winter 1994	Warm	Departing
Phoenix freeway: I-10 at 13th Street	Summer 1994	Hot, low humidity, thunder storms, lightning	Approaching

9.1 MINNEAPOLIS EVALUATION SITES

The Minneapolis freeway site at I-394 and Penn Avenue is shown in Figure 9-1 as the overhead detectors were installed. The boom truck was used to attach the pipe trees to the concrete overpass structure and adjust the alignment of the detectors so that they observed traffic in their designated lanes and at manufacturer-specified incidence angles. Details of the pipe tree attachment to the overpass are contained in Appendix E. This site was unique in that a reversible traffic flow lane was instrumented with several detectors along with the permanent eastbound freeway lanes. The reversible lane was located between the nonreversible westbound and eastbound lanes as shown in Figure 9-2. Data from approaching traffic using the reversible lane was recorded during afternoon rush hours. The approximate locations of the areas viewed by the detectors are indicated in the figure. The size of the ground footprints of the detectors is a function of the mounting height, aperture beamwidth, and incidence angle as tabulated in Appendix F.

Overhead detector mounting locations on the pipe tree are shown in Figures 9-3 and 9-4. Lane 1 refers to the reversible lane, lane 2 to the leftmost eastbound lane, and lane 3 to the rightmost eastbound lane. The lowest pipe on

Table 9-2. Detectors Used During Field Tests

Symbol	Technology	Manufacturer	Model	Output Data
U-1	Ultrasonic Doppler	Sumitomo	SDU-200 (RDU-101)	Count, speed
U-2	Ultrasonic Presence	Sumitomo	SDU-300	Count, presence
U-3	Ultrasonic Presence	Microwave Sensors	TC-30C	Count, presence
M-1	Microwave Detector Motion Medium Beamwidth	Microwave Sensors	TC-20	Count
M-2	Microwave Detector Doppler Medium Beamwidth	Microwave Sensors	TC-26	Count, speed binning
M-4[a]	Microwave Detector Doppler Narrow Beamwidth	Whelen	TDN-30	Count, speed
M-5	Microwave Detector Doppler Wide Beamwidth	Whelen	TDW-10	Count, speed
M-6	Microwave Radar Presence Narrow Beamwidth	Electronic Integrated Systems	RTMS-X1	Count, presence, speed, occupancy
IR-1	Active IR Laser Radar	Schwartz Electro-Optics	780D1000 (Autosense I)	Count, presence, speed
IR-2	Passive IR Presence	Eltec	842	Count, presence
IR-3	Passive IR Pulse Output	Eltec	833	Count
IR-4[b]	Imaging IR	Grumman	Traffic Sensor	Presence, speed
VIP-1	Video Image Processor	Econolite	Autoscope 2003	f
VIP-2	Video Image Processor	Computer Recognition Systems	Traffic Analysis System	f
VIP-3[c]	Video Image Processor	Traficon	CCATS-VIP 2	f
VIP-4[b]	Video Image Processor	Sumitomo	IDET-100	f
VIP-5[d]	Video Image Processor	EVA	2000	f
A-1[e]	Passive Acoustic Array	AT&T	SmartSonic TSS-1	Count
MA-1	Magnetometer	Midian Electronics	Self-Powered Vehicle Detector	Count, presence
L-1[b]	Microloop	3M	701	Count, presence
T-1[e]	Tube-Type Vehicle Counter	Timemark	Delta 1	Count

a. M-3 was designated for a microwave radar detector that was not received.

b. Used at Tucson, Arizona test site only.

c. Used at all Arizona test sites.

d. Used in Phoenix, Arizona 7/94 test only.

e. Used in Phoenix 11/93 and Tucson tests.

f. Count, presence, occupancy, speed, classification based on length. Some provide headway, density, and alarm functions.

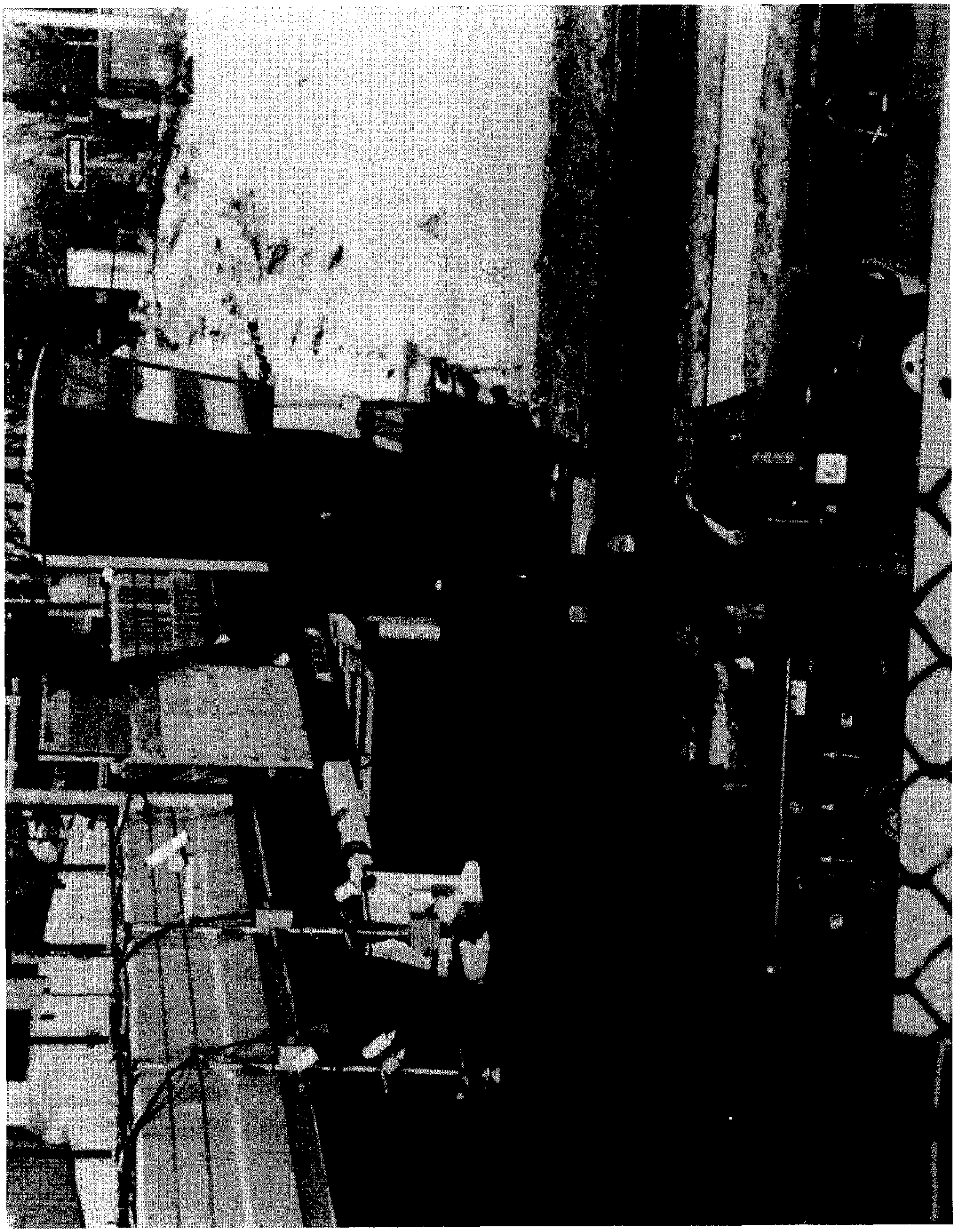
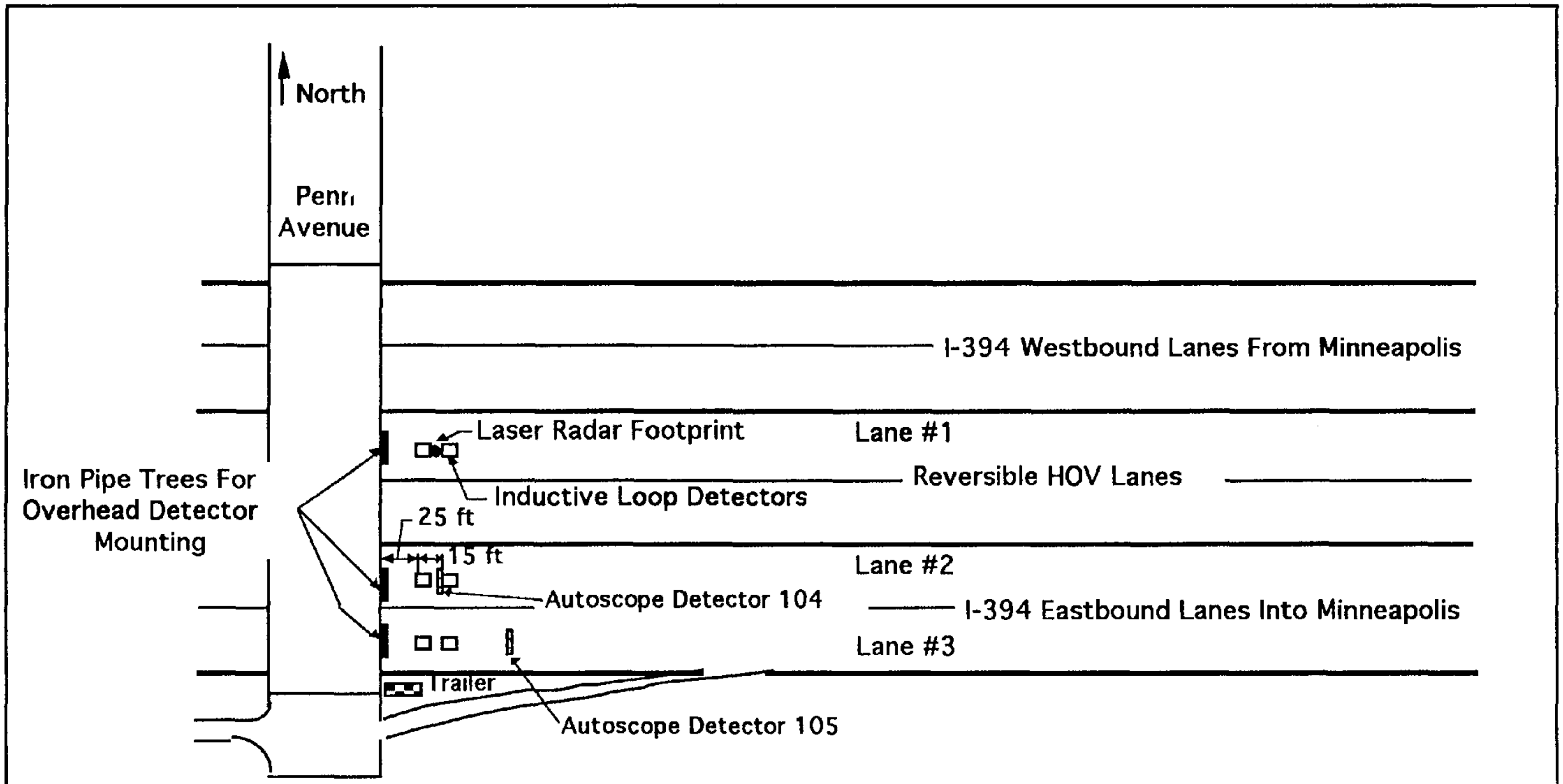


Figure 9-1. Installation of Overhead Detectors at I-394 Freeway Site



The bottom pipe tree brace is 18 ft above the road surface

Pipe tree braces on which the overhead detectors are mounted are separated by 2 ft

Detection zones for the loop emulation mode of the Computer Recognition Systems VIP correspond to the location of the actual inductive loops

1 ft = 0.305 m

Figure 9-2. Location of Detectors on I-394

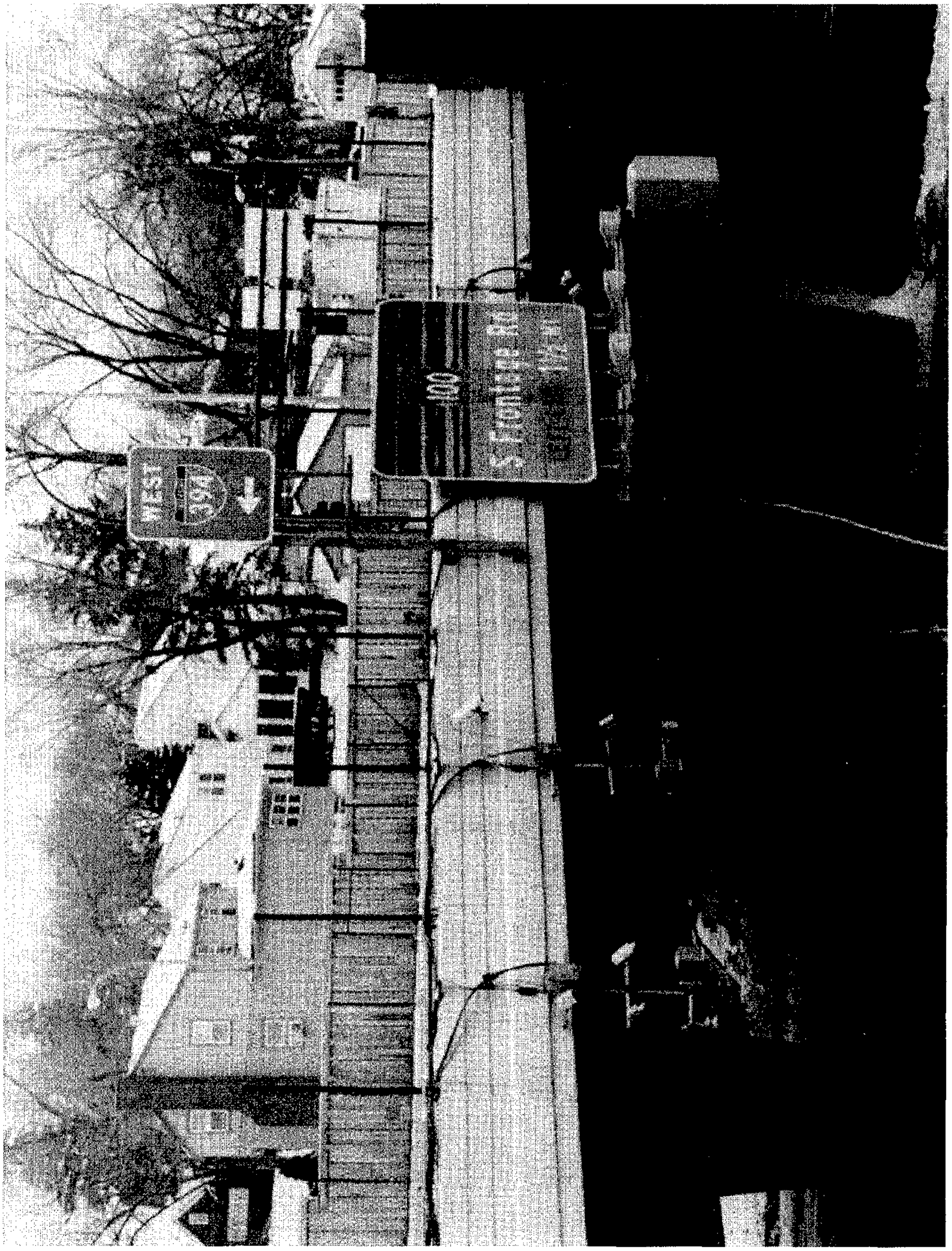
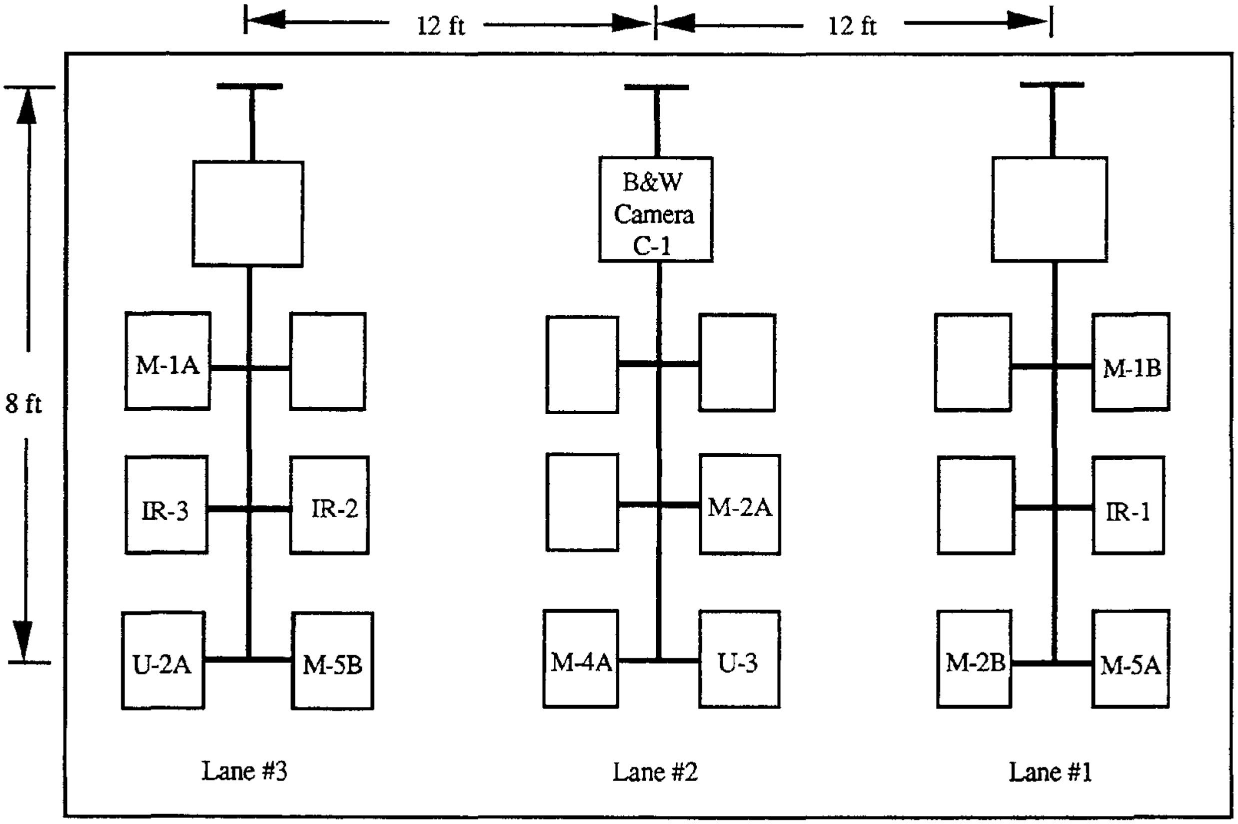


Figure 9-3. Detectors Over Eastbound and Reversible Lanes on I-394



1 ft = 0.305 m

Figure 9-4. I-394 Overhead Detector Layout

the pipe tree was 18 feet (5.5 m) above the road surface and the separation between pipes was 2 feet (0.6 m). The black-and-white video camera was located 24 feet (7.3 m) above lane 2. A pair of 6-foot (1.8-m) square inductive loop detectors was installed in each of the three lanes with a 15-foot (4.6-m) leading-edge-to-leading-edge spacing. Inductive loop specifications used by each of the states are furnished in Appendix G. The self-powered magnetometers were not available at this site. Traffic cones were placed on the freeway shoulder at 50-foot (15.2-m) intervals to aid in video image processor field-of-view calibration.

The trailer that housed the detector data and video recording equipment, power supplies, and detector electronics is shown in Figure 9-5. It was located at the southeast corner of the intersection of Penn Avenue with the I-394 freeway, behind a barrier rail. About 200 wires were run from the trailer to the detectors to supply power and record the output data as shown in Figure 9-6.

After data acquisition at the freeway site was completed, the trailer and overhead detectors were removed and transported to the surface-street evaluation site at Olson Highway and East Lyndale Avenue North. Here, westbound departing traffic was monitored as shown in Figure 9-7. The trailer is shown in Figure 9-8. The pipe trees were fastened to a sign bridge, as illustrated in Appendix E, that spanned the westbound lanes. Two of the overhead detectors, the TC-20 microwave detector and the 780D1000 laser radar, monitored approaching traffic. The laser radar could only respond to approaching traffic at this stage in its design (it was later modified to monitor both approaching and departing traffic), while the TC-20 was used to provide vehicle-count data to compare with the laser radar since the video camera did not record traffic flow in this region. Cables were run from the trailer on the south side of Olson Highway to the overhead sign structure on the north side of the street as shown in Figure 9-9. A high-gain antenna was mounted on one corner of the trailer to receive signals from the self-powered magnetometers. The overhead detector layout for the Olson High-way site is shown in Figures 9-10 and 9-11. White stripes, spaced at intervals of 50 feet (15.2 m) as measured from the sign bridge, were painted on the edges of the westbound lanes to aid in calibration of the field of view seen by the video image processors.

Figure 9-12 shows Olson Highway being cored in the center of the loops in lane 2 (middle through lane) for the self-powered magnetometer detectors. The hole was approximately 22 inches (559 mm) deep by 6 inches (152 mm) in diameter. Two to three inches (51 to 76 mm) of cold patch were placed on top of the magnetometer to seal the hole as in Figure 9-13. The extra magnetometer in the upper part of the photograph shows the relative size of the detector that was buried. A side-mounted TC-30C ultrasonic detector and a Remote Traffic Microwave Sensor (RTMS) microwave radar were attached to a streetlight pole as shown in Figure 9-14. The TC-30C monitored traffic in lane 3 (the rightmost lane) of Olson Highway and the RTMS-monitored traffic in the three westbound lanes. Both detectors were lowered from the positions shown in the photograph before they were made operational. Since the video camera did not record traffic in this area, there is no video ground truth for these two devices. The time of occurrence of the green-phase signal at the Olson Highway-Lyndale Avenue intersection was recorded on a relay data logger input. The green phase was used to correlate the occurrence of vehicle queues with detector output.

The electronics racks that housed the power supplies, terminals for the outgoing power and input data, video recorder, video monitor, video image processor equipment, and inductive loop electronics cards at the Minneapolis sites are shown in Figure 9-15. In the lower left of the photograph is the data logger with the front panel removed. On the top of the leftmost rack is the video monitor used to observe traffic flow. Mounted in the rack, from top to bottom, are the Autoscope 2003 electronics, a personal computer (PC)-controlled video recorder, sliding shelf on which the computer keyboard is shown, a Type 170 chassis in which inductive loop electronics cards were inserted, and power-supply modules. The power output to the detectors came from a panel on the right side of this rack. The rack on the right of the photograph shows the panel to which the

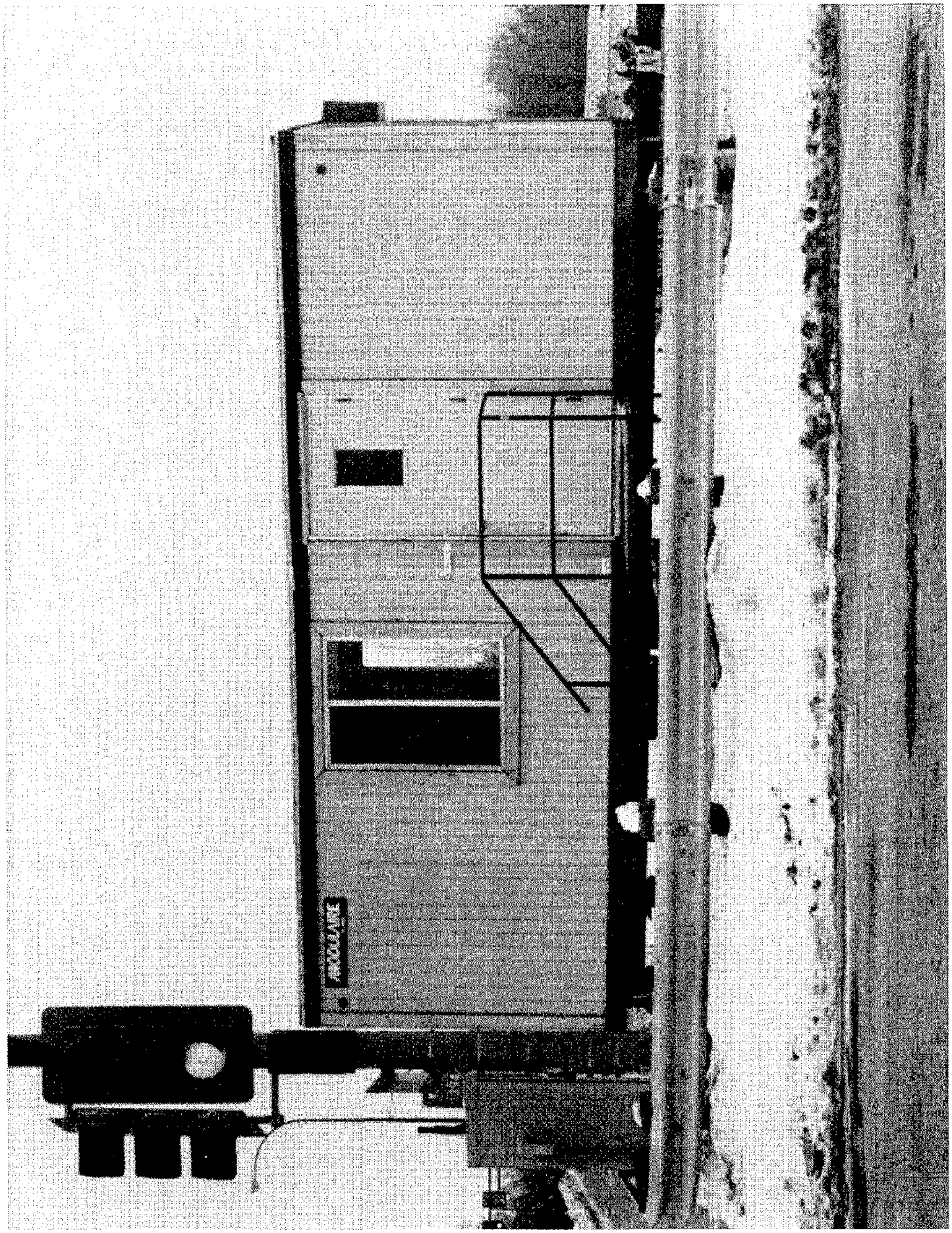


Figure 9-5. Data Acquisition Trailer at I-394

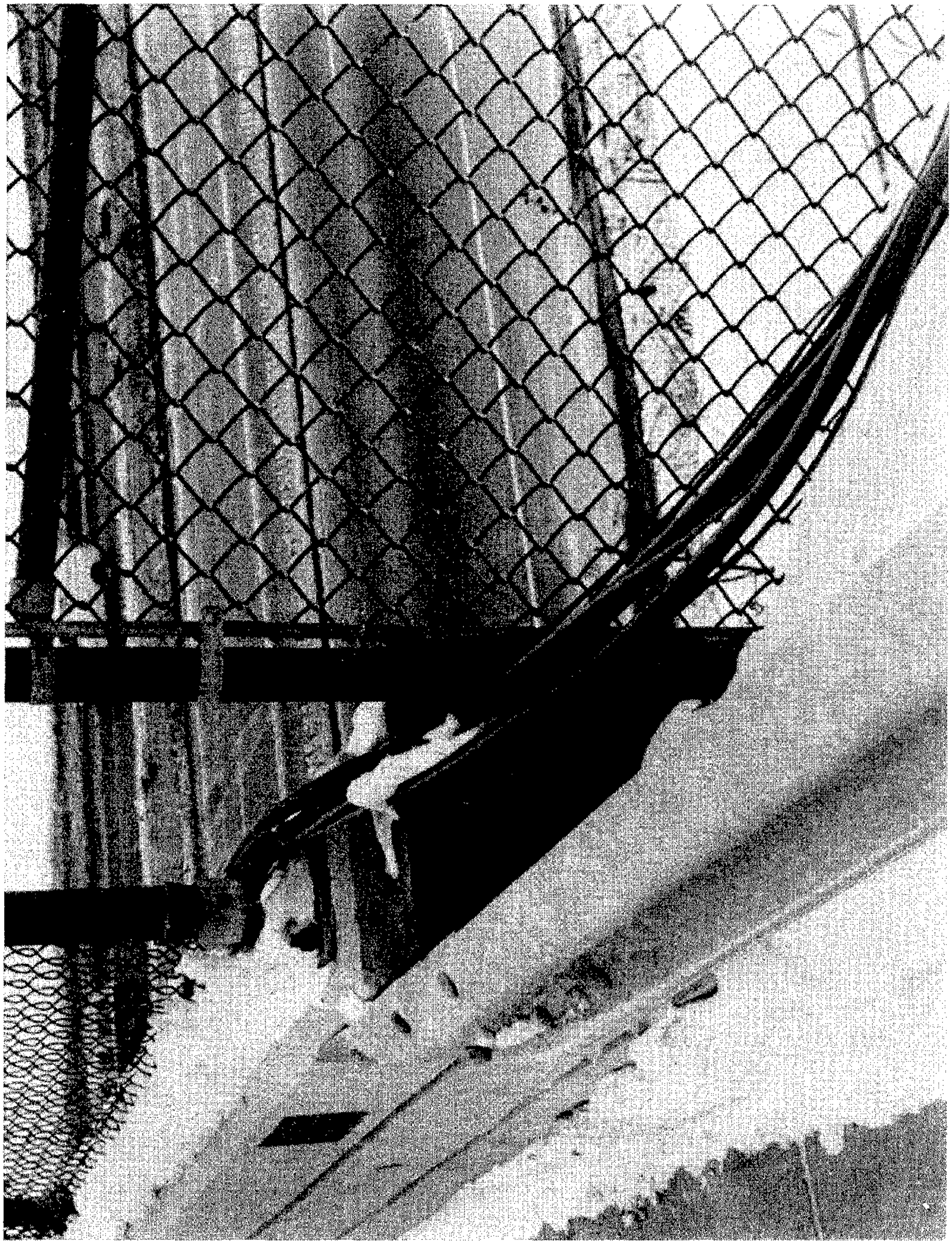
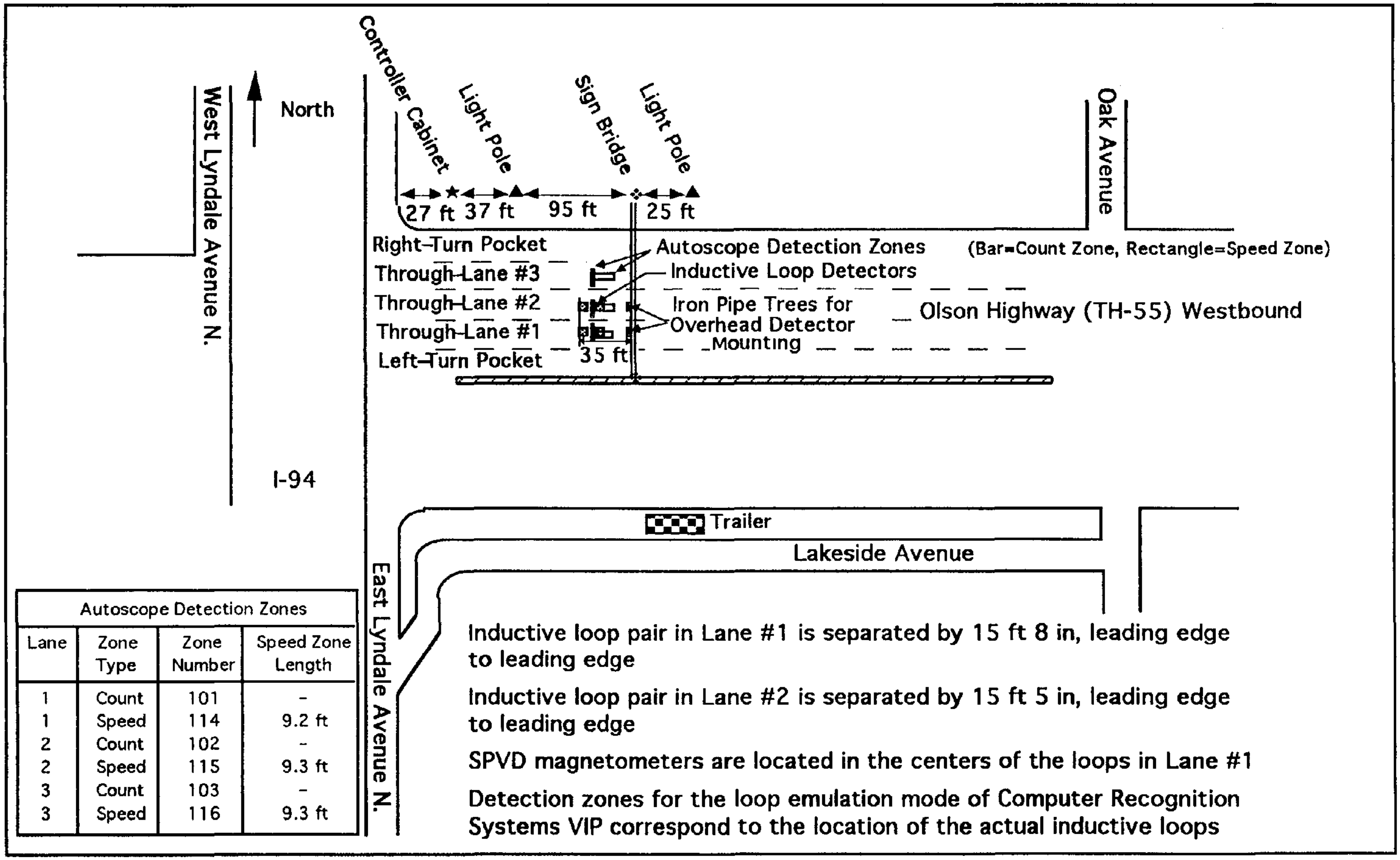


Figure 9-6. Cable Run From Trailer to Detectors at I-394



Autoscope Detection Zones

Lane	Zone Type	Zone Number	Speed Zone Length
1	Count	101	-
1	Speed	114	9.2 ft
2	Count	102	-
2	Speed	115	9.3 ft
3	Count	103	-
3	Speed	116	9.3 ft

Inductive loop pair in Lane #1 is separated by 15 ft 8 in, leading edge to leading edge

Inductive loop pair in Lane #2 is separated by 15 ft 5 in, leading edge to leading edge

SPVD magnetometers are located in the centers of the loops in Lane #1

Detection zones for the loop emulation mode of Computer Recognition Systems VIP correspond to the location of the actual inductive loops

1 in = 25.4 mm
1 ft = 0.305 m

Figure 9-7. Olson Highway Surface-Street Site in Minneapolis

Figure 9-8. Data Acquisition Trailer at Olson Highway

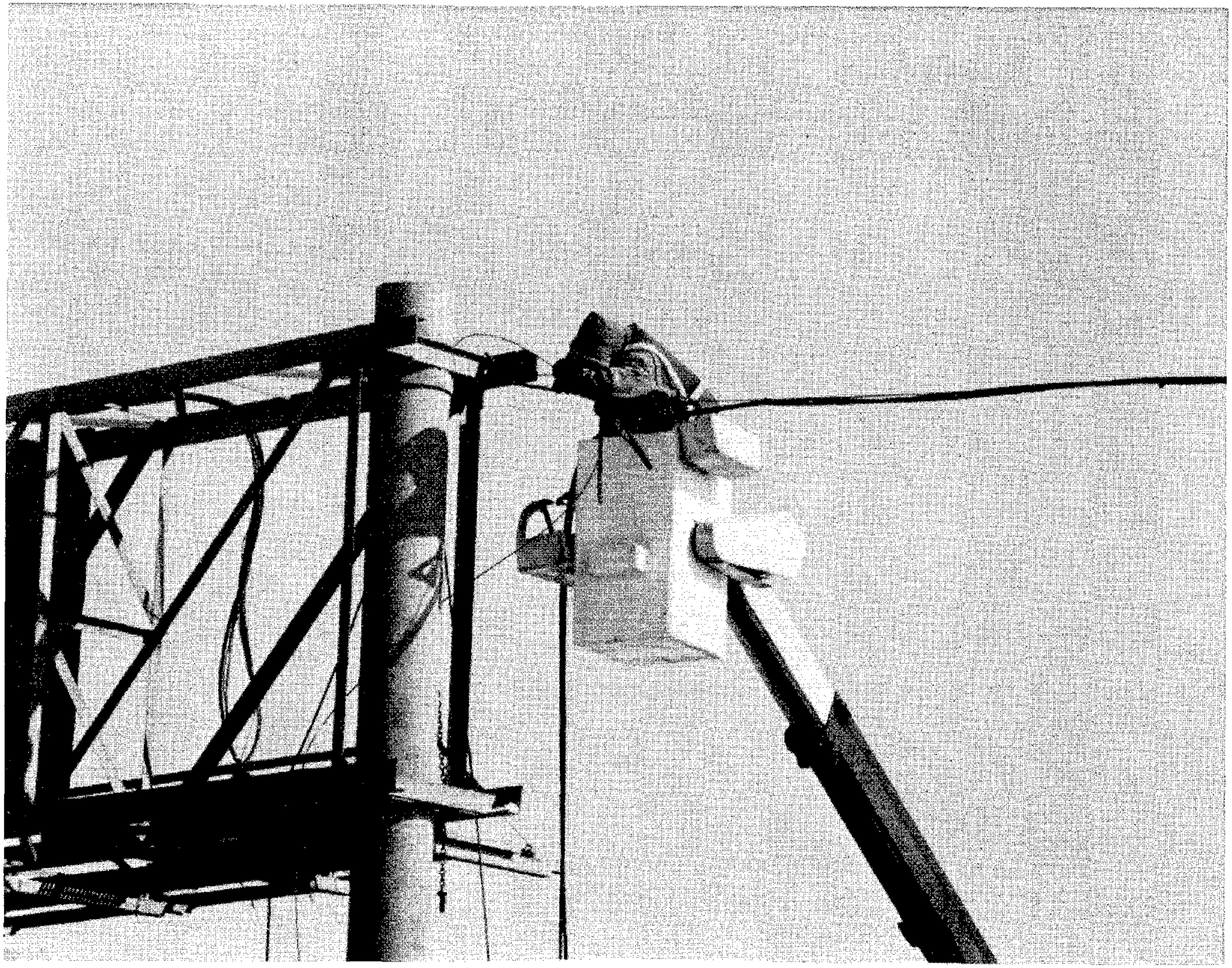


Figure 9-9. Installation of Detector Output Data Cables and Input Power Cables at Olson Highway Surface-Street Site

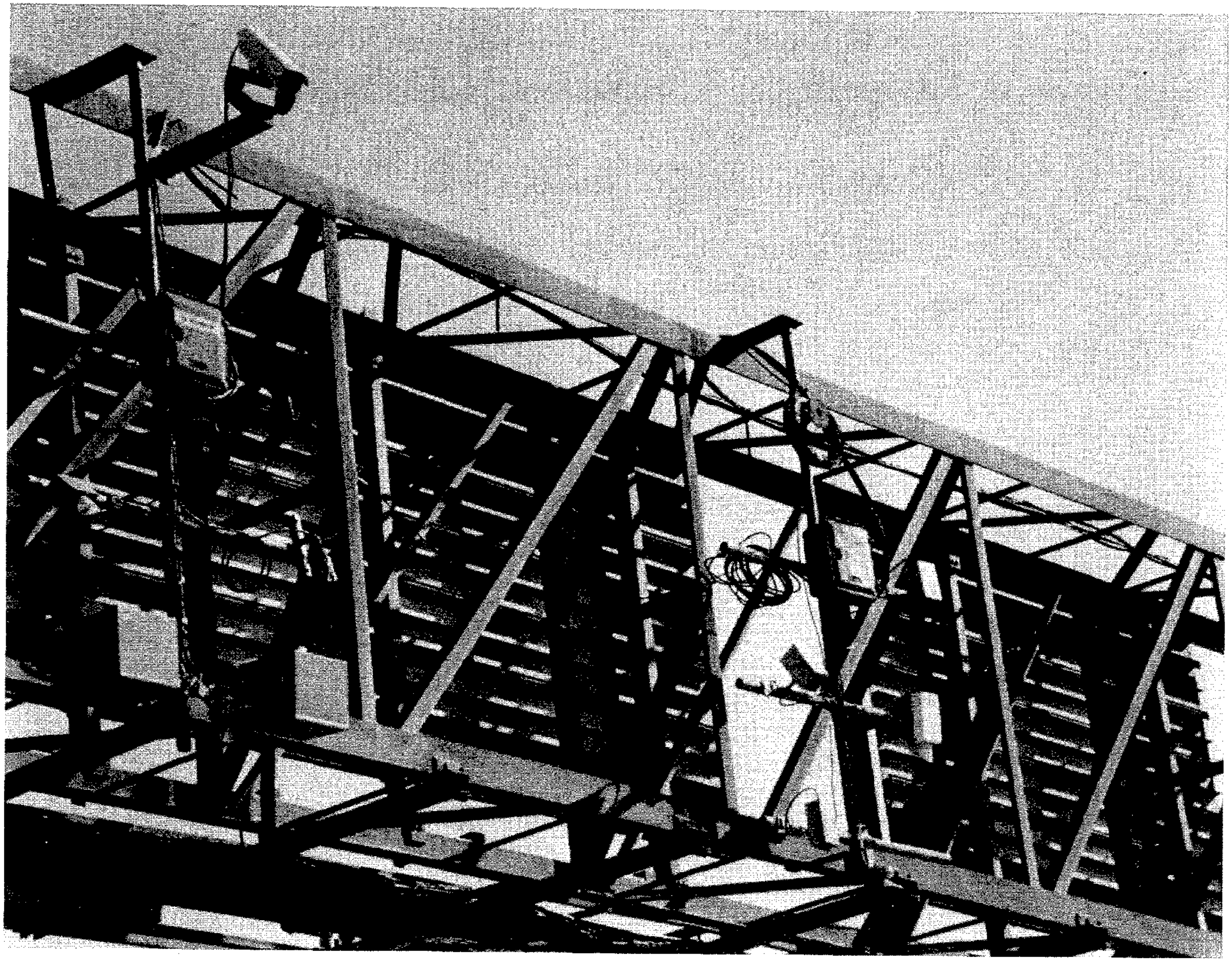
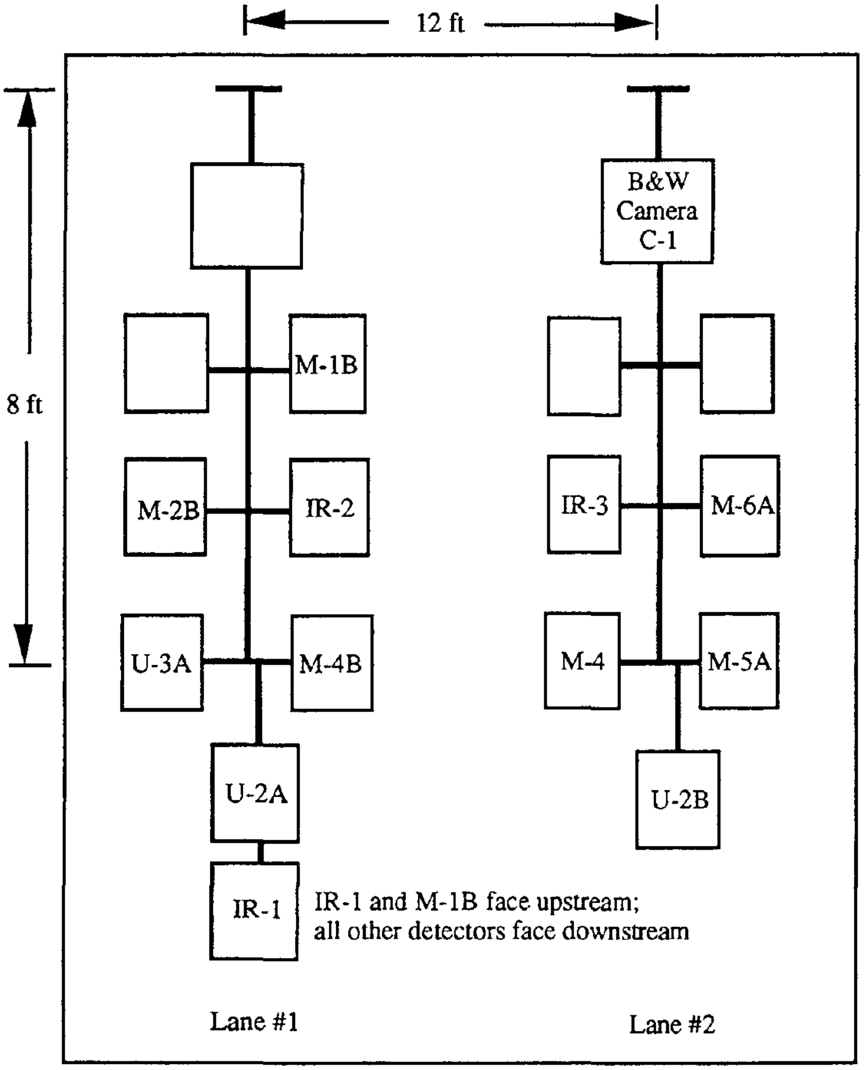


Figure 9-10. Detectors Over Westbound Lanes on Olson Highway Surface-Street Site



1 ft = 0.305 m

Figure 9-11. Olson Highway Overhead Detector Layout

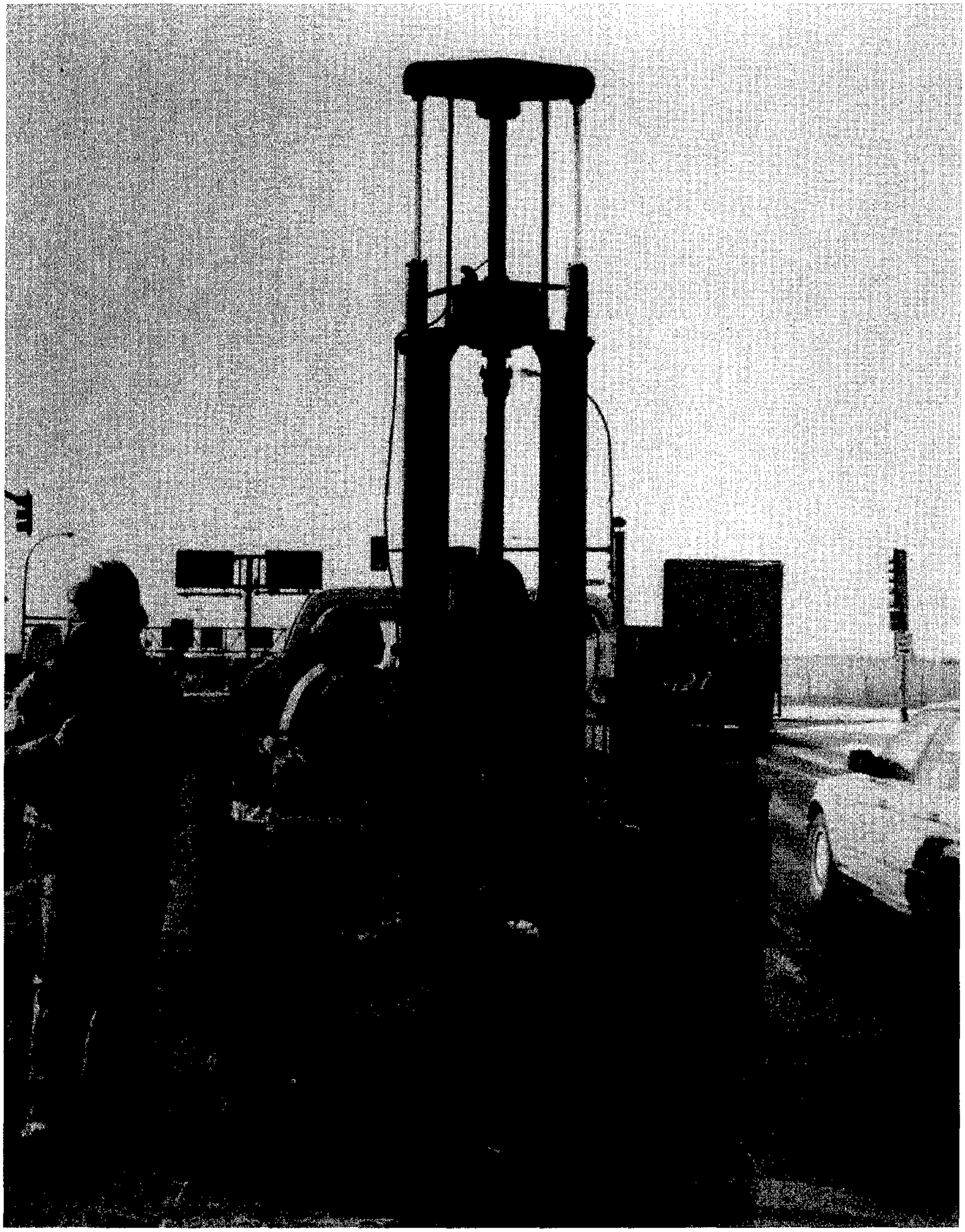


Figure 9-12. Coring of Olson Highway for Self-Powered Magnetometers

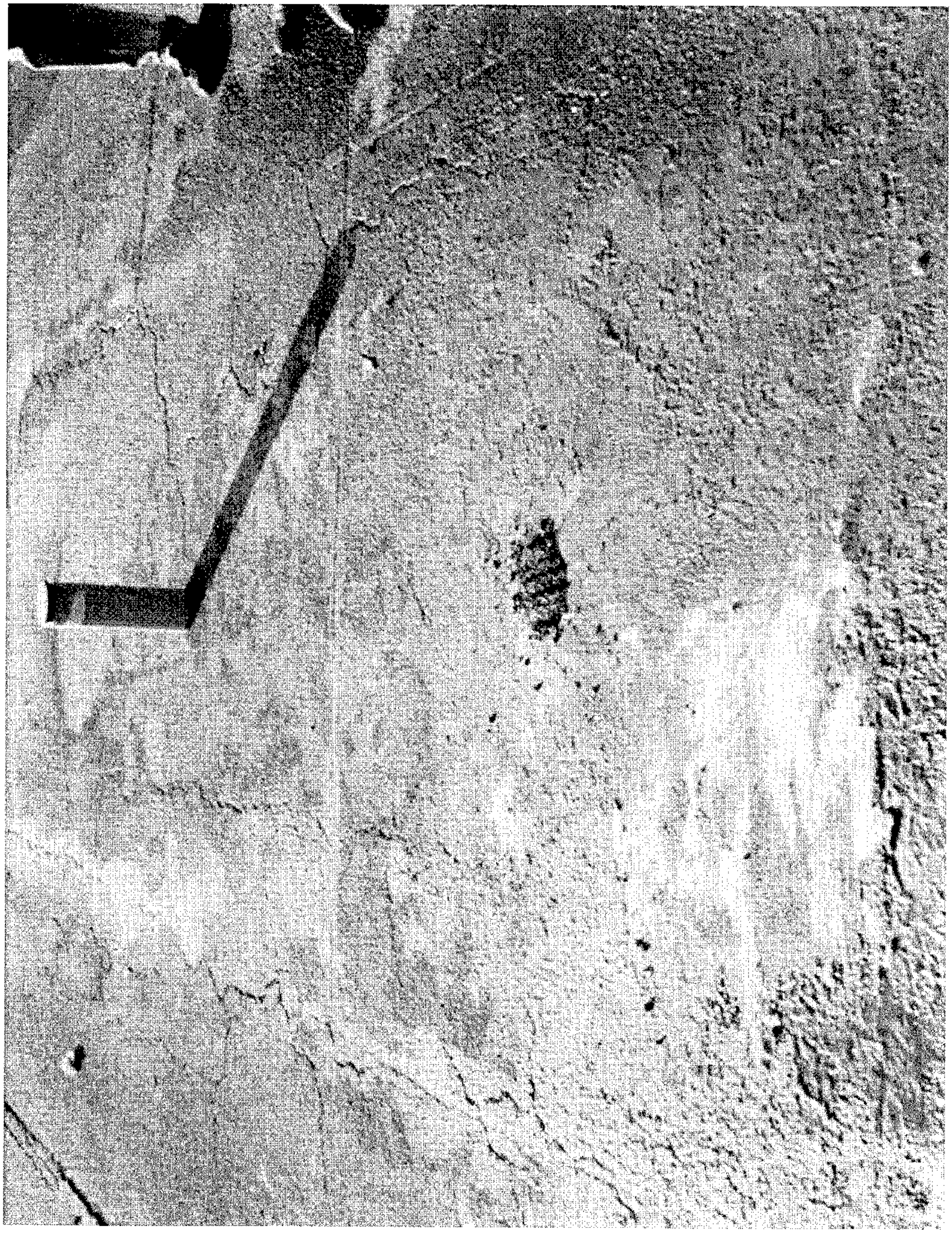


Figure 9-13. Hole With Magnetometer In Place

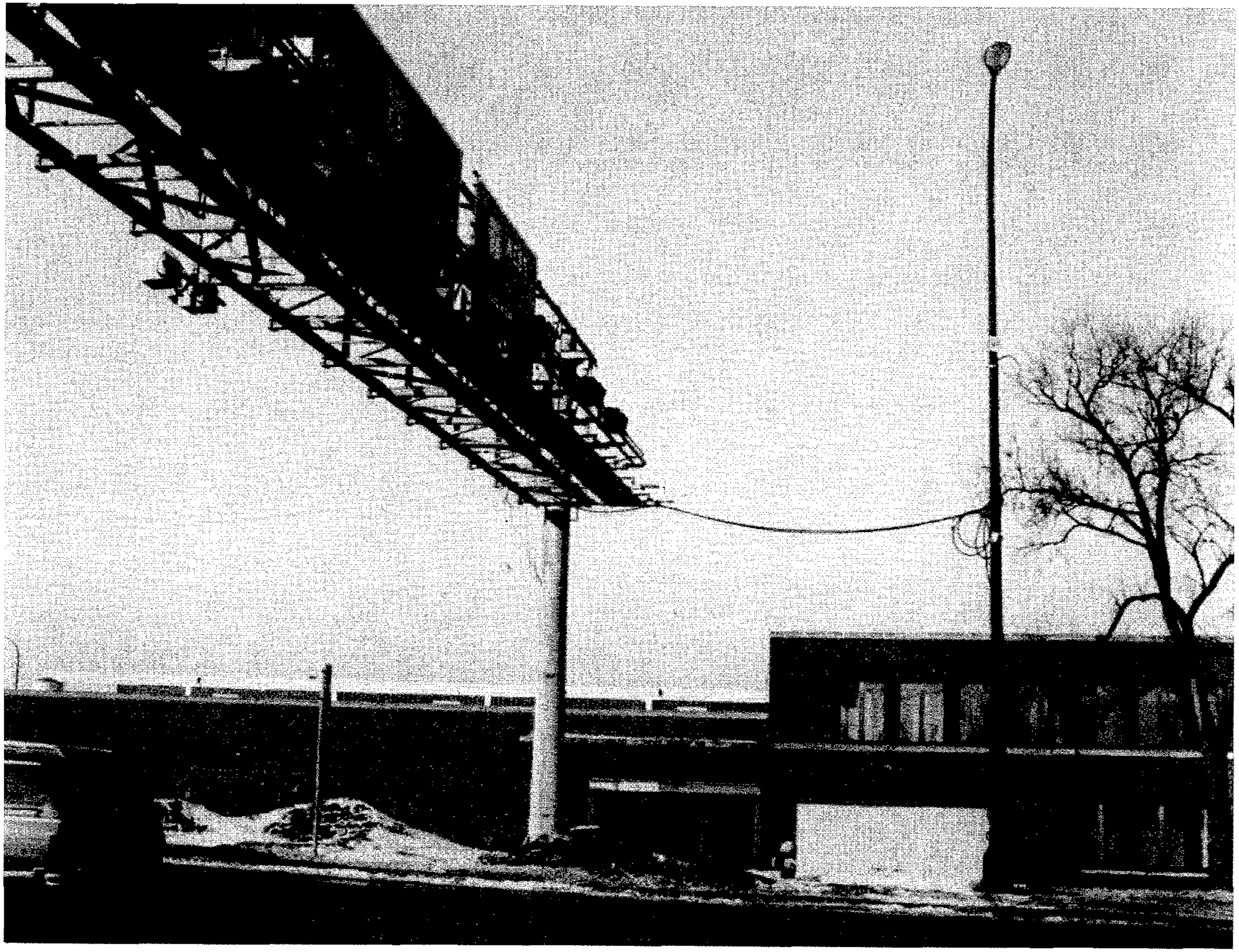


Figure 9-14. Olson Highway Overhead Site Showing Detectors Mounted on Sign Bridge and Light Pole

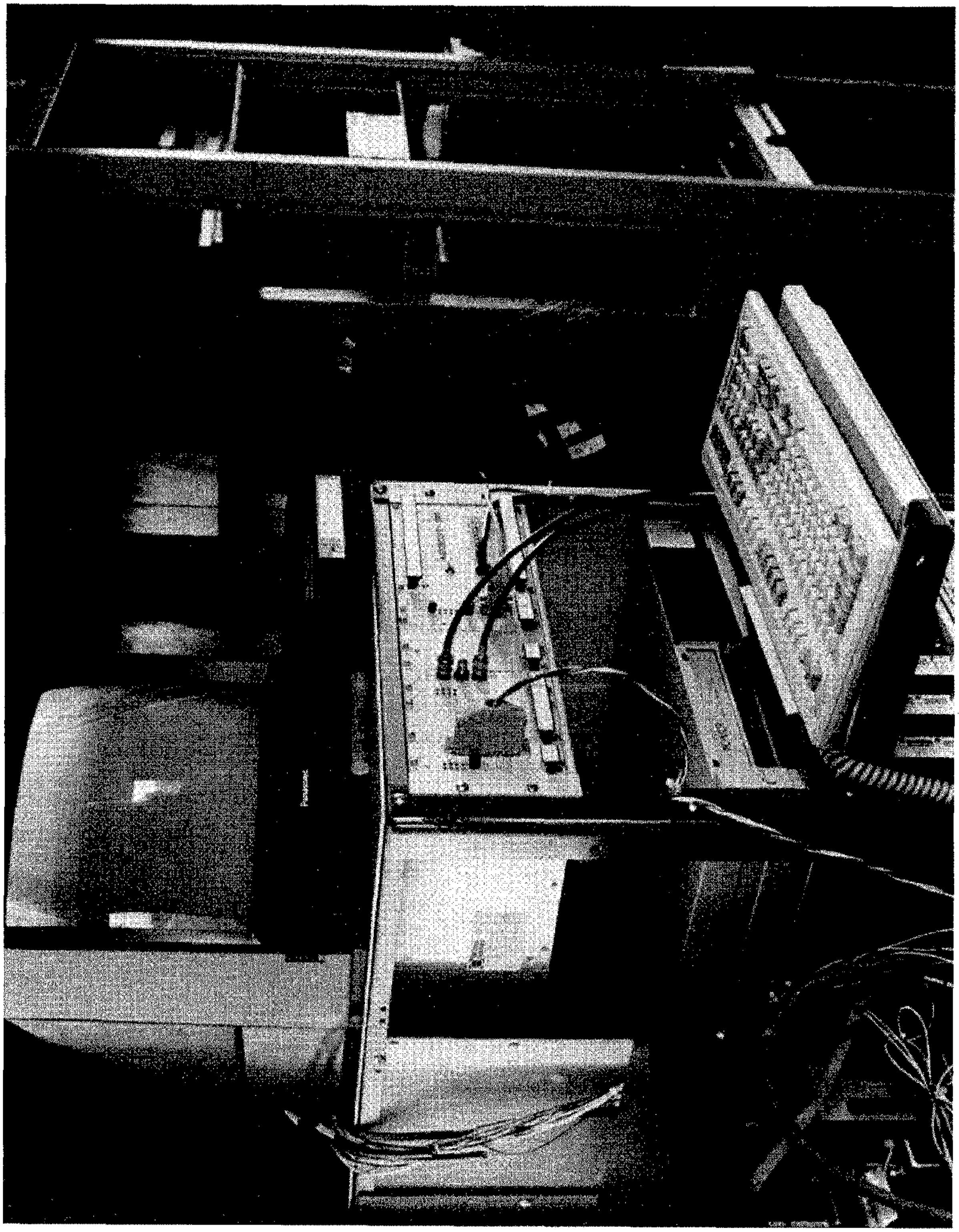


Figure 9-15. Data Recording Equipment as Configured at I-394 and Olson Highway

detector outputs were connected before being routed to the data logger. The connections from the detectors to the data logger and power supplies are shown in Appendix H for all the sites.

9.2 ORLANDO EVALUATION SITES

The Florida freeway detector evaluation site was located on I-4 at SR 436 just north of Orlando in Altamonte Springs. The overhead detector configuration of Figures 9-16 and 9-17 viewed approaching traffic in the leftmost and middle lanes (lanes 1 and 2, respectively) of the westbound freeway into Orlando. The pipe trees were attached to the north face of the SR 436 overpass. The bottom pipe was 16.56 feet (5.05 m) above the road surface in lane 1 and 16.26 feet (4.96 m) above the road surface in lane 2. Horizontal pipe sections were 2 feet (0.6 m) apart. The modified Burle camera supplied with the Autoscope VIP had an 8-mm, f/1.4 lens and was mounted 24.26 feet (7.39 m) above lane 2. Pairs of 6-foot (1.8-m) square inductive loop detectors were installed in lanes 1, 2, and 3 (the rightmost lane) as shown in Figure 9-18. The self-powered magnetometer detectors with 15-foot (4.6-m) center-to-center spacing were located in the center of the loops in lane 1. The Autoscope detection zones, inductive loop detectors, and camera field of view are shown in Figure 9-19. The south loop in each lane was not in the viewing area of the camera.

A TC-20 microwave detector was side-mounted on an overpass support in the median to view traffic in the left westbound lane of I-4 as shown in Figure 9-20. The traffic flow was at an angle of between 20 and 30 degrees with respect to the antenna boresight. A side-mounted RTMS microwave radar was bolted to a round wooden utility-type pole on the shoulder of the eastbound lanes. The antenna boresight of the detector was perpendicular to the traffic flow as in Figure 9-21. The pole was set in a grassy area 16 feet (4.9 m) from the right edge of the right-most eastbound freeway lane and 27 feet (8.2 m) from the north face of the SR 436 overpass. It monitored traffic in the three westbound lanes within the viewing area of the video camera. In this way, the video imagery could be used to obtain vehicle count ground truth to calibrate the RTMS detector. The side-mounted RTMS detector was also configured to monitor traffic in the three eastbound lanes. However, the video imagery did not cover this area. The trailer, video camera, overhead detectors, and chain-link fence are also shown in the photograph. Traffic cones and paint stripes numbered 1, 2, 3, ... (also shown in Figure 3-8) were placed on the right shoulder of the westbound freeway in 25-foot (7.6 m) intervals for video image processor calibration.

The trailer was located on the shoulder of the eastbound lanes under the SR 436 overpass. This location was chosen so that the overhead detectors could later be moved to the surface street above the freeway without moving the trailer. A high-gain antenna was mounted on one corner of the trailer to receive signals from the self-powered magnetometers. The cables were run from the trailer along the overpass to the detectors. A chain-link fence was installed on the overpass to prevent tampering with the overhead detectors and the cables.

The data recording configuration used in Orlando is shown in Figure 9-22. The edge of the PC keyboard is at the extreme lower left corner of the photo. To its right is the Puma 88 drive that contains the removable 88MB cartridges used to record the digital and analog outputs of the detectors during each run. The 386 PC containing the application-specific software that controls the data logger is to the right of the Puma drive. The interface for the 16 detector RS-232 serial inputs is on top of the computer. The main data logger is located to the right of the computer. It contains hardware and software that support the 8 analog detector outputs, 16 relay outputs, and 16 optically isolated detector outputs. To its right is a panel on which the outputs from the traffic detectors and environmental sensors are connected as they enter the trailer on cables. The Sumitomo electronics for the SDU-200 (RDU-101) and SDU-300 ultrasonic detectors were placed on the floor under the table. An uninterruptable power supply and surge protectors on each data line entering the trailer from the outside protected the recording equipment from lightning strikes.

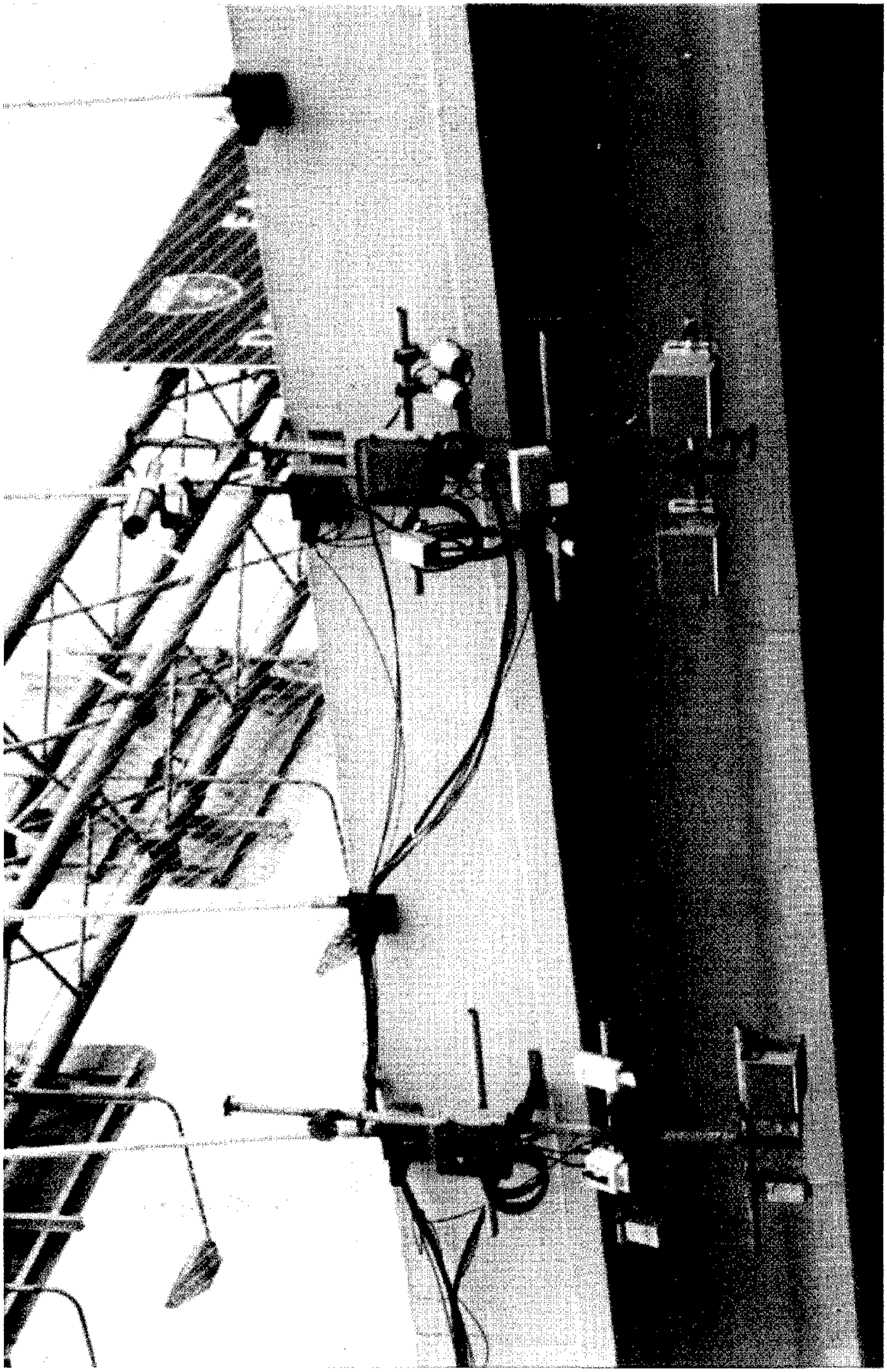
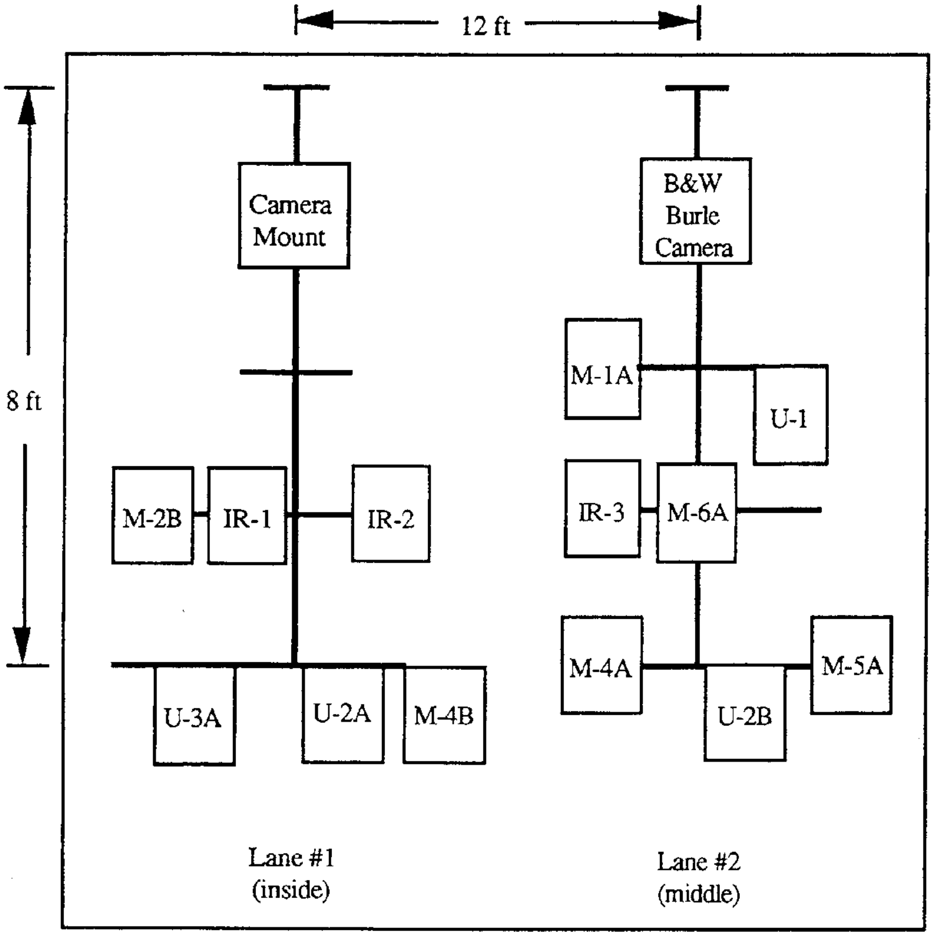


Figure 9-16. Detectors Over Westbound Lanes at Orlando I-4 Freeway Site



1ft = 0.305 m

U-1	SDU-200
U-2	SDU-300
U-3	TC-30C
M-1	TC-20
M-2	TC-26
M-4	TDN-30
M-5	TDW-10
M-6	RTMS
IR-1	780D1000
IR-2	842
IR-3	833

Figure 9-17. I-4 Overhead Detector Layout

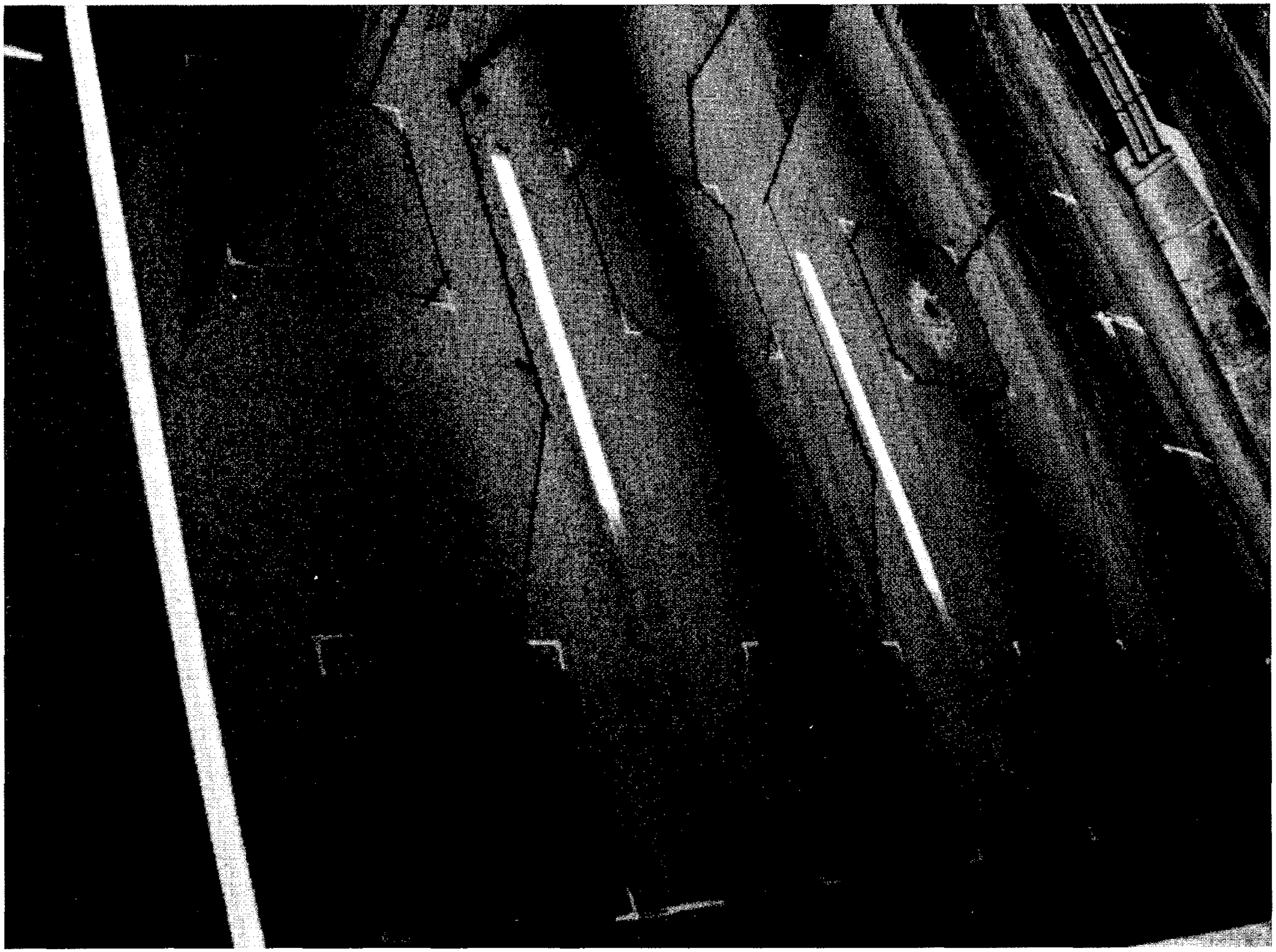
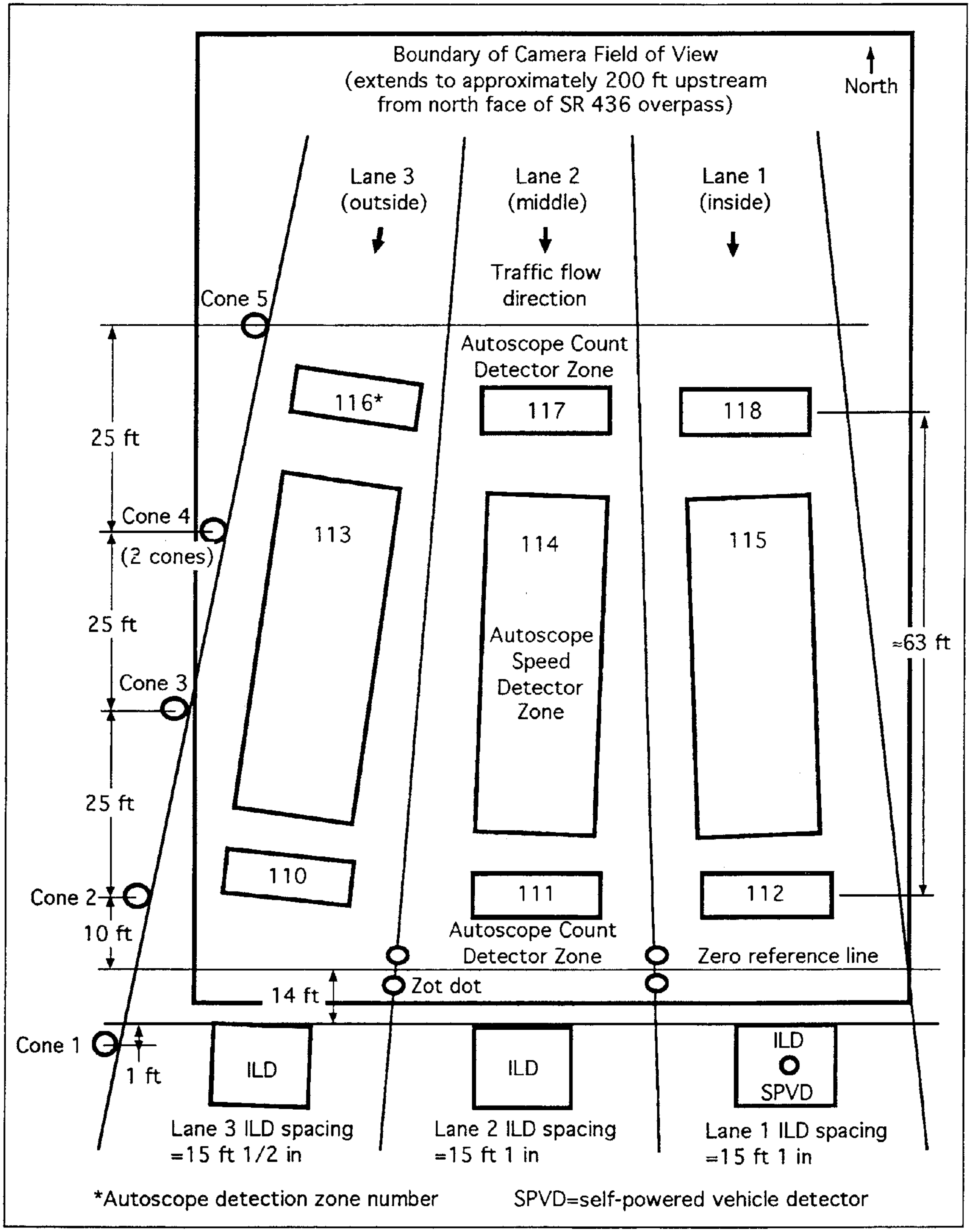


Figure 9-18. I-4 Freeway Lanes Showing Installed Inductive Loops and Self-Powered Magnetometers



1 in = 25.4 mm
1 ft = 0.305 m

Figure 9-19. Location of Inductive Loop Detectors, Autoscope Detection Zones, and Camera Field of View on I-4

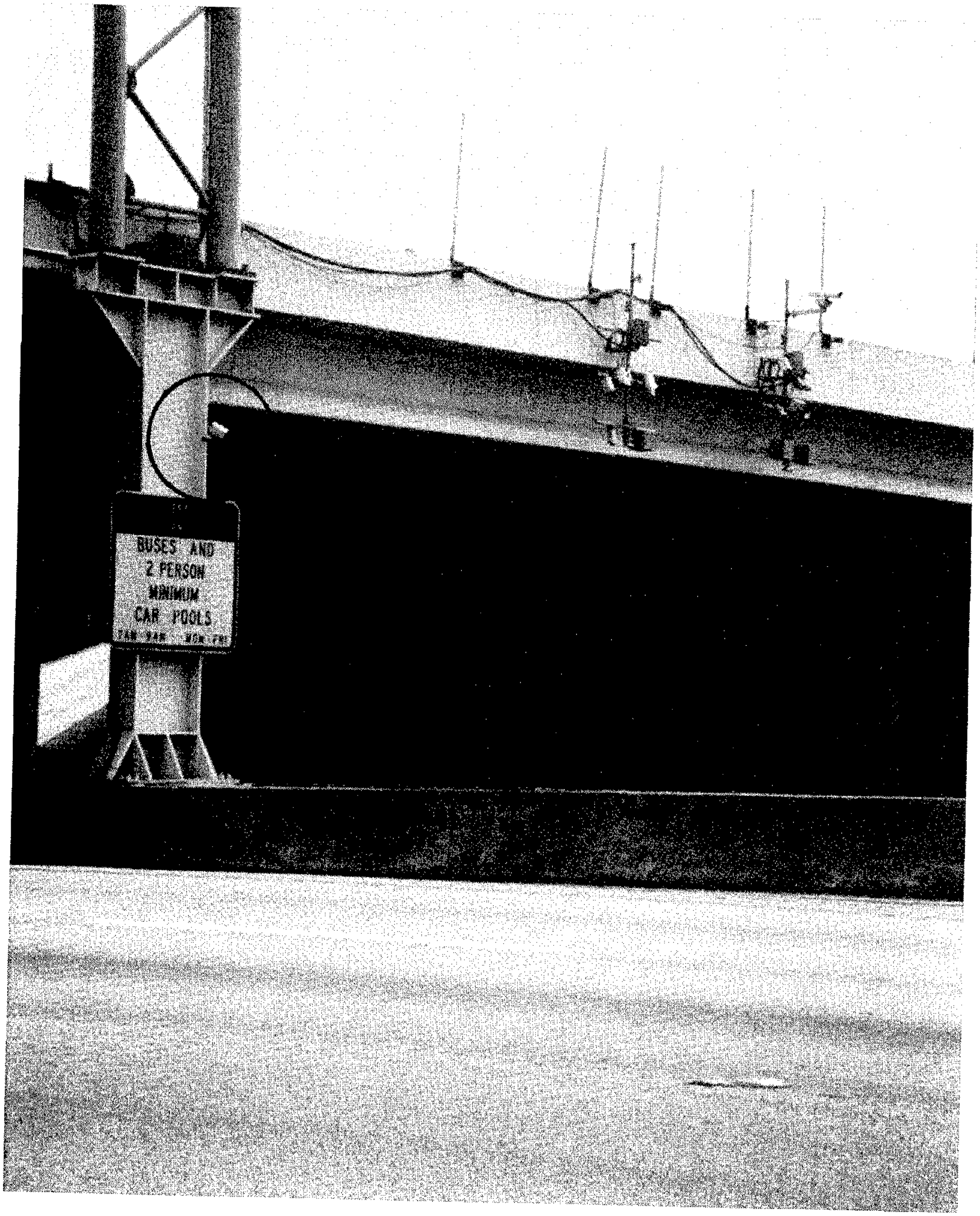


Figure 9-20. Side-Mounted TC-20 Microwave Detector on Overpass Support Structure on I-4 Freeway Median

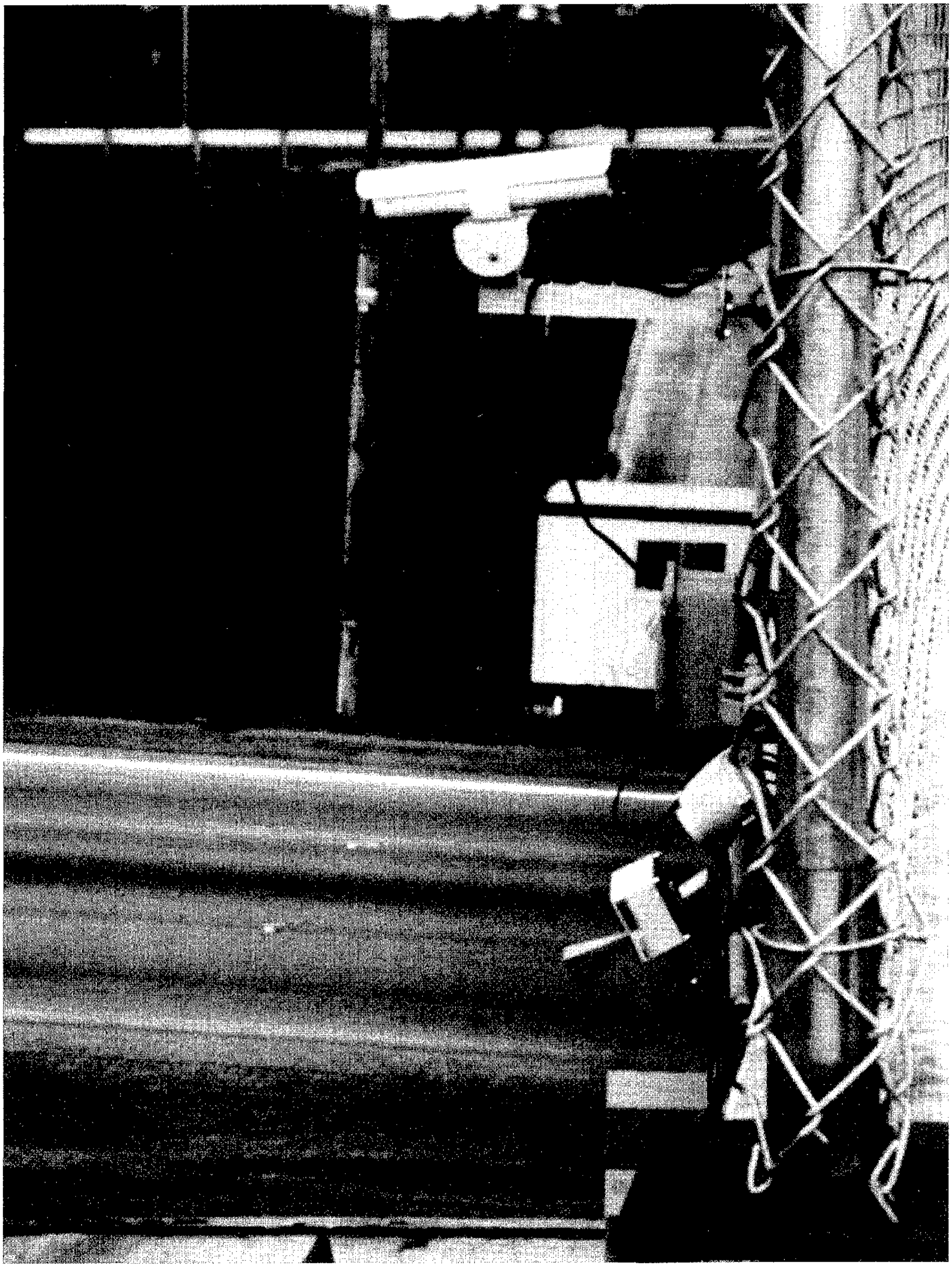


Figure 9-21. View Toward Eastbound I-4 Showing Side-Mounted RTMS Microwave Detector, Trailer, Video Camera, and Overhead Detectors

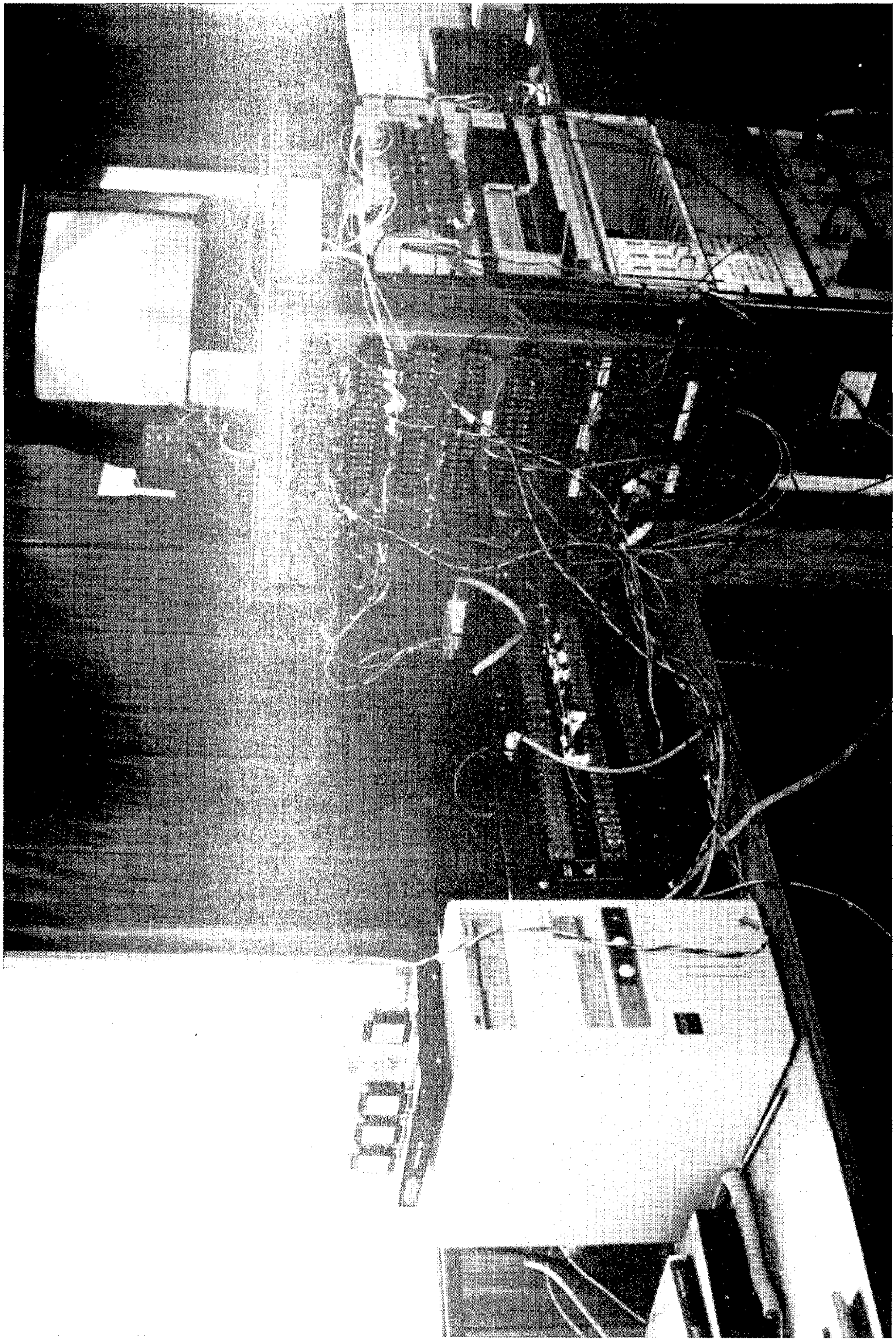


Figure 9-22. Data Recording Equipment as Configured at Orlando

Sitting on top of the 19-inch (483-mm) rack are a monitor that displays video of the traffic flow, the receiver for the self-powered magnetometer detectors, and a speaker that emits a tone when a vehicle passes over the magnetometers. Mounted in the rack, from top to bottom, are the auxiliary data logger that records an additional 24 optically isolated detector outputs, a computer-controlled VHS video recorder upon which the traffic flow is recorded, a Type 170 electronics chassis in which inductive loop electronics cards were inserted, and the Autoscope 2003 video image processor electronics. Output power to the detectors is available on the right side of the rack (not shown).

When the evaluation on the I-4 freeway was completed, the overhead detectors were moved to the SR 436 overpass and mounted behind the signs on a sign-bridge structure. Here they monitored westbound departing traffic on the SR 436 surface arterial as shown in Figures 9-23 and 9-24. The construction details for the overpass are given in Appendix I. The software in the 780D1000 laser radar required it to monitor approaching traffic in lane 1. A monochrome, 1/2-inch (12.7-mm) (6.4- x 4.8-mm) Charge Coupled Device (CCD) Cohu series 4910 camera with an 8- to 48-mm zoom lens was mounted 32 feet (9.8 m) above lane 2. RS-170 resolution was 580 horizontal TV lines by ≥ 350 vertical TV lines. Figure 9-25 shows the road surface as marked for video image processor calibration. Since SR 436 went over a bridge at the evaluation site, the self-powered magneto-meters were mounted under the road at the approximate center of the loops in lane 2 as indicated in Figure 9-26. The magnetometers were put into wooden boxes that were placed on bridge vertical support structures that were already located under the overpass.

An RTMS microwave radar was mounted on a specially erected pole on the south edge of the overpass across the road from the westbound lanes as in Figure 9-27. It was aimed at traffic (side viewing) in the stopbar region of the roadway. During its calibration, the video camera was repositioned to view traffic in the area observed by the RTMS. After calibration of the side-viewing unit, an interruption in the serial communication between the RTMS and the data logger occurred. As a result, no valid data were recorded for the side-looking unit at the Florida surface-street site. The locations of the loops, self-powered magnetometers, and Traffic Analysis System calibration zones are shown in Figure 9-28. The time of occurrence of the green phase signal at the SR 436 and I-4 off-ramp intersection was recorded using a relay data logger input.

9.3 PHOENIX EVALUATION SITE

The westbound I-10 freeway near Thirteenth Street in Phoenix was used as the detector evaluation site for regions representative of warm and hot dry climates. This site was used twice, once in Autumn 1993 and again during the Summer of 1994. Approaching traffic was observed by the overhead detector configuration shown in Figures 9-29 and 9-30 during the Autumn 1993 evaluation and by Figures 9-31 and 9-32 during the Summer 1994 evaluation. The AT&T acoustic array was designed to look downstream and view departing traffic as shown in Figure 9-33. The AT&T array and Sumitomo IDET-100 video image processor were evaluated in the Autumn 1993 period. The EVA 2000 video image processor was evaluated during the Summer 1994 period. A side-mounted RTMS microwave radar, shown in Figure 9-34, was installed in the shoulder area on a wooden pole aligned with the first inductive loop.

The stub antenna that received the signals from the self-powered magnetometers installed in the center of the inductive loops in lane 2 was also mounted on this pole. We found that the larger, higher gain antenna was not needed since the trailer containing the magnetometer signal receiver was relatively close to the magnetometers. The higher gain antenna also appeared to pick up more of the noise generated by the PCs in the trailer, even though it was attached to the outside of the trailer. The noise prevented the receiver from generating tones corresponding to the signals transmitted by the magnetometers. Another remedy that eliminated most of the external noise from the magnetometer receiver was to connect the receiver to its own AC voltage circuit in the trailer.

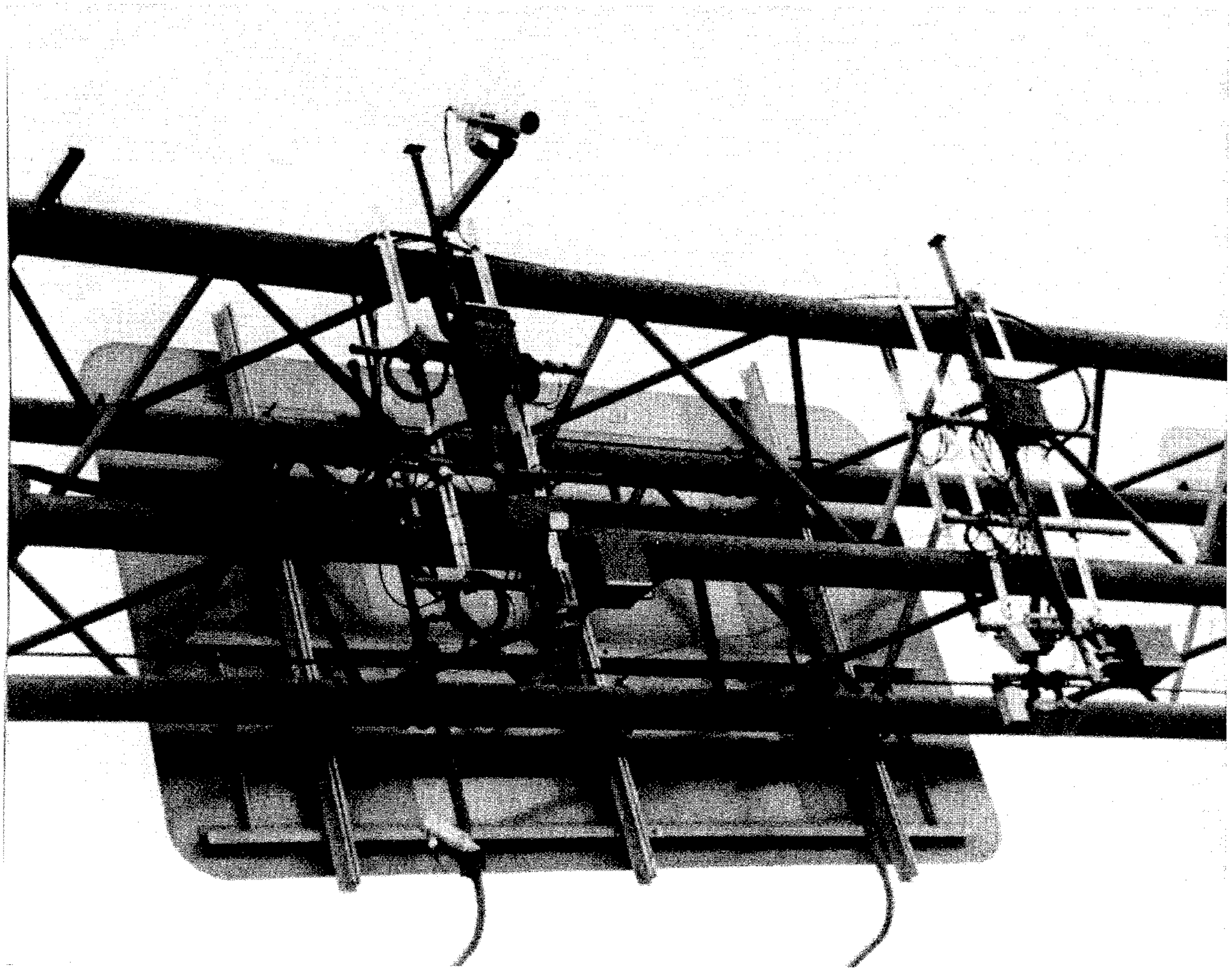
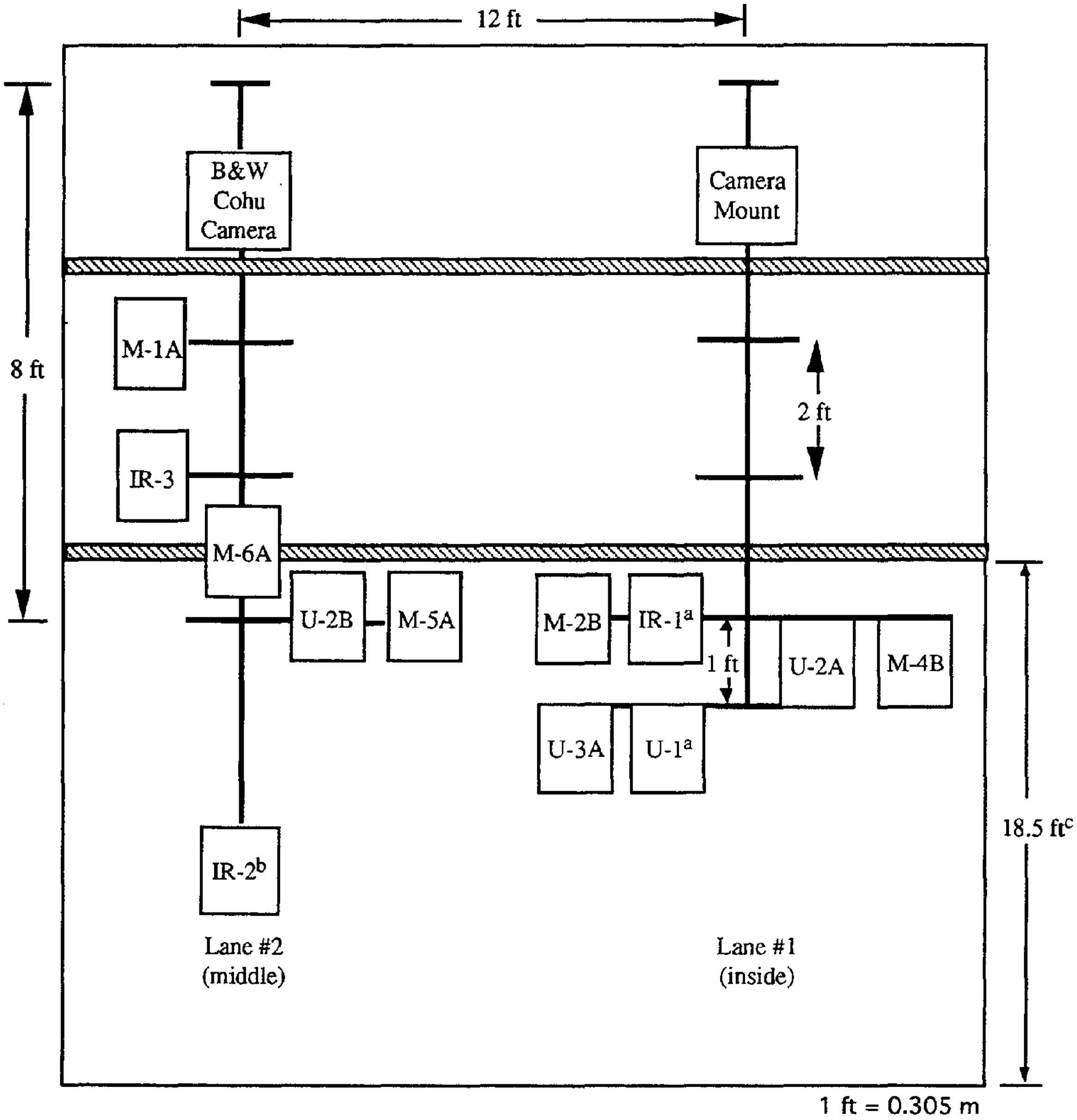


Figure 9-23. Detectors Over Westbound Lanes on SR 436 Surface-Street Site North of Orlando



a. IR-1 and U-1 face approaching traffic. All other detectors face departing traffic.

b. IR-2 mounted on sign-bridge light fixture above lane 2, looking at traffic in lane 1. M-6A mounted to sign-bridge span.

c. Measured from bottom of sign-bridge to high point of roadway.

▨ - Existing sign-bridge span.

Figure 9-24. SR 436 Overhead Detector Layout

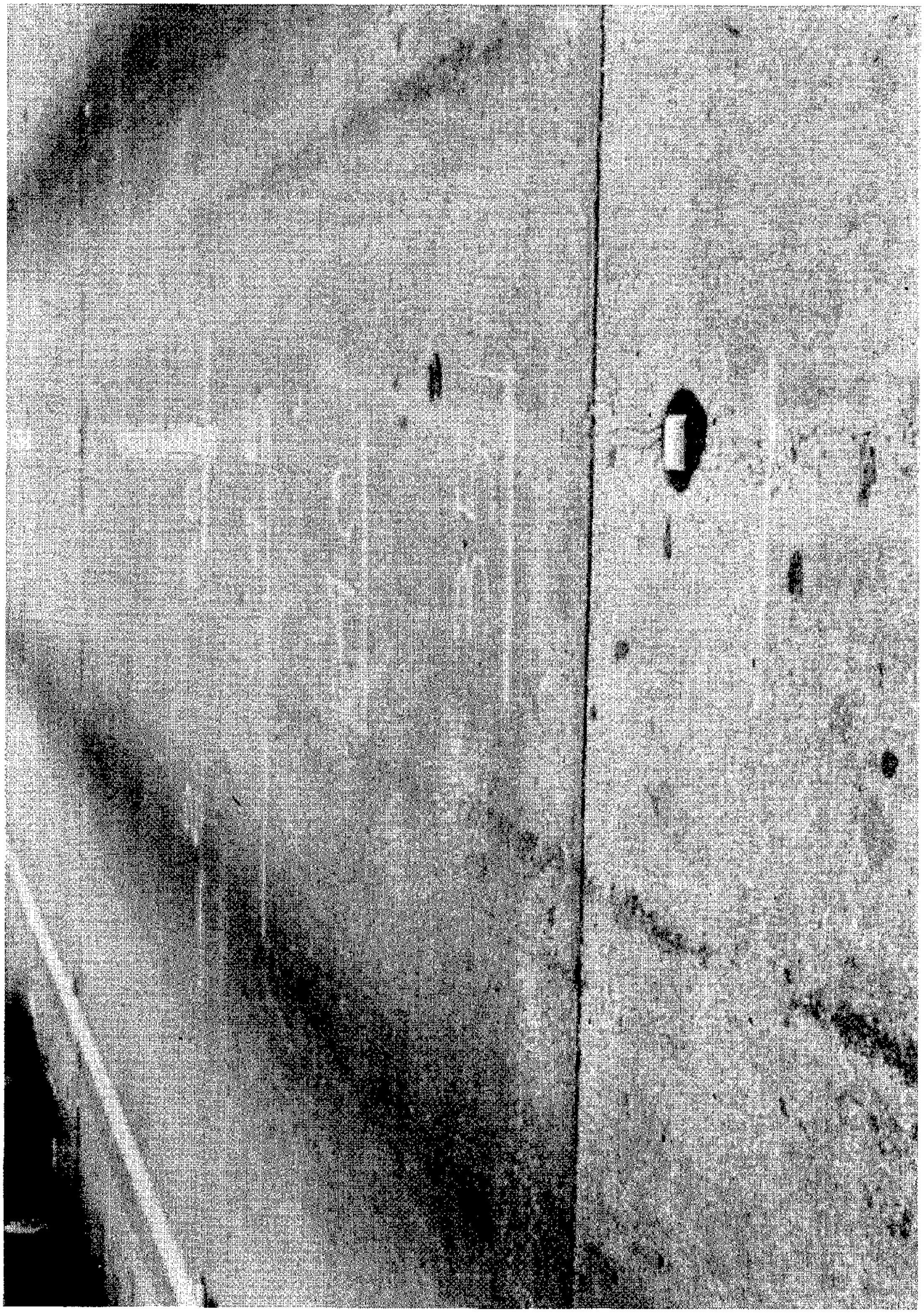


Figure 9-25. SR 436 Marked With Calibration Distances for Video Image Processors

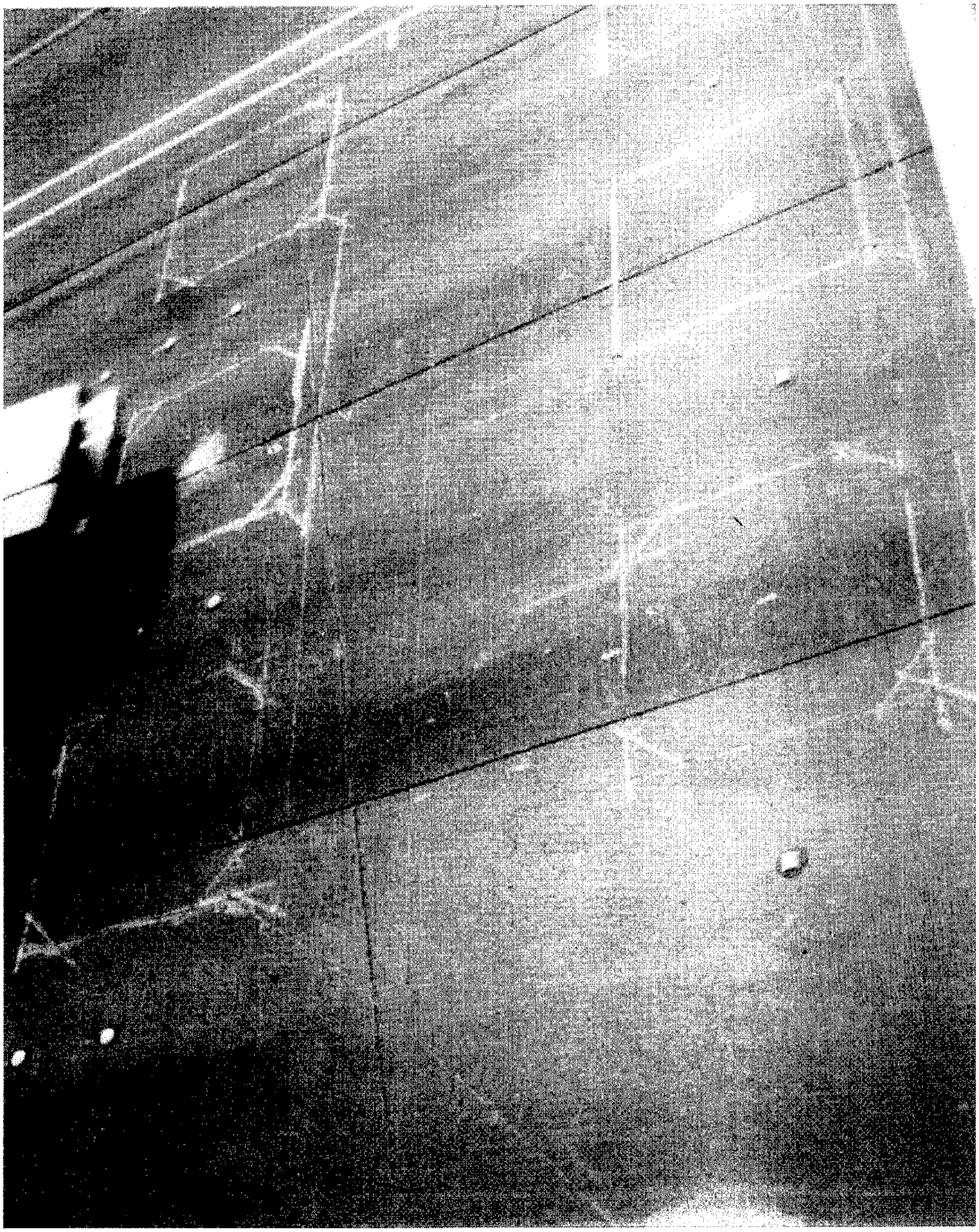


Figure 9-26. SR 436 Road Surface Showing Inductive Loop and Self-Powered Magnetometer Locations

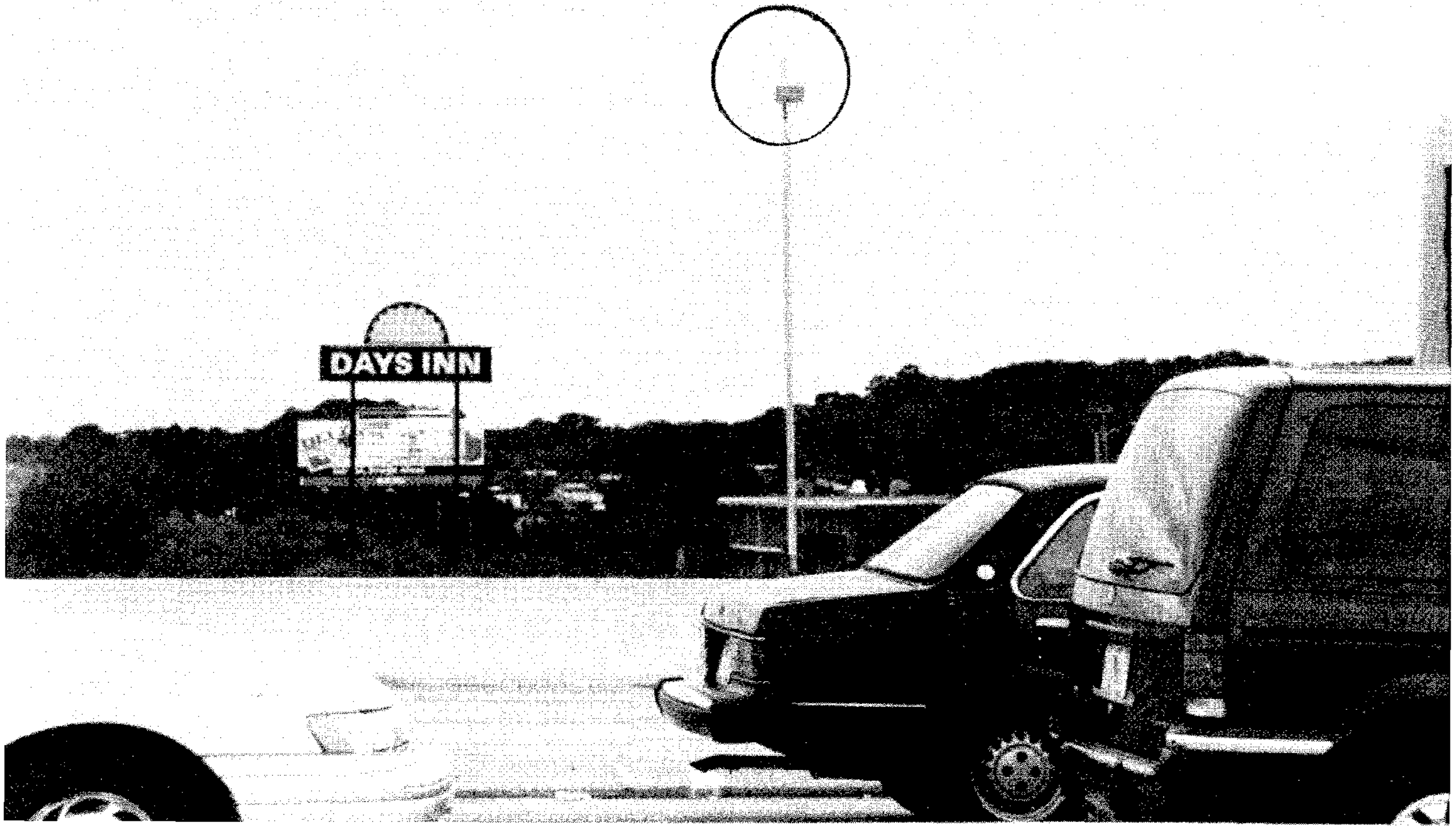
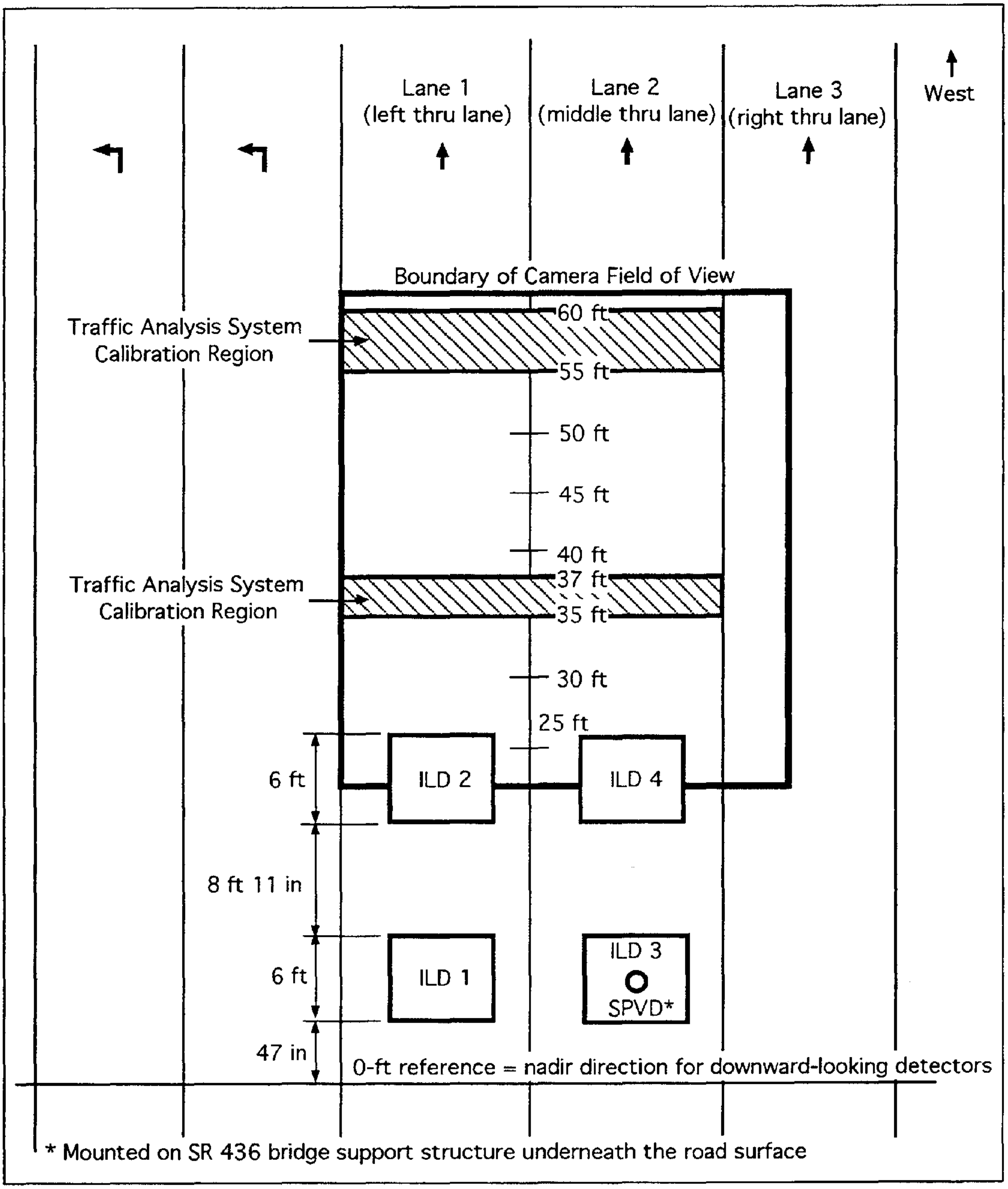


Figure 9-27. Side-Mounted RTMS Microwave Detector on SR 436



1 in = 25.4 mm
1 ft = 0.305 m

Figure 9-28. Location of Inductive Loop Detectors, Self-Powered Magnetometers, Traffic Analysis System Calibration Regions, and Camera Field of View on SR 436

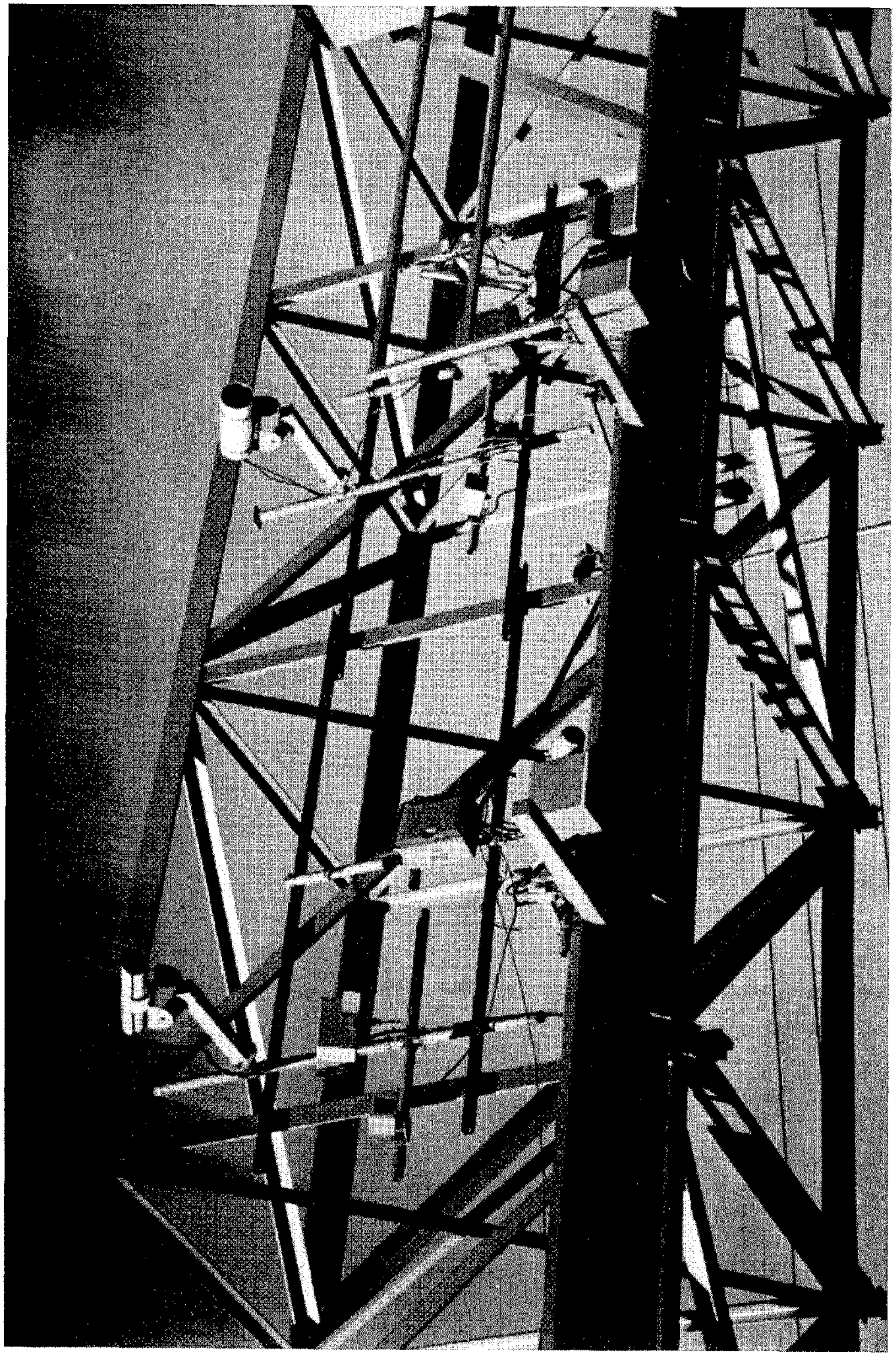
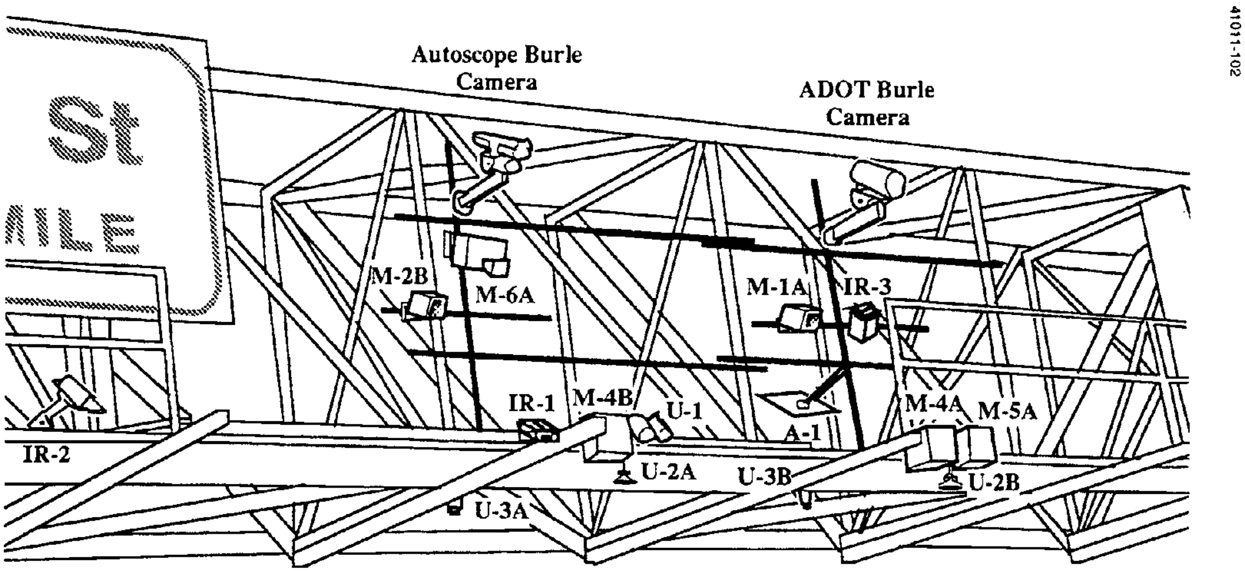


Figure 9-29. Detectors Over Westbound Lanes of Phoenix I-10 Freeway Site (Autumn 1993)

Overhead Detector Array for Phoenix I-10 Test Site
November-December 1993



U-1	SDU-200
U-2	SDU-300
U-3	TC-30C
M-1	TC-20
M-2	TC-26
M-4	TDN-30
M-5	TDW-10
M-6	RTMS
IR-1	780D1000
IR-2	842
IR-3	833
A-1	SmartSonic TSS-1

Figure 9-30. I-10 Overhead Detector Layout (Autumn 1993)

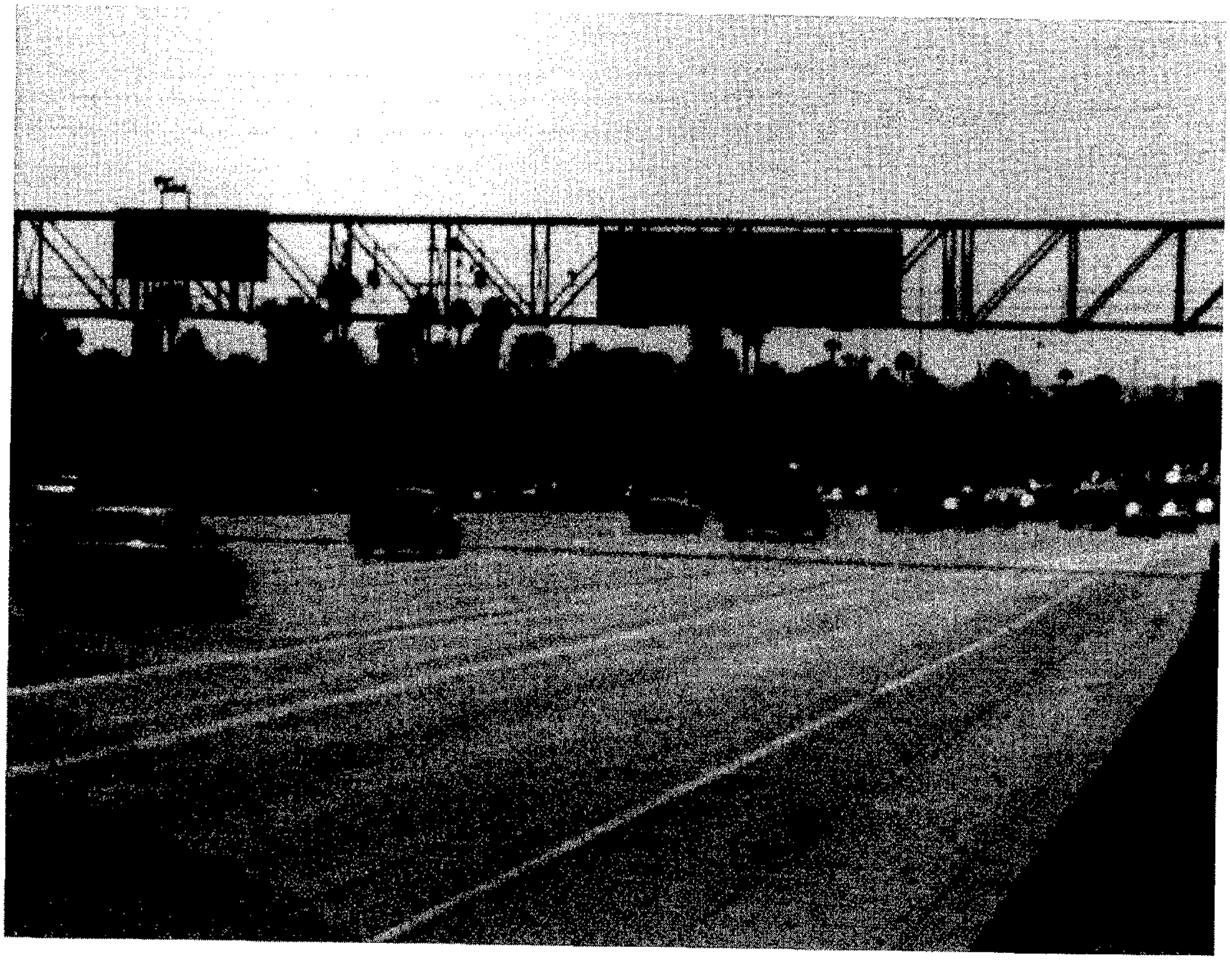
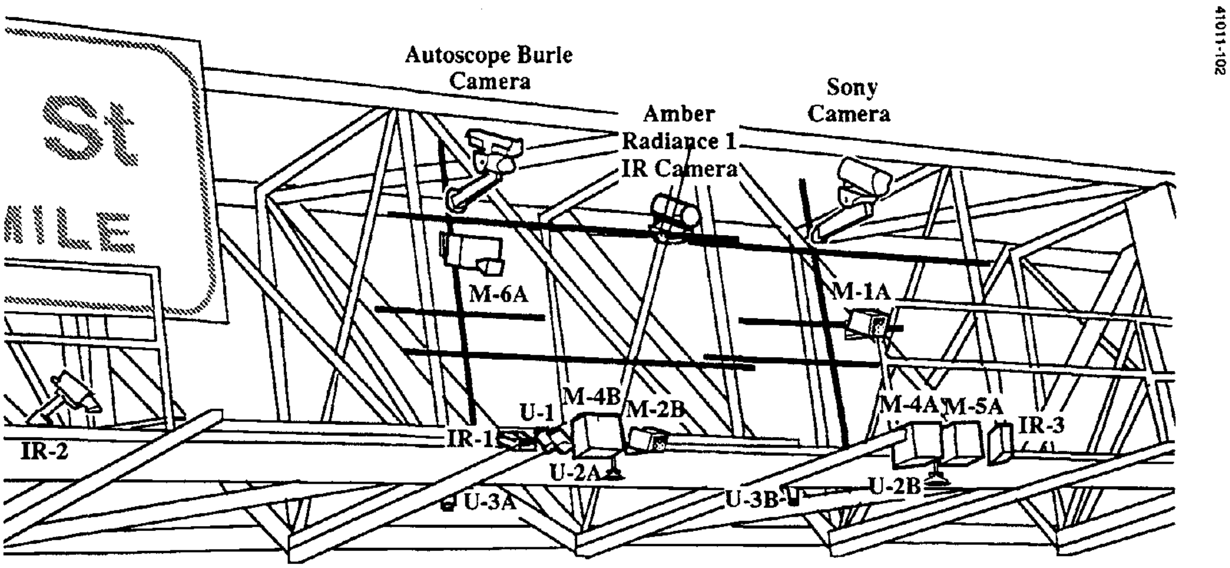


Figure 9-31. Detectors Over Westbound Lane of Phoenix I-10 Freeway Site (Summer 1994)

Overhead Detector Array for Phoenix I-10 Test Site
July-August 1994



U-1	SDU-200
U-2	SDU-300
U-3	TC-30C
M-1	TC-20
M-2	TC-26
M-4	TDN-30
M-5	TDW-10
M-6	RTMS
IR-1	780D1000
IR-2	842
IR-3	833

Figure 9-32. I-10 Overhead Detector Layout (Summer 1994)

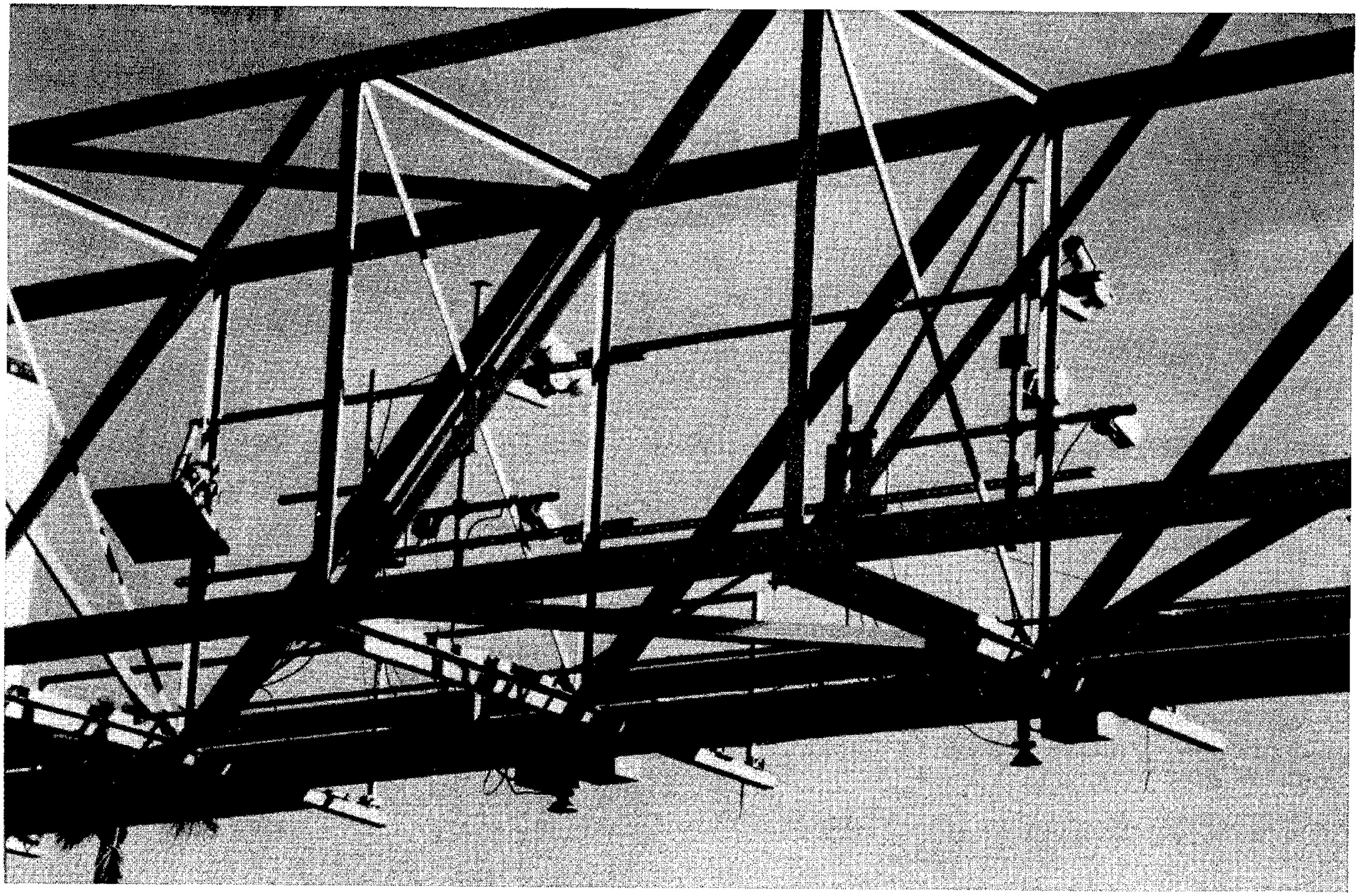


Figure 9-33. Overhead Detectors at I-10 Freeway Showing AT&T Acoustic Array Monitoring Departing Traffic (Autumn 1993)

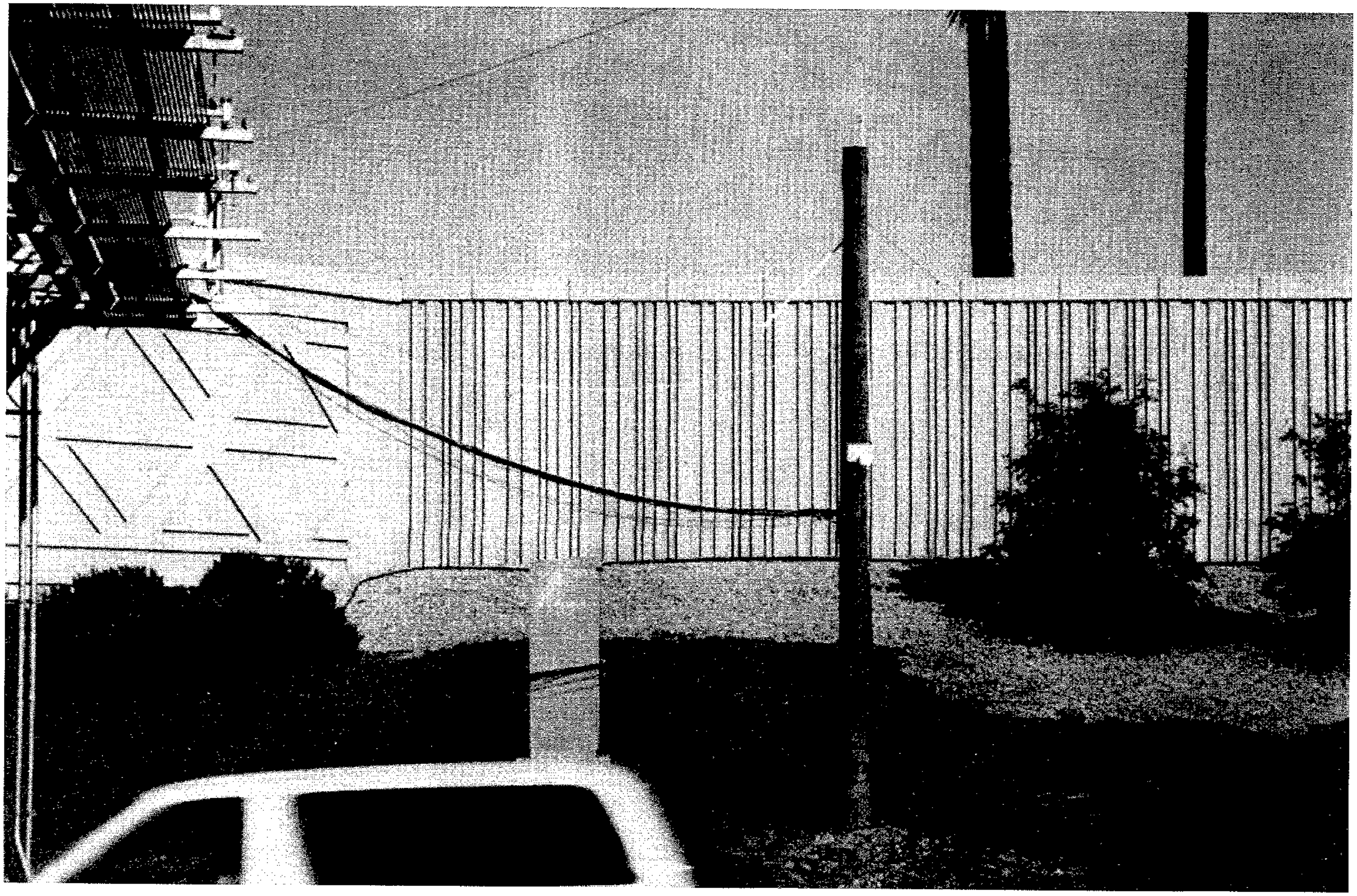


Figure 9-34. I-10 Freeway Site Showing Side-Mounted RTMS Microwave Detector

Locations of in-ground detectors and video image processor calibration zones were measured from the poles that support the sign structure, as shown in Figures 9-35 and 9-36 for the Autumn 1993 evaluation and in Figure 9-37 for the Summer 1994 evaluation. The downward-looking detectors observed traffic directly below the sign structure. The others, with the exception of the acoustic array and the Eltec 833, observed approaching traffic in the vicinity of the inductive loops. The acoustic array was designed to detect departing traffic and was, therefore, aimed toward the other side of the sign structure, observing traffic in lane 2 (middle through-traffic lane).

The trailer was located at the far edge of the shoulder for the westbound lanes at the top of an incline as shown in Figure 9-38. The cables were run out of the trailer through an opening in the bottom, along the ground and to the top of the wooden pole on which the side-looking RTMS detector was mounted, and then over to the sign-bridge structure.

The sign structure was accessed with a ladder that led to a hatch in the walkway. The detectors were attached to the walkway, located 19 feet 8 inches (6.0 m) above the freeway, or to vertical and horizontal elements on the structure with an assortment of clamps. The walkway provided a relatively easy way to aim the overhead detectors at the desired traffic lanes. The heights of the detectors above the top surface of the walkway are shown in Table 9-3.

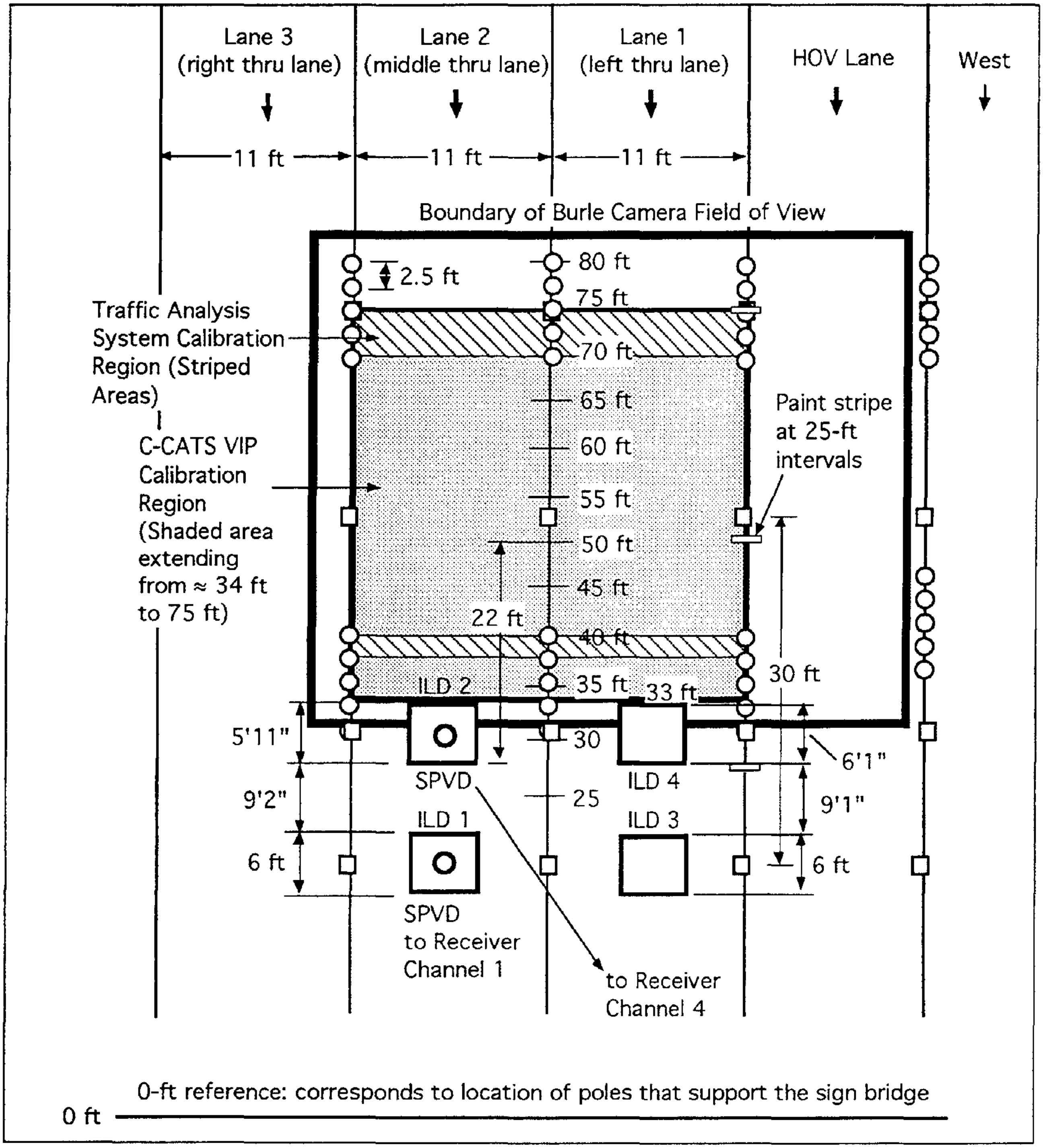
Table 9-3. Heights of Detectors Above Walkway* at Phoenix 1993 Evaluation

Detector	Symbol	Height Above Walkway
SDU-200 (RDU-101)	U-1	36 inches
SDU-300	U-2A, U-2B	8 inches to center of horn aperture
TC-20	M-1A	37-3/4 inches to bottom of detector
TDN-30	M-4A, M-4B	0 inch
TDW-10	M-5A	0 inch
RTMS-X1	M-6A	50 inches
780D1000 (Autosense I)	IR-1	0 inch
842	IR-2	6 inches
833	IR-3	39 inches to bottom of detector 36 inches to center of lens
SmartSonic TSS-1	A-1	37 inches to bottom of array 43 inches to center of array

* Walkway is 19 feet 8 inches above freeway surface

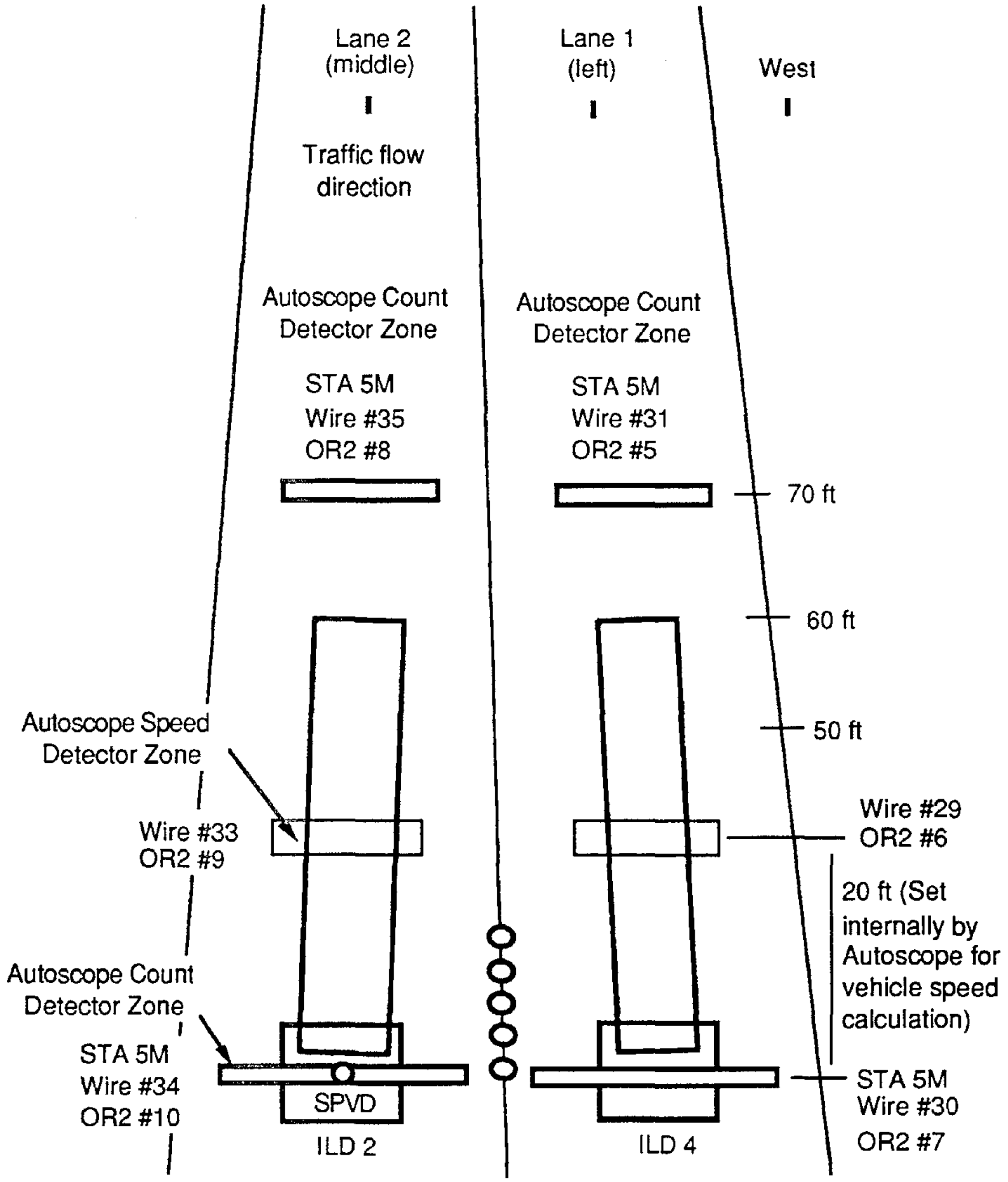
1 in = 25.4 mm
1 ft = 0.305 m

Two video cameras were used in both the Phoenix and Tucson locations, one for the Autoscope video image processor and one for the other image processors. The Autoscope employed a specially modified camera to provide imagery features that maximized its performance. It was mounted 26-1/4 feet (8.0 m) above the freeway road surface. Since the Autoscope manufacturer believed that his camera would enhance the performance of the other image processors, we obtained a second camera from the Arizona Department of Transportation for the Autumn 1993 runs that provided imagery to the rest of the image processors. This camera was a Burle Model TC301 with a 12.5-mm, f/1.4 lens. It was also mounted 26-1/4 feet (8.0 m) above the road surface and covered the same viewing area as the Autoscope camera. In Summer 1994, the camera was supplied by Sumitomo and was the model recommended for use with the IDET-100 video image processor. Its characteristics were: 1/2-inch (12.7-mm) CCD format (6.2 mm x 4.6 mm), auto iris on, Automatic Gain Control (AGC) off, and 525 useful Electronic



1 in = 25.4 mm
1 ft = 0.305 m

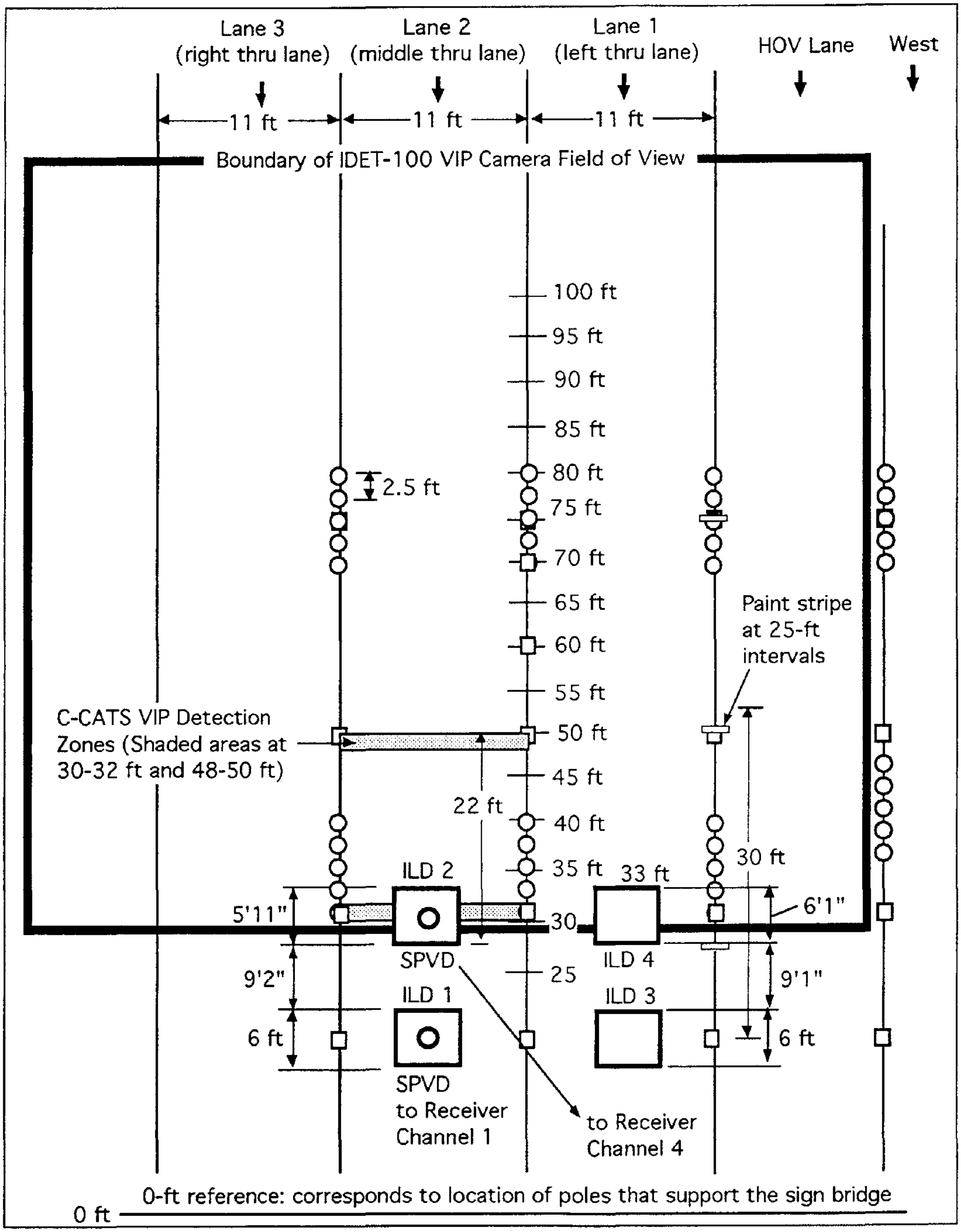
Figure 9-35. Location of Inductive Loop Detectors, Self-Powered Magnetometers, Traffic Analysis System and CCATS Calibration Regions, and Burle Camera Field of View on I-10 (Autumn 1993)



0-ft reference: corresponds to location of poles that support the sign bridge
SPVD=self-powered vehicle detector
OR2 = rack-mounted chassis that contains optically isolated detector inputs 17-40
Autoscope software version 3.23

1 ft = 0.305 m

Figure 9-36. Location of Autoscope Detection Zones on I-10 (Autumn 1993 and Summer 1994)



1 in = 25.4 mm
1 ft = 0.305 m

Figure 9-37. Location of In-Ground Detectors, CCATS Detection Zones, and IDET-100 Camera Field of View on I-10 (Summer 1994)

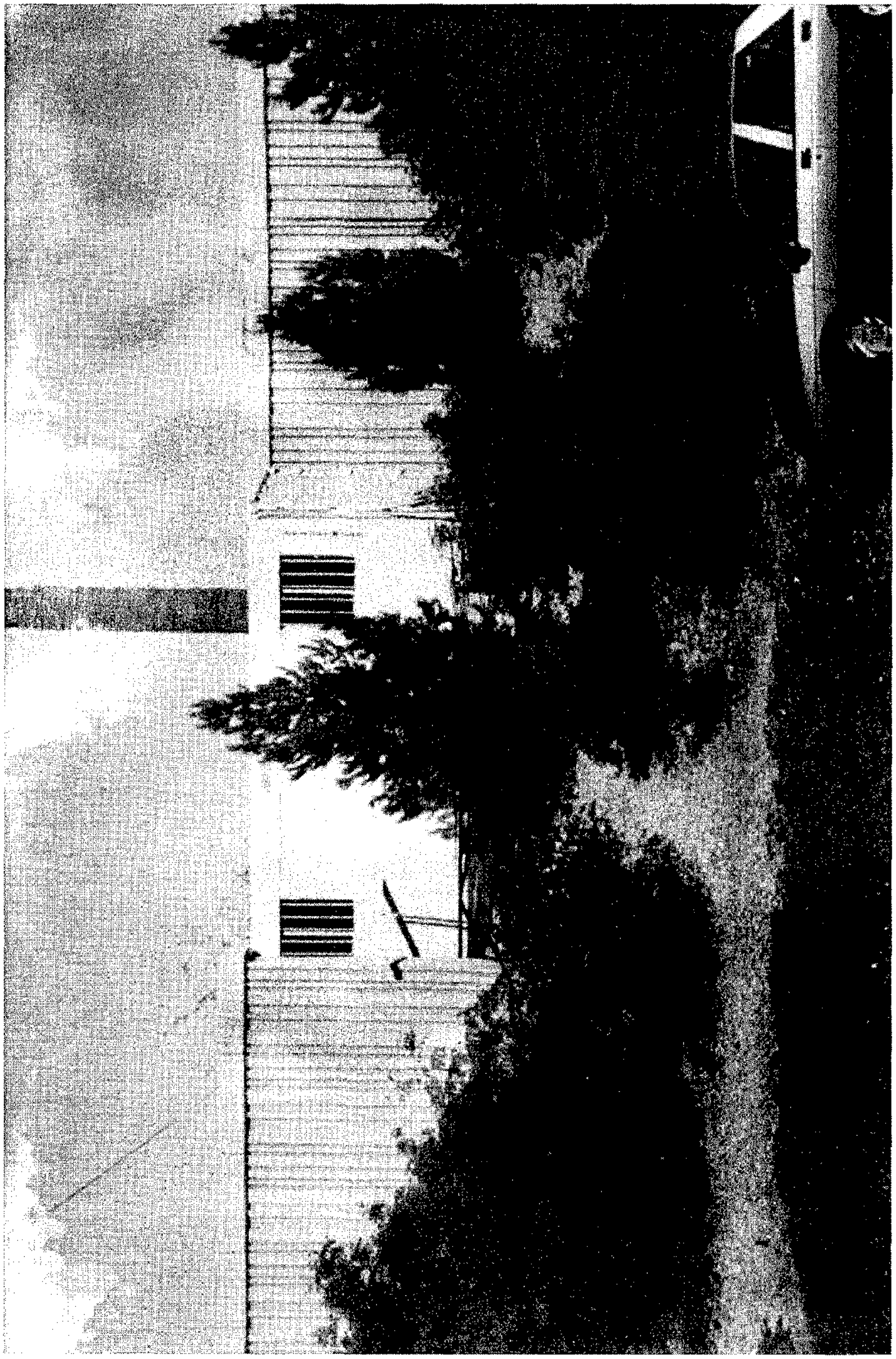


Figure 9-38. Data Acquisition Trailer on I-10

Industry Association (EIA) lines. During the Summer 1994 evaluation, an infrared camera was obtained from Amber and was used to record concurrent imagery of the traffic flow in the 8- to 12-μm region of the infrared spectrum on a third video recorder. However, this infrared video was not frame or time synchronized with the other detector data recorded by the data logger. (The data logger was designed to operate with two VCRs only.) Because of lens focal length restrictions, the area monitored by the Amber camera was several hundred feet upstream of the sign bridge and did not coincide with the viewing area of the other detectors.

The equipment rack as configured for Phoenix in Autumn 1993 is shown in Figure 9-39. On the top is one of the monitors, the distribution amplifier for the video image processors except Autoscope, and the CCATS-VIP 2 video image processor. Mounted in the top of the rack is the Autoscope 2003. Below it are the two PC-controlled VCRs, the Type 170 interface that holds the inductive loop detector amplifier electronics cards and the AT&T SmartSonics card, and the power supply modules. Near the bottom of the rack is the auxiliary data logger that supports up to 24 optically isolated detector inputs. Mounted on the left side of the rack is the panel that accepts the outputs from the detectors. A connection panel on the right side of the rack, shown in Figure 9-40, supplies input power to the detectors.

Figure 9-41 shows the table on which were placed the data logger, keyboard, 386 PC and computer monitor, the video monitor for the Autoscope camera, and the Puma 88 disk drive. The DigiChannel interface for the RS-232 detector serial outputs is on top of the PC. The electronics for the Sumitomo SDU-200 (RDU-101) and SDU-300 ultrasonic detectors and IDET-100 video image processor were located under the table. The Traffic Analysis System (TAS) video image processor is next to the table with the laptop PC.

The equipment rack as configured for Phoenix in Summer 1994 is shown in Figure 9-42. The layout of the equipment is similar to that used before. On the left, above a monitor, is the EVA 2000 video image processor. The TAS video image processor is to the right of the rack on its shipping case. Unfortunately, it was not operational during the Summer 1994 Phoenix evaluation because it was not shipped with the configuration needed for freeway traffic data collection. The table with the rest of the electronics is shown in Figure 9-43. The self-powered magnetometer signal receivers and Detector Systems 613-SS inductive loop detector amplifiers are on the right side of the table. The data logger, computer, and monitor are to their left. The electronics for the Sumitomo ultrasonic detectors and the uninterruptable power supply are on the floor of the trailer as shown in Figure 9-44.

In the Phoenix 1994 evaluation, the Detector Systems Model 613-SS inductive loop detectors were used to aid in ground truth vehicle speed measurement. Used in pulse mode, they provided a solid-state optically isolated transistor closure each time a vehicle passed over the loops. In addition, a probe vehicle equipped with the Loop Comm Model 600A vehicle transmitter generated a pulse output on another wire each time it passed over one of the loops connected to a 613-SS detector. By mounting the transducer on the bumper of our probe vehicle, as shown in Figure 9-45, vehicle speed ground truth data were obtained by noting the time, lane number, and speed from the vehicle's speed indicator when the probe vehicle passed over a loop in a particular lane. This procedure was repeated several times during a run for each monitored traffic lane.

9.4 TUCSON EVALUATION SITE

The Tucson surface-street evaluation site was located at the southwest corner of Oracle Road and Auto Mall Drive, across the street from the Tucson Mall. All three southbound lanes were instrumented with loops and the right and center lanes (lane 3 and lane 2, respectively) had the overhead detectors installed above them as shown in Figures 9-46 and 9-47. The Autoscope and Sumitomo IDET-100 VIP video cameras were used in Tucson. The field of view for the IDET-100 camera (also used for CCATS) is shown in Figure 9-48, along with the locations of the other detectors. The Autoscope, CCATS, and Grumman imaging infrared calibration areas

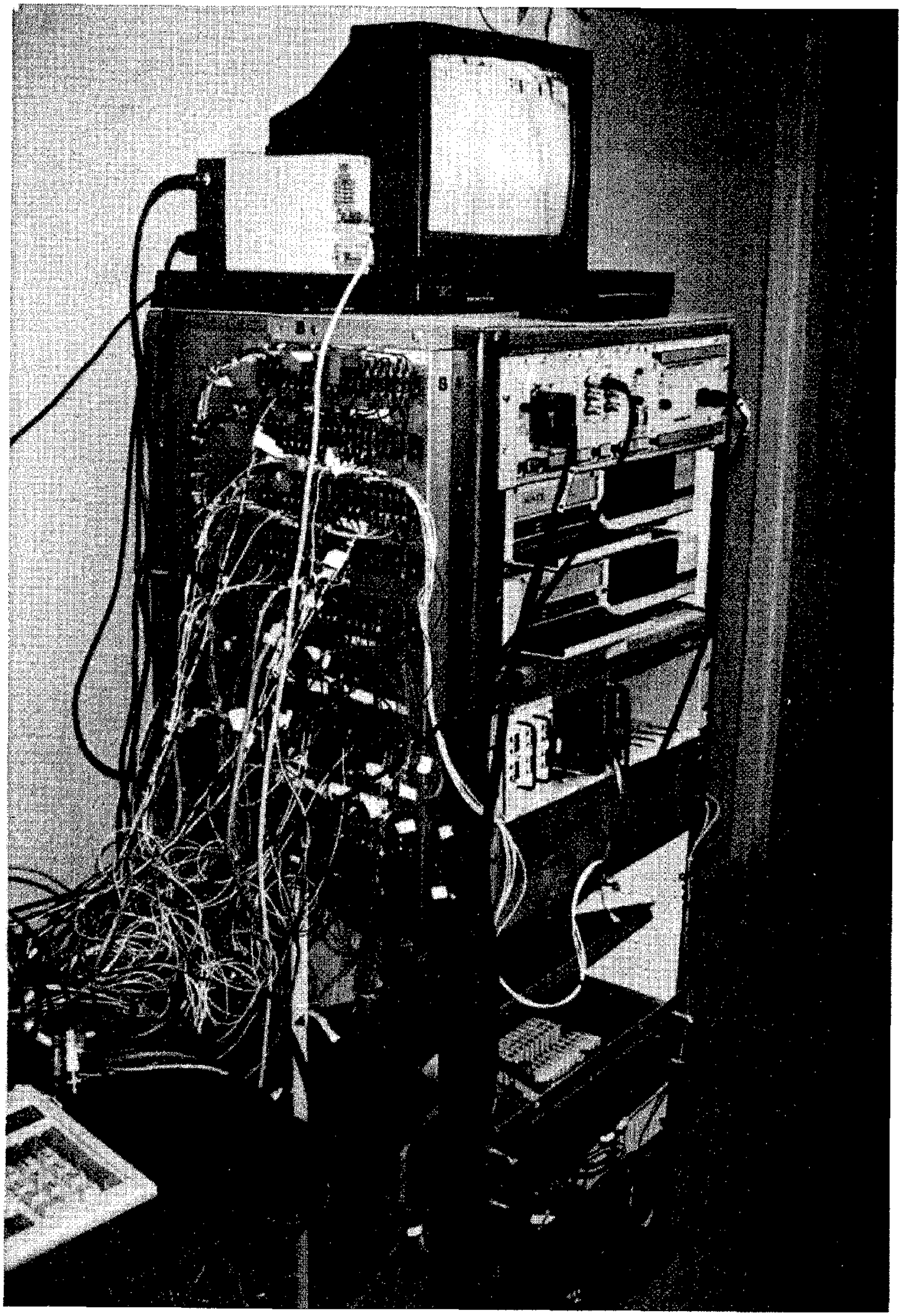


Figure 9-39. Data Recording Equipment Configured for I-10 (Autumn 1993)

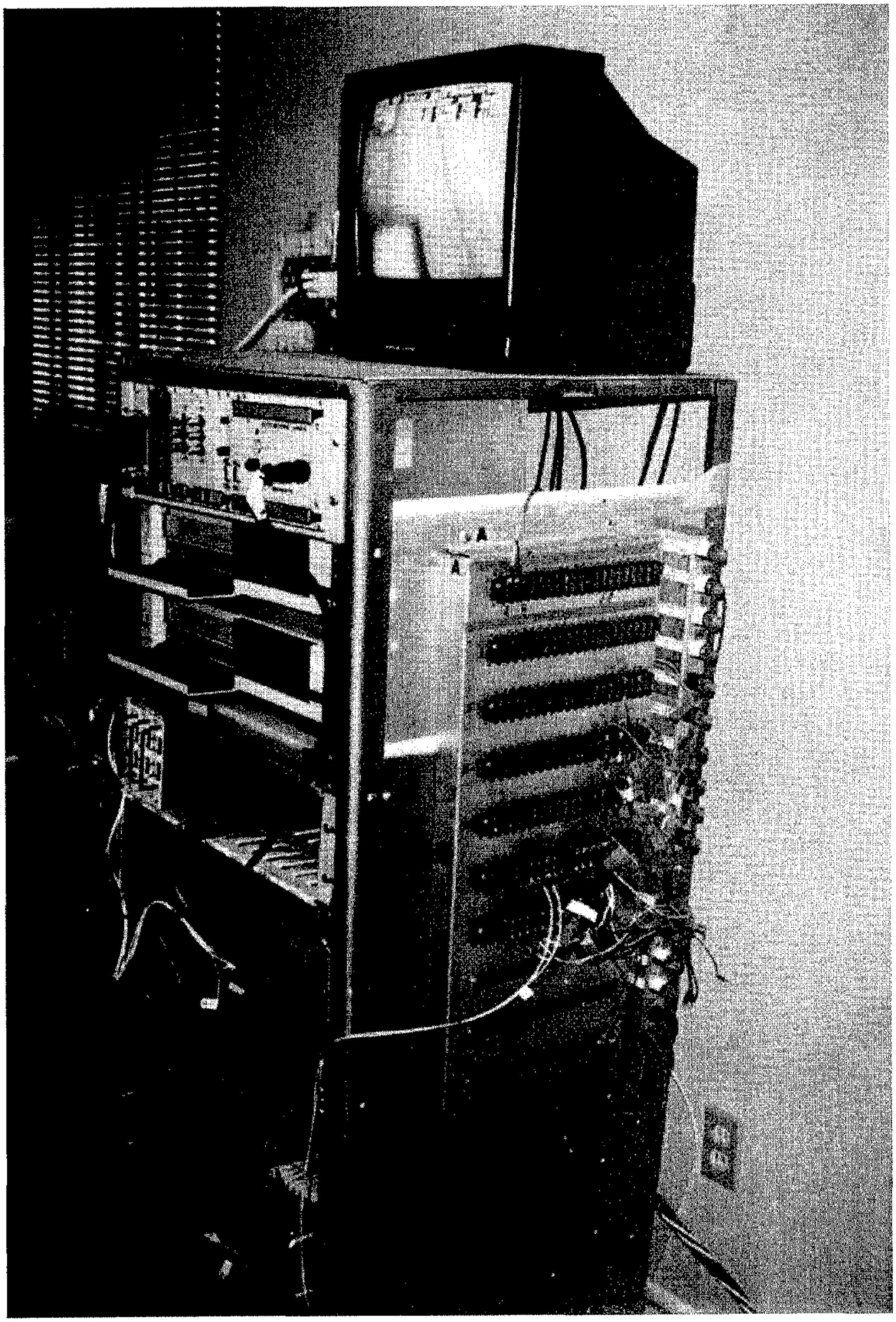


Figure 9-40. Data Recording Equipment Showing Detector Power Panel

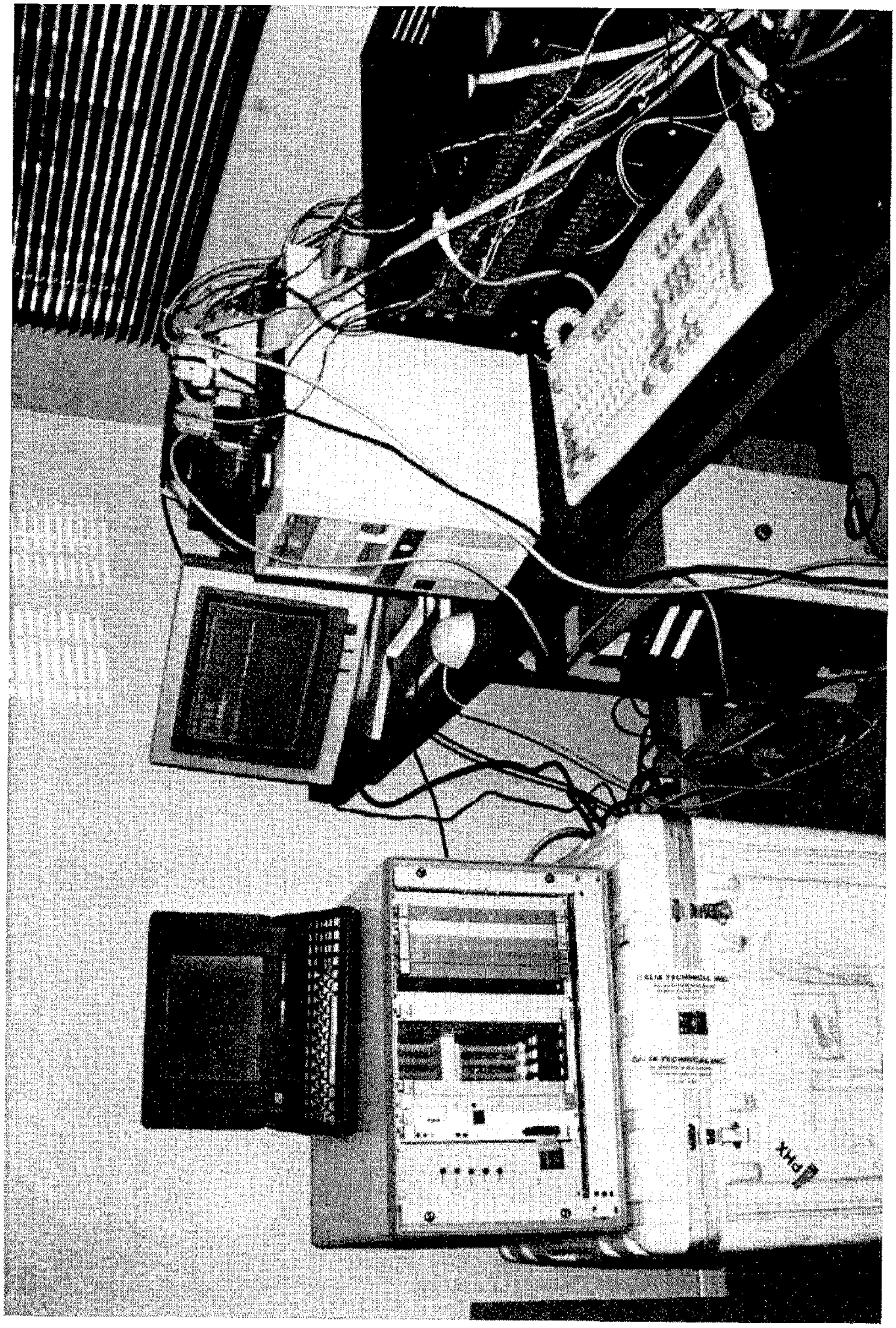


Figure 9-41. Data Logger, Computer, and Traffic Analysis System Video Image Processor As Used on I-10 (Autumn 1993)

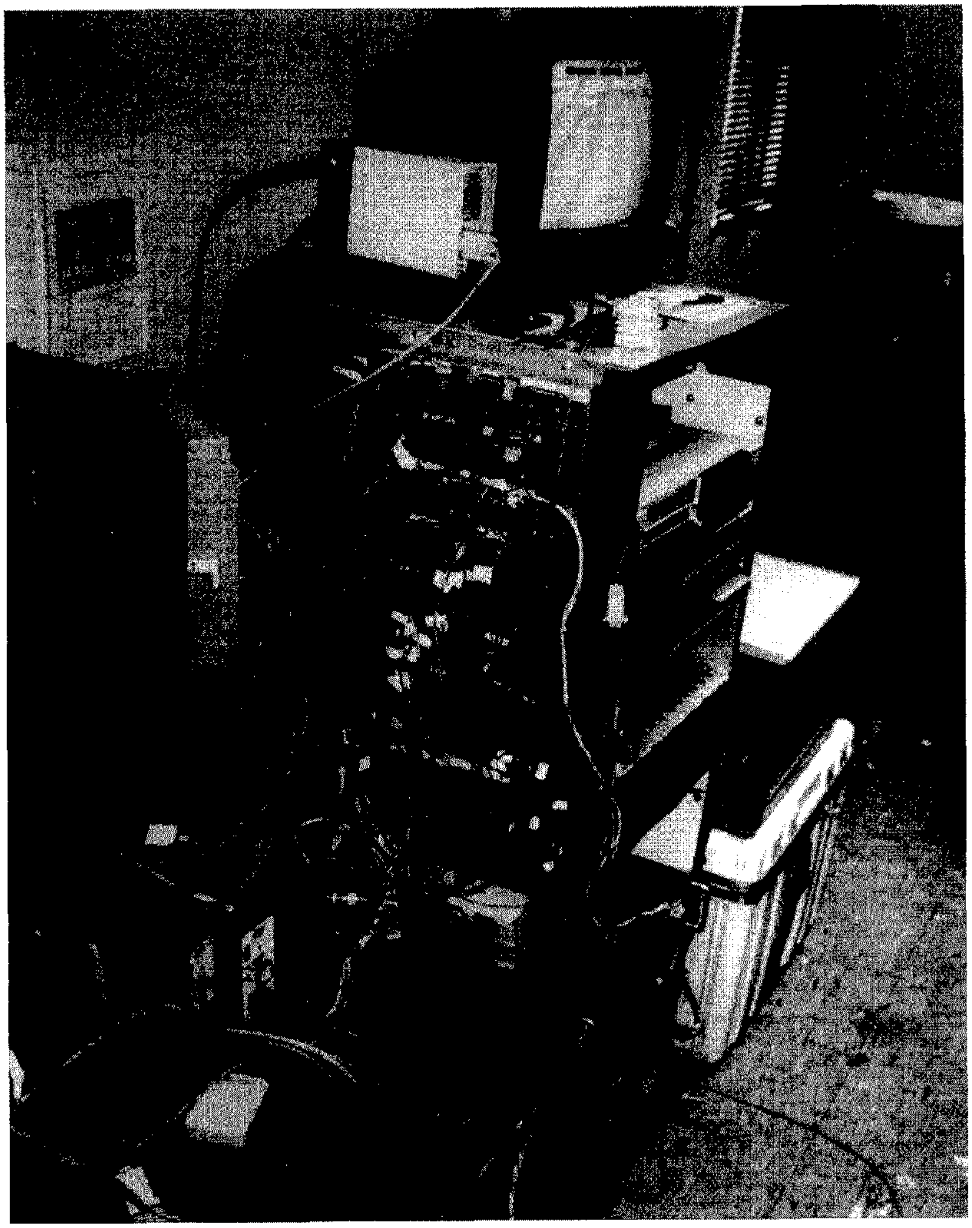


Figure 9-42. Data Recording Equipment Configured for I-10 (Summer 1994)

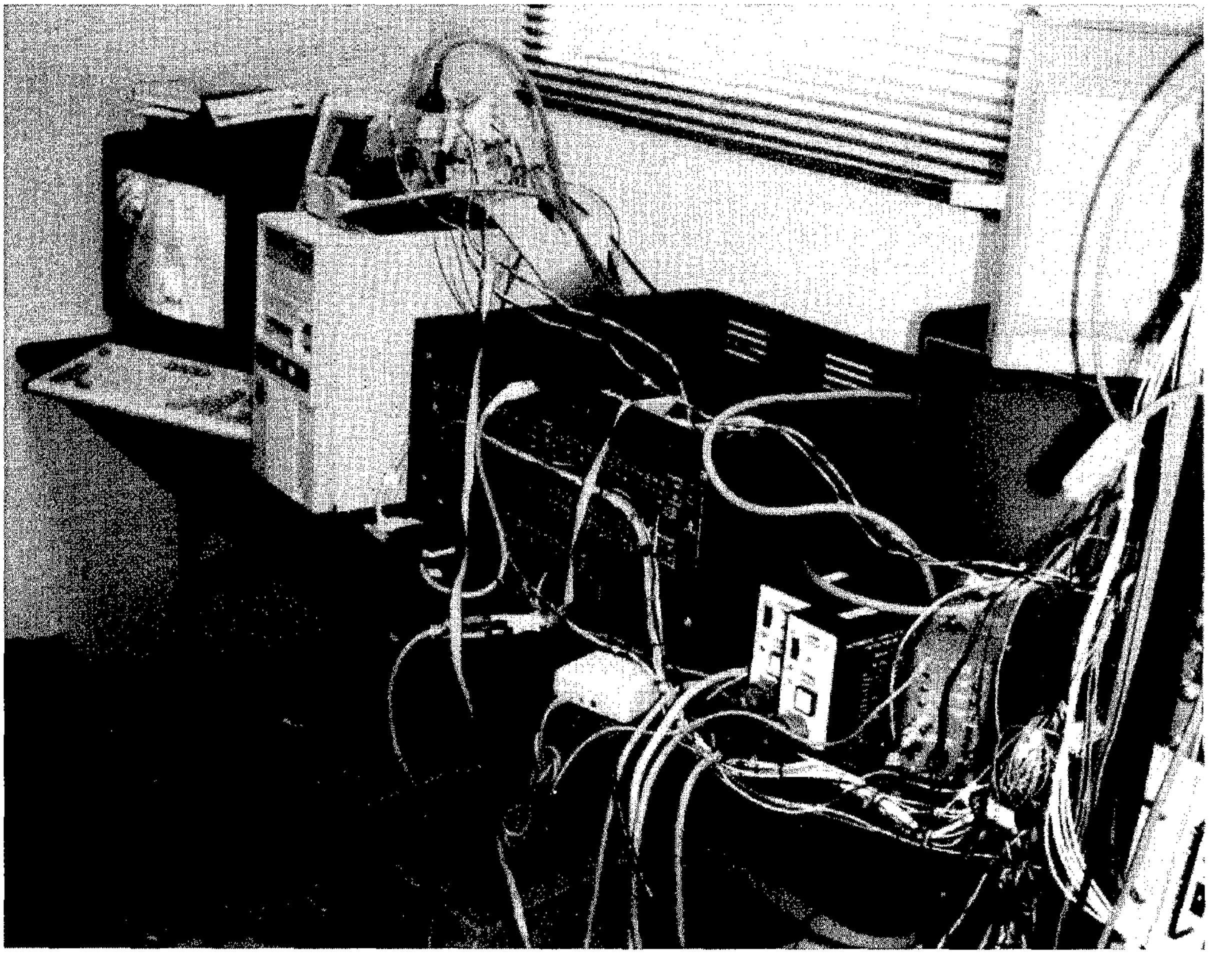


Figure 9-43. Data Logger, Computer, and Detectors as Configured for I-10 (Summer 1994)

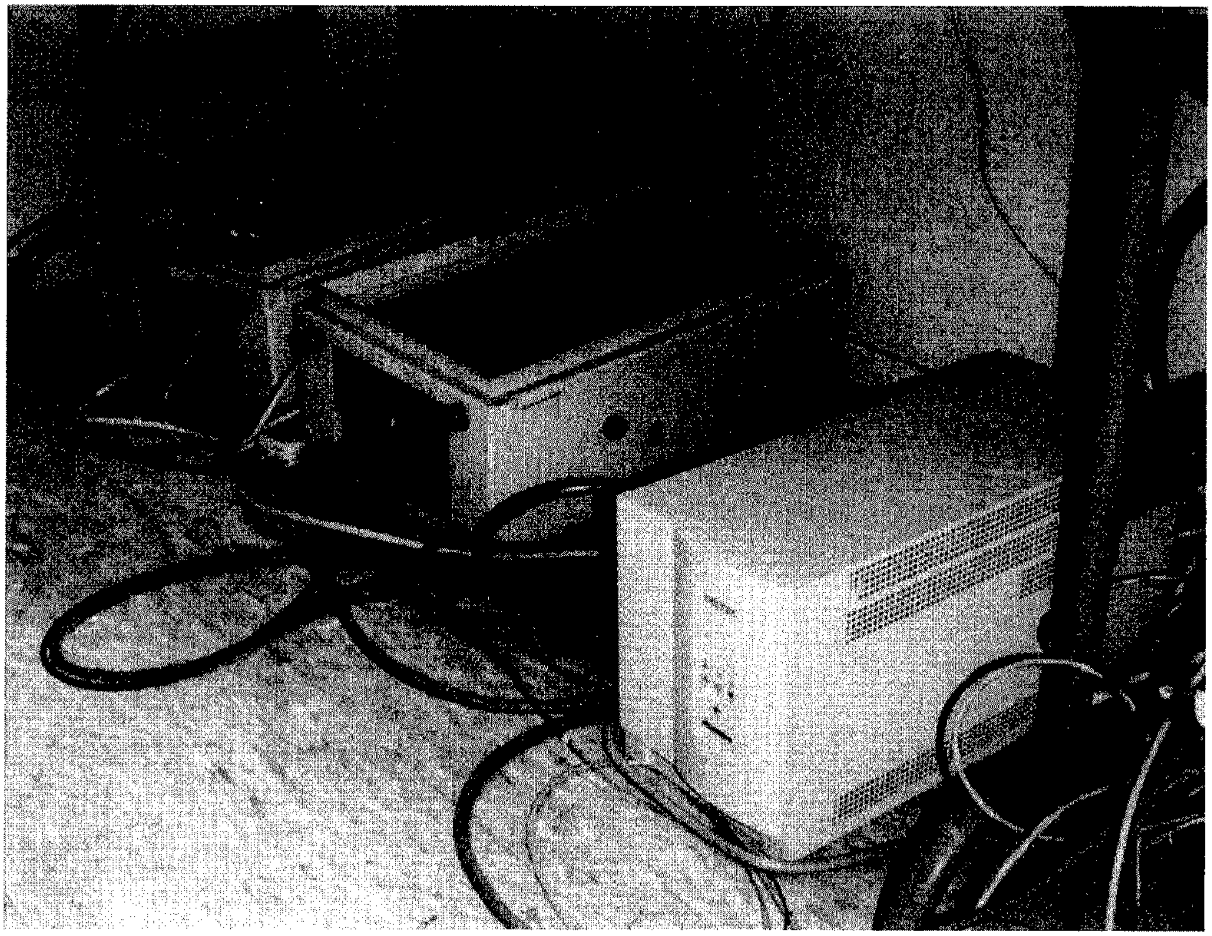


Figure 9-44. Sumitomo Ultrasonic Detector Electronics and Uninterruptable Power Supply in I-10 Trailer (Summer 1994)

Figure 9-45. Detector Systems LoopComm Transducer Installed on Front Bumper of Probe Vehicle

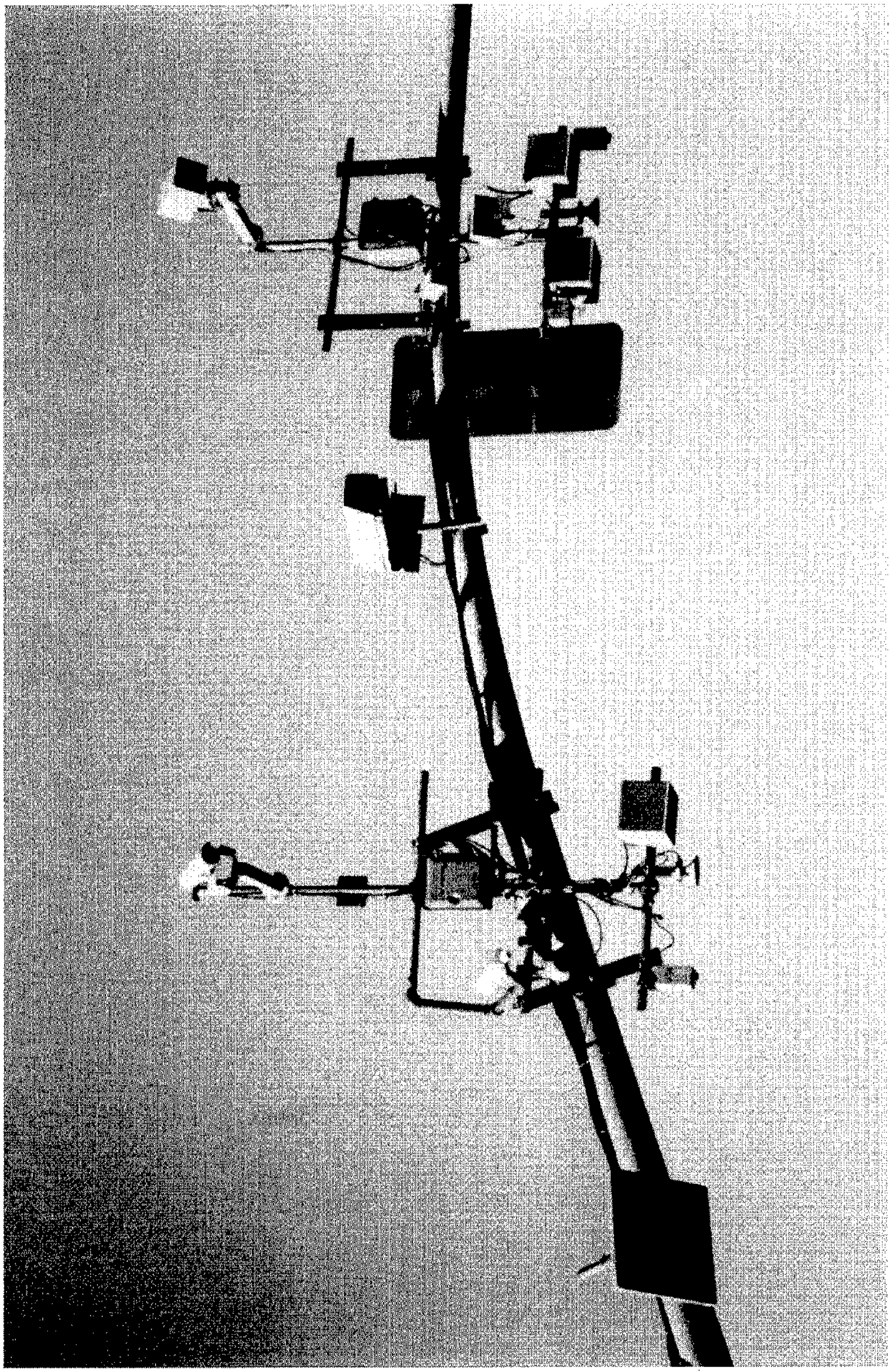
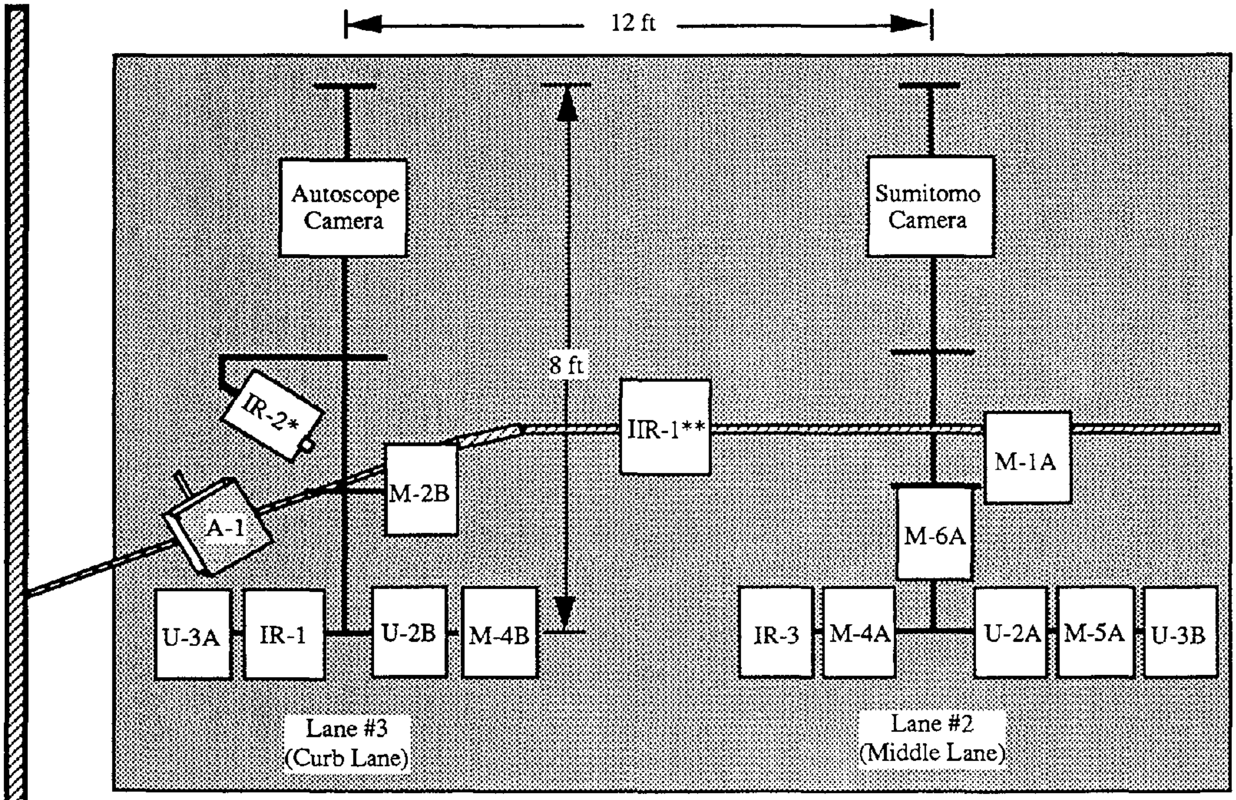


Figure 9-46. Detectors Over Southbound Lanes of Tucson Oracle Road Surface-Street Site



U-1	SDU-200 (RDU-101)
U-2	SDU-300
U-3	TC-30C
M-1	TC-20
M-2	TC-26
M-4	TDN-30
M-5	TDW-10
M-6	RTMS
IR-1	780D1000
IR-2	842
IR-3	833
IIR-1	Cat Eye
A-1	SmartSonic TSS-1

The "A" and "B" designations are used when more than one unit of the same detector model are mounted.

┼ represents detector-supporting pipe structure.

▨ represents traffic signal pole and mast arm.

Detectors monitor downstream traffic except for M-1A.

* IR-2 is mounted above lane 3, but monitors traffic in lane 2 in a side-looking configuration.

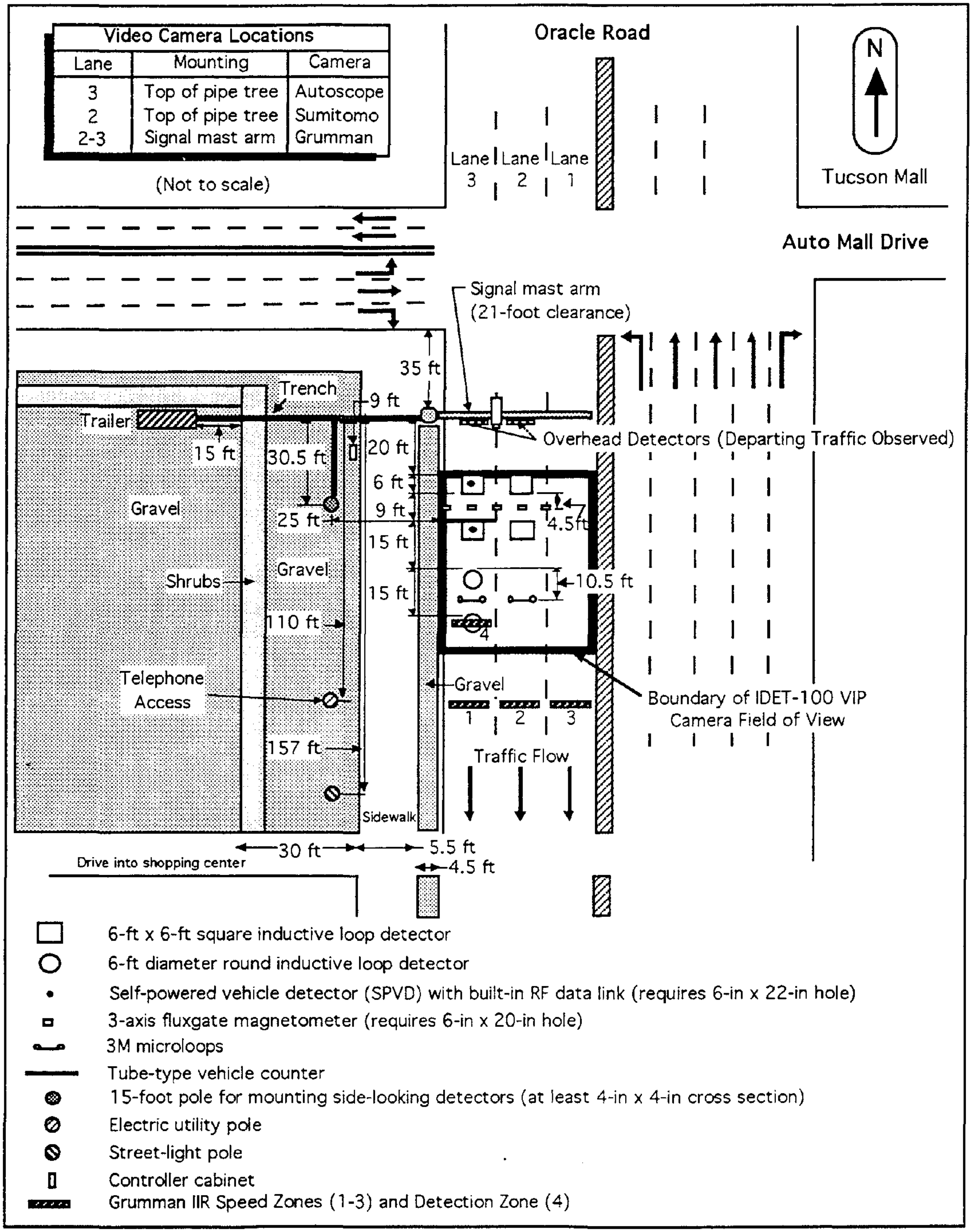
** IIR-1 is mounted in between lanes 2 and 3 on the mast arm and monitors traffic in both lanes.

A-1 is mounted on the mast arm between the pipe structure for the lane 3 detectors and the traffic signal pole.

M-6B is mounted in a side-looking configuration on a pole in the sidewalk area west of Oracle Road, 30 feet downstream of the mast arm. It monitors traffic in lanes 1, 2, and 3.

1 ft = 0.305 m

Figure 9-47. Oracle Road Overhead Detector Layout



Video Camera Locations		
Lane	Mounting	Camera
3	Top of pipe tree	Autoscope
2	Top of pipe tree	Sumitomo
2-3	Signal mast arm	Grumman

1 in = 25.4 mm
1 ft = 0.305 m

Figure 9-48. Location of Detectors on Oracle Road are illustrated in Figure 9-49. A rubber tube for a Timemark Delta 1 traffic counter was installed across lane 3 at the leading edge of each square loop. The counter was modified with an RS-232 interface that transmitted the count information to the data logger. The AT&T sonic array was installed to monitor traffic in lane 3. In addition to the usual 6-foot (1.8-m) square loop pairs, 6-foot (1.8-m) diameter round loops installed by Max Kutter and 3M microloops were placed in lane 3 as shown in Figure 9-50. The microloops in lane 3 are in between the pair of round loops (near the 60-foot (18.2-m) mark) and in lane 2 are at the same relative location. The numbers on the pavement show the distance in feet from the mast arm on which the overhead detectors are mounted.

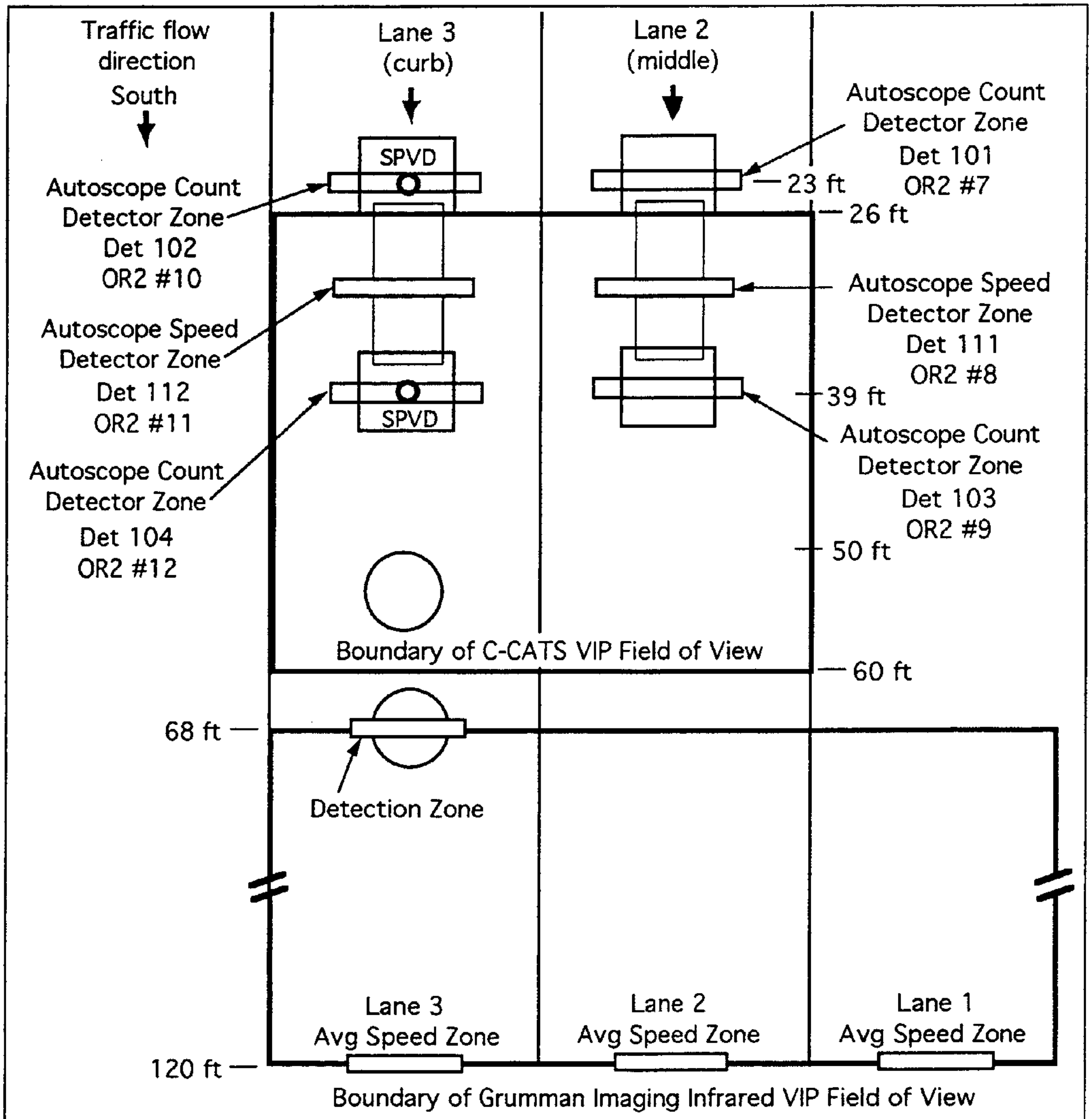
The wind speed and direction sensors and side-looking RTMS microwave radar, shown in Figure 9-51, were mounted on a 4-inch by 4-inch (101.6-mm by 101.6-mm) pole approximately 30 feet (9.1 m) south of the mast arm. The trailer and barricades around the trenches for the cables can be seen in the photo. The stub antenna for the magnetometer was mounted and hidden in a tree north of the pole. The time of occurrence of the green-phase signal at the southbound Oracle Road and Auto Mall Drive intersection was recorded using a relay data logger input.

The Tucson evaluation had other unique features. An array of five three-axis fluxgate magnetometers was installed across lanes 2 and 3 as sketched in Figure 9-48 and shown in the photograph of Figure 9-50 parallel with the 30-foot (9.1-m) paint mark. A sixth magnetometer was buried off the road near the 4-inch by 4-inch (101.6-mm by 101.6-mm) pole. Cables from the magnetometers ran to electronic signal amplifiers mounted on the 4-inch by 4-inch pole shown in the lower part of Figure 9-51. From here, cables brought the signals into the trailer where they were input to a Metrum recorder and recorded on VCR magnetic media as shown on the left side of Figure 9-52. The magnetometer array data was stripped from the VCR tapes in later processing at Hughes and placed into files that were archived on 1/4-inch (6.4-mm) magnetic tape used for 250MB PC backup systems.

A high sampling frequency Model 2020 detector built by 3M was connected to the second 6-foot by 6-foot (1.8-m by 1.8-m) square loop in lane 3. This allowed signals produced by the undercarriage of vehicles to be sampled and recorded by the data logger. Because of the high data rate output of the 2020 detector, a separate PC incorporating a fast serial input/output board with the 16550 Universal Asynchronous Receiver-Transmitter (UART) was used to record these data. The second PC also recorded the time code furnished by the data logger to aid in the correlation of the 2020 data with data from the other detectors.

As part of the data collection effort associated with the three-axis magnetometer array and high sample rate inductive loop detector, lane 3 was closed to normal traffic and several types of test vehicles were driven through the lane at slow speeds and were also stopped at several stations in the lane. In this way, signature data were obtained for known vehicles corresponding to known areas under the vehicle. The vehicles used in these tests are listed in Table 9-4. The large-boom lift truck is shown in Figures 9-53 and 9-54 and the Dodge Caravan in Figure 9-55. The stations are shown in Figure 9-56. In the tests where the vehicle was stopped in lane 3, the front bumper of each vehicle was stopped parallel to each station. At station 5, the vehicles were also stopped so that the middle of the vehicle and the rear bumper were parallel to the station.

An imaging infrared detector developed by Grumman Aircraft Company was evaluated at Tucson. The infrared camera was mounted on the mast arm between lanes 2 and 3, as shown in Figure 9-48, and viewed the area downstream from the second round loop between approximately 68 and 120 feet (20.7 and 36.6 m) from the mast arm. The infrared imagery processing electronics were located in the trailer as shown in the background of Figure 9-52. An infrared image of vehicles is shown in Figure 9-57. In the infrared spectrum, the hotter areas appear lighter in color and the colder areas appear darker. Since the character of the infrared image does not change appreciably from day to night (even when a vehicle's lights are on), it may be possible to use the same signal processing



<u>Computation of vehicle speed from Autoscope data</u>:

Lane 2 speed = 25 feet/(Det 103 trip time - Det 111 trip time)
Lane 3 speed = 25 feet/(Det 104 trip time - Det 112 trip time)

25 feet is set internally by Autoscope for the vehicle speed calculation
Autoscope software version 3.23

0-ft reference: corresponds to location of mast arm that supports the traffic signals
SPVD=self-powered vehicle detector
OR2 = Rack-mounted chassis that contains optically isolated detector inputs 17-40

1 ft = 0.305 m

Figure 9-49. Fields of View and Calibration Areas for Autoscope, CCATS, and Grumman Video Image Processors on Oracle Road

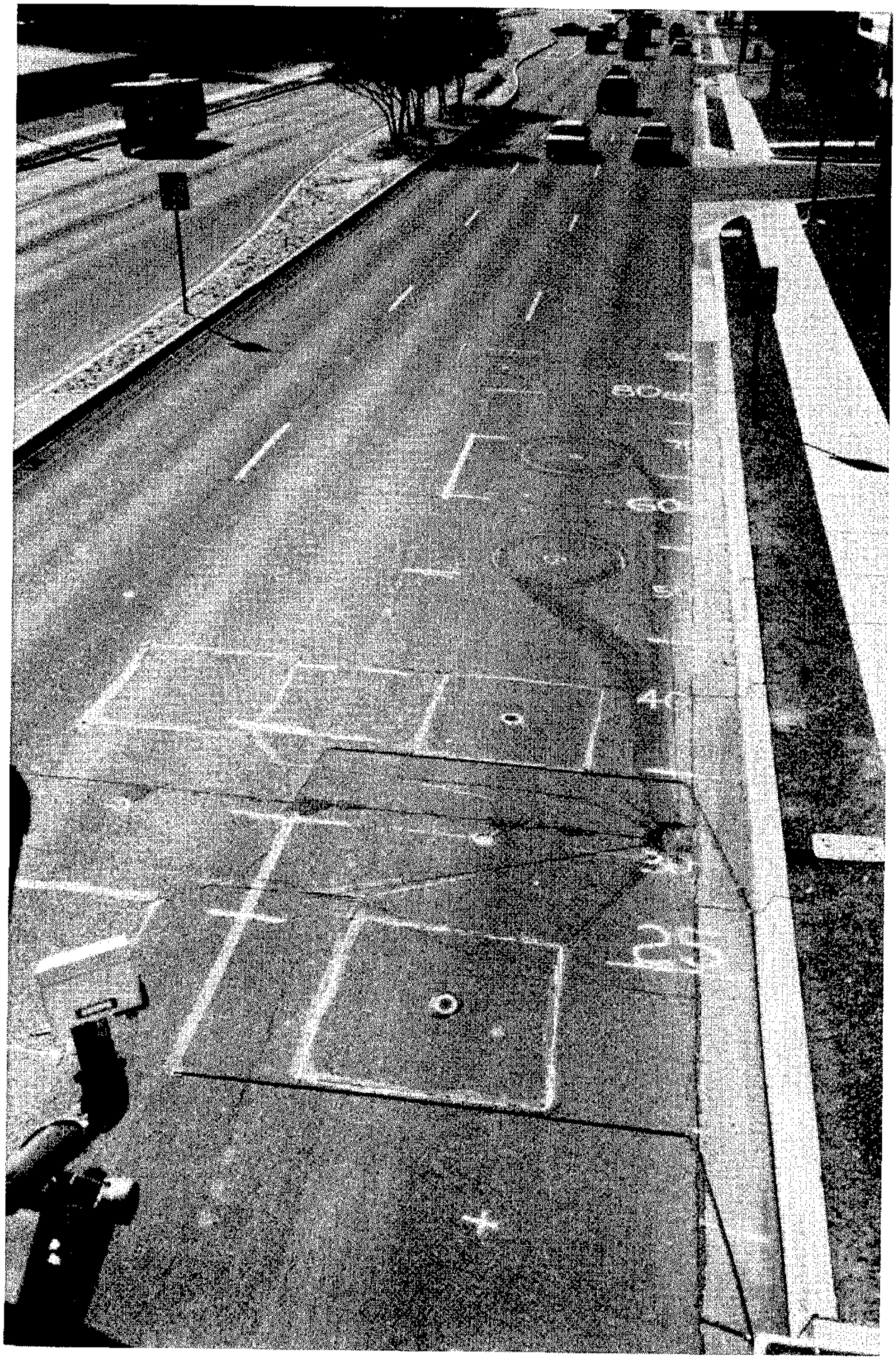


Figure 9-50. Oracle Road Marked with Calibration Distances for Video Image Processors and Subsurface Detectors

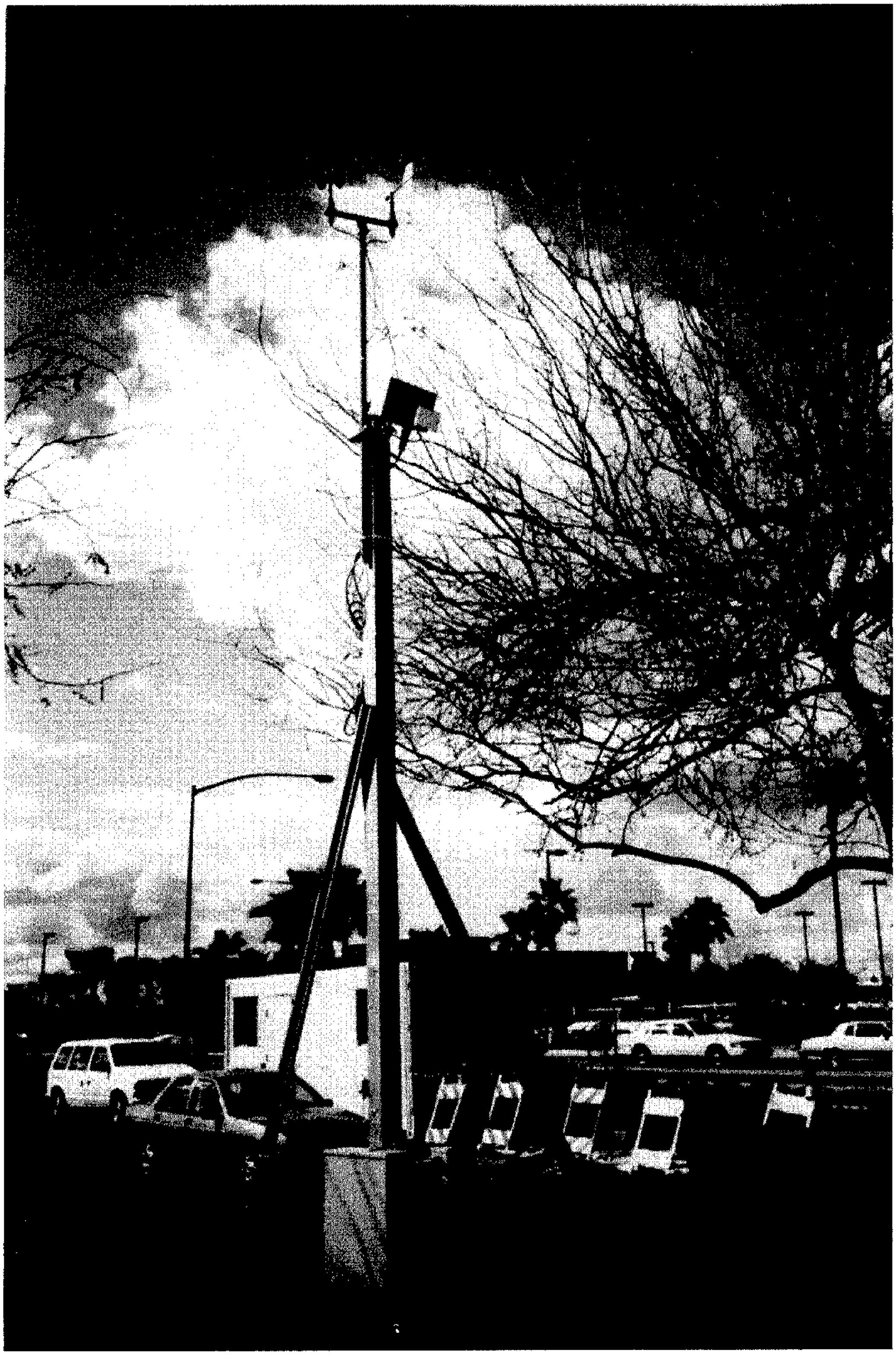


Figure 9-51. Pole-Mounted Wind Speed and Direction Sensors and Side-Viewing RTMS Microwave Detector at Oracle Road Site

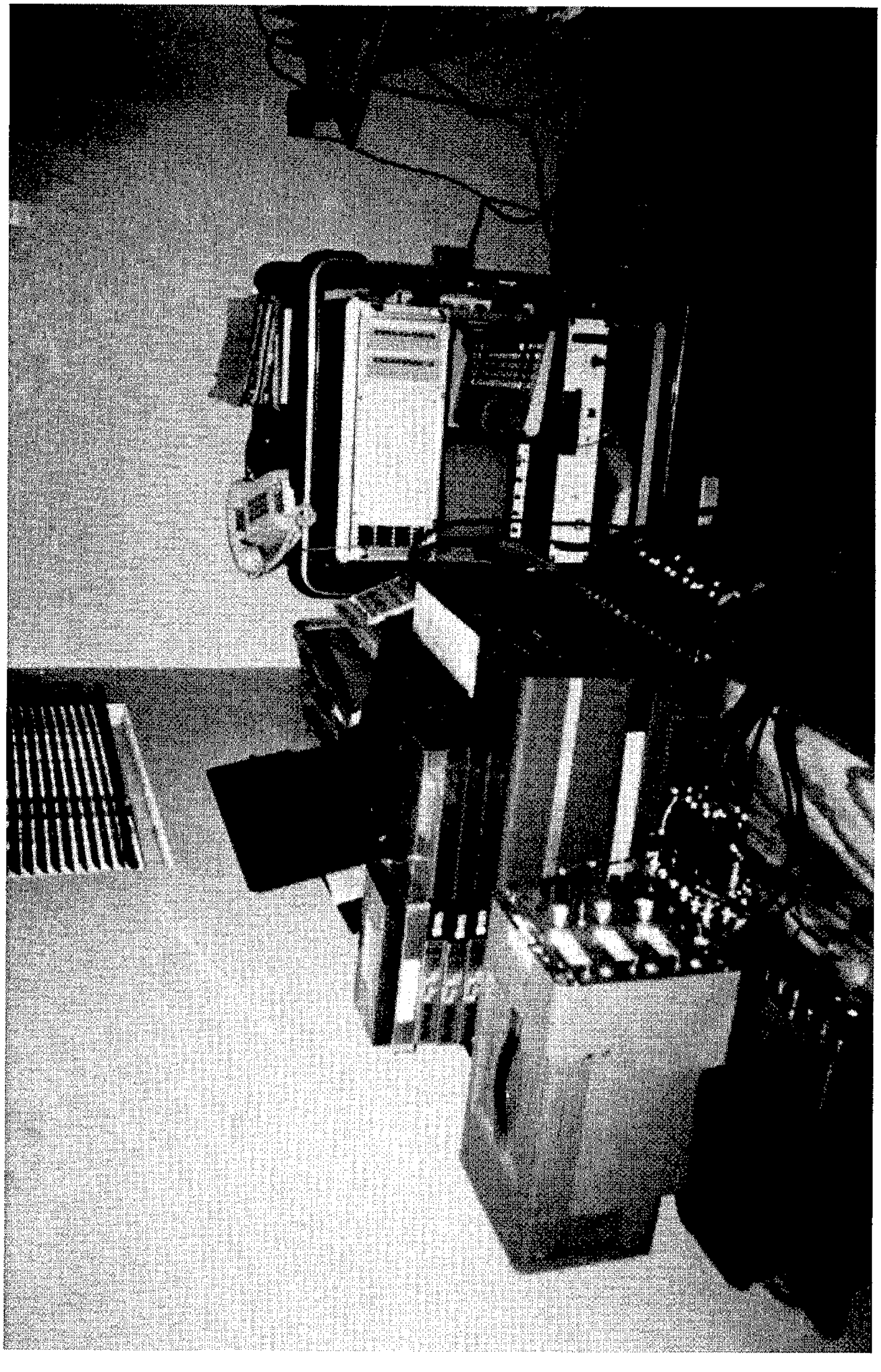


Figure 9-52. Metrum Recorder and Power Supplies Used to Record Three-Axis Magnetometer Signals at Oracle Road Site

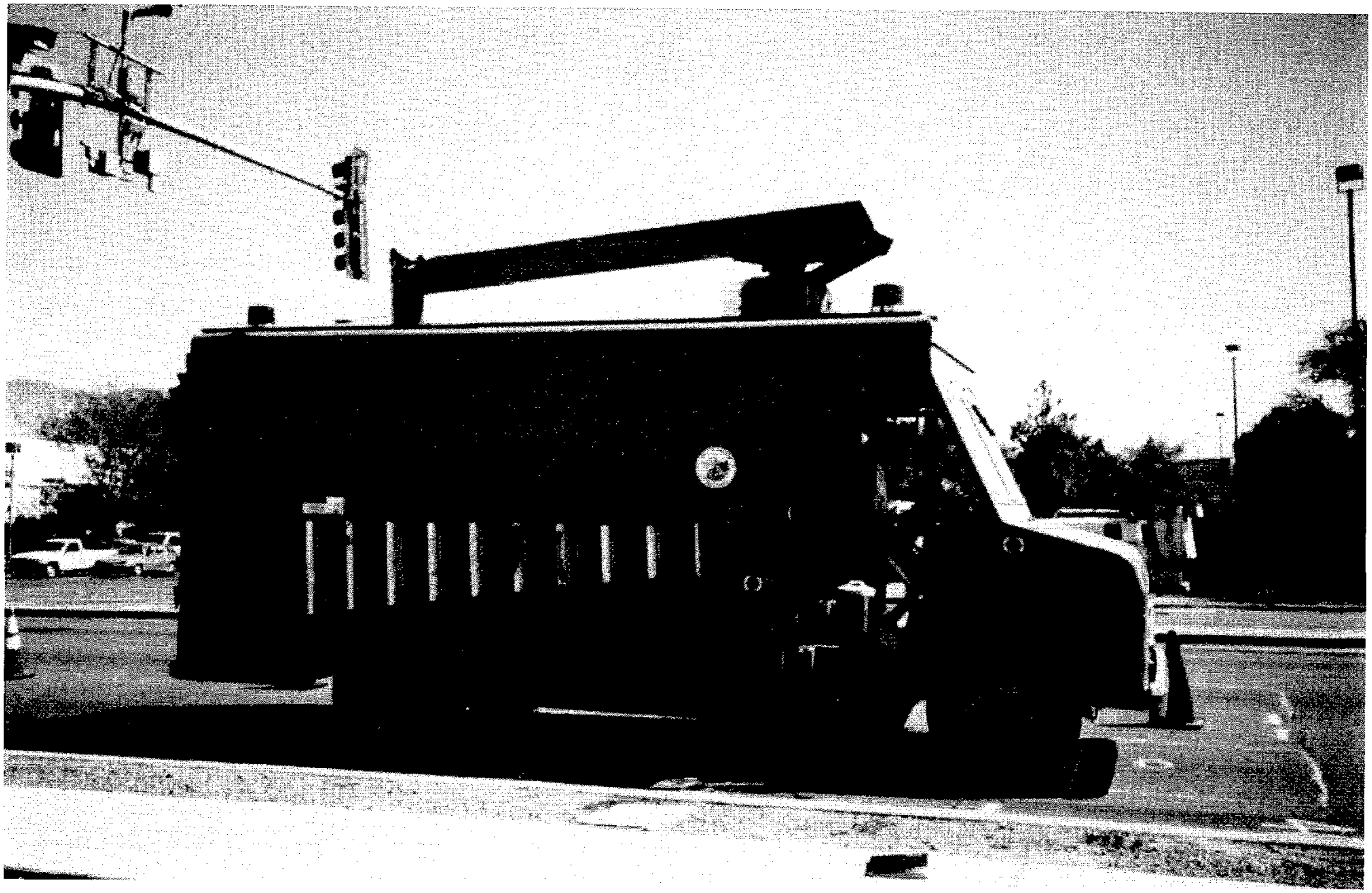


Figure 9-53. International S1600 Large Boom-Lift Truck (Side)

Figure 9-54. International S1600 Large Boom-Lift Truck (Front)

Figure 9-55. Dodge Caravan

Table 9-4. Vehicles Used to Ground Truth Three-Axis Magnetometer Array and High Sampling Frequency Inductive Loop Amplifier Signatures

Vehicle	Length (ft)	Width (ft)
International S1600 (Model 1654) large boom-lift truck	27.25	-
1980 Boyertown truck	22.0	7.0
1985 Dodge Caravan	14.5	5.6
1994 Chevrolet Corsica	15.0	5.0
Kawasaki Arizona Highway Patrol Police 1000 Motorcycle	7.3	-

1 ft = 0.305 m

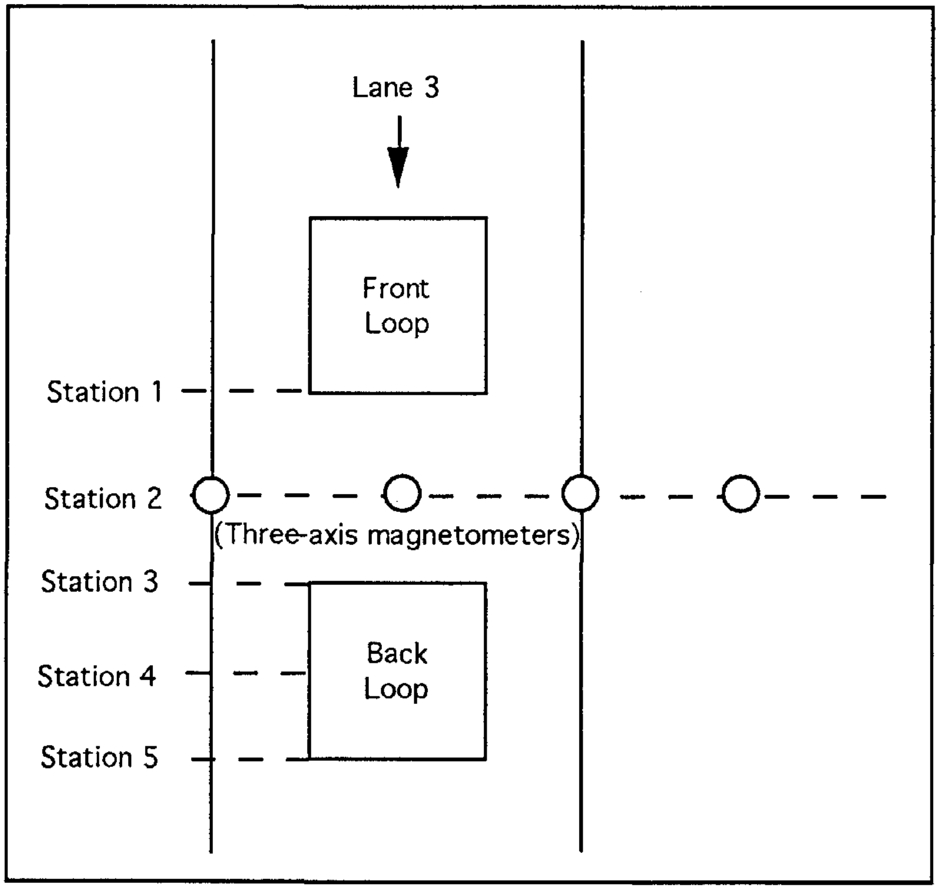


Figure 9-56. Stations Used to Record Signatures of Stopped Vehicles in Lane 3 on Oracle Road

Figure 9-57. Infrared Image of Vehicles Taken With Grumman Imaging Infrared Detector

algorithms for day and night operation. The infrared image processing technology may thus avoid possible performance degradation that can occur when transitioning from day to night algorithms in visible-spectrum video image processors.

The trailer was located in a shopping center parking lot on the southwest corner of the intersection. The cables were laid in a trench dug from the trailer to the sidewalk and then under the sidewalk to the pole that supported the mast arm upon which the detector pipe trees were hung. Additional trenches were dug for cables to the side-viewing RTMS microwave radar and the telephone service connection. Trenching had two drawbacks: flooding of the trench by a rain storm and having to erect barriers to prevent people from walking into the trench. Overhead cable installation is, therefore, preferable.

The equipment rack for Tucson is shown in Figure 9-58. On the top is one of the monitors used to view the traffic flow. To its right is the CCATS-VIP 2 image processor. The Autoscope 2003 is mounted in the top of the rack. Under it are the two PC-controlled VCRs that were used to record the traffic flow. Under these is the Type 170 electronics rack that held the Detector Systems inductive loop detectors, 3M 2020 high-frequency loop detector, and the AT&T SmartSonics detector. The power supply panel appears next. At the bottom of the rack is the auxiliary data logger for the additional 24 optically isolated detector inputs. The Detector Systems LoopComm inductive loop detector amplifiers are shown on the table to the left of the rack. They were connected to the downstream (second) square loop in lanes 2 and 3 to provide vehicle speed ground truth data. Behind them is the receiver for the self-powered magnetometers.

Figures 9-59 and 9-60 show the inductive loop detector electronics, self-powered magnetometer receiver, main data logger, 386 PC and monitor, keyboards, a 486 PC and monitor on which the 3M 2020 high-frequency loop data were recorded, and a monitor for the second video camera, all located on a table in the trailer. The electronics for the Sumitomo SDU-300 ultrasonic detector, uninterruptable power supply, Sumitomo IDET-100 video image processor, and Sumitomo SDU-200 (RDU-101) ultrasonic detector were placed on the floor of the trailer under the table as shown in Figure 9-60.

In addition to the conventional traffic monitoring, we also mounted 4-foot by 8-foot (1.2-m by 2.4-m) sheets of styrofoam on the top of a Chevrolet Corsica and drove it through the field of view of the overhead detectors as shown in Figures 9-61 and 9-62. The purpose of these tests was to simulate the effects of snow on the performance of the ultrasonic, infrared, and microwave detectors. The styrofoam layers were 1, 2, and 3 inches (25.4, 50.8, and 76.2 mm) thick. This evaluation was performed at the same time lane 3 was closed to gather data for the three-axis magnetometers and high sample frequency inductive loop amplifier.

9.5 AMOUNT OF DATA COLLECTED AT EACH SITE

Table 9-5 shows the amount of data collected at each field test and evaluation site. Since the Tucson site included the three-axis magnetometer detector array, high sampling rate inductive loop detector amplifier, imaging infrared detector, circular inductive loops, and microloops not installed at the other sites, the data quantity at Tucson was greater than at the other sites.

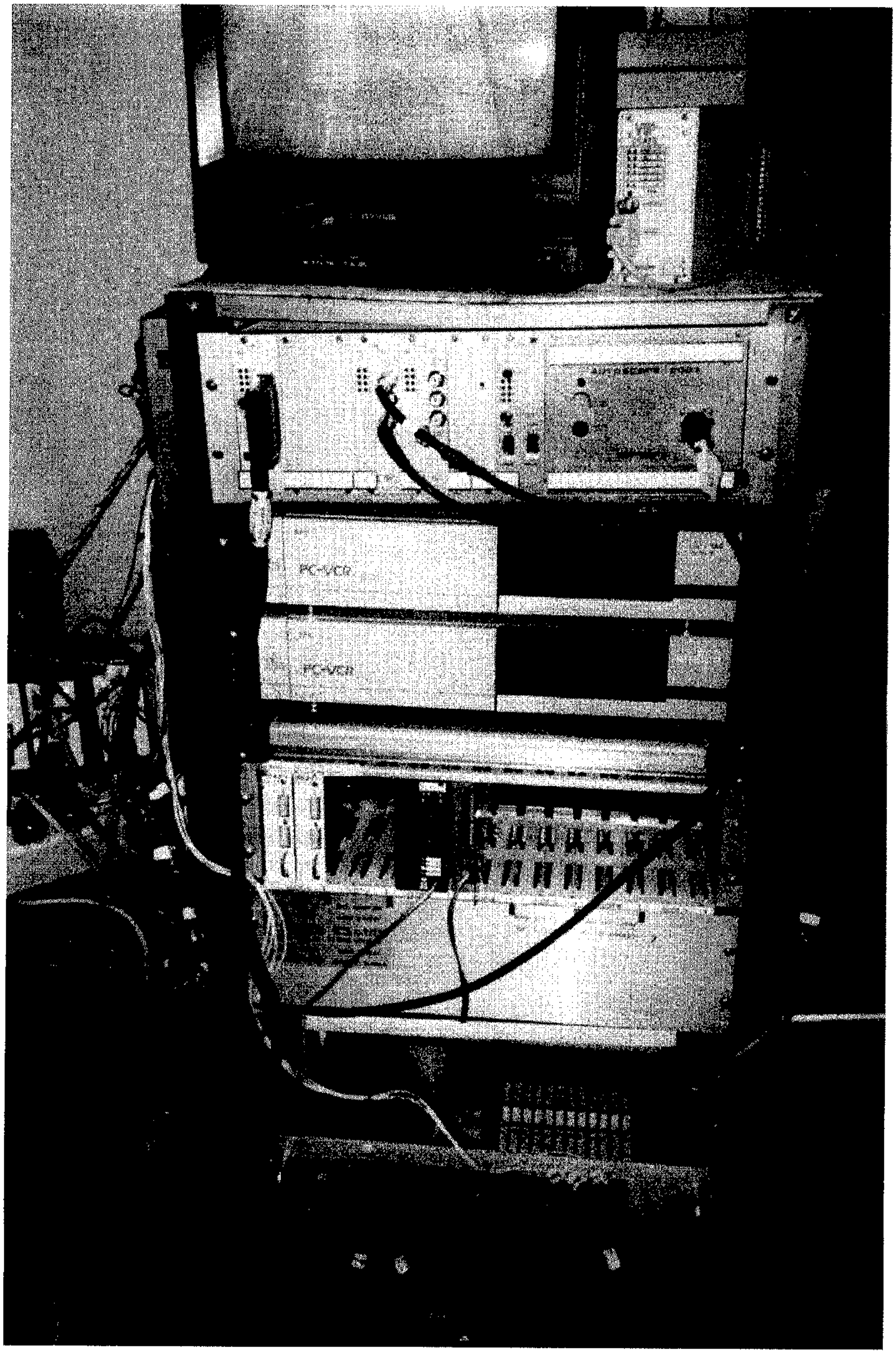


Figure 9-58. Data Recording Equipment as Configured for Oracle Road

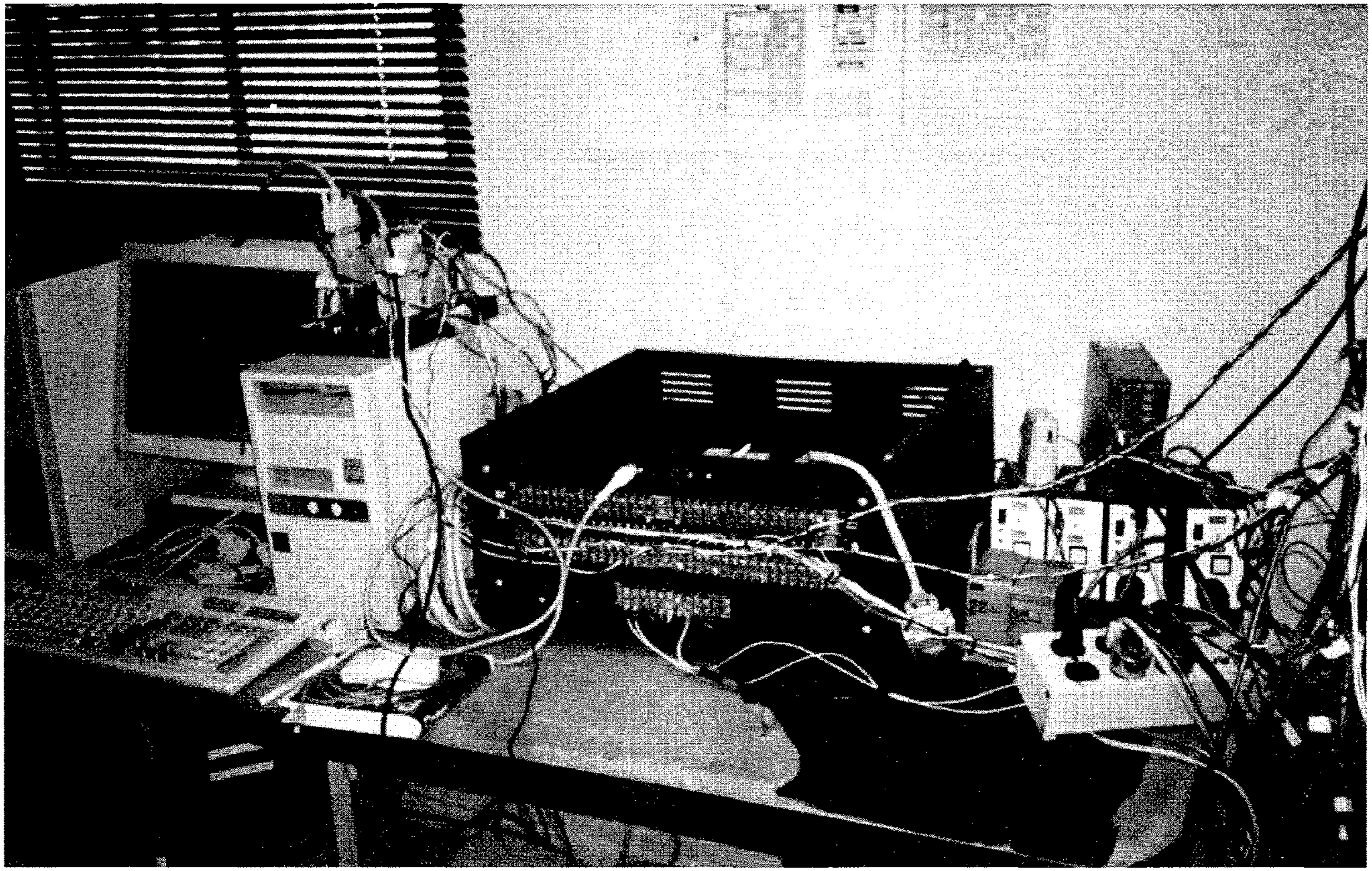


Figure 9-59. Data Logger, Computer, and Subsurface Detector Electronics at Oracle Road

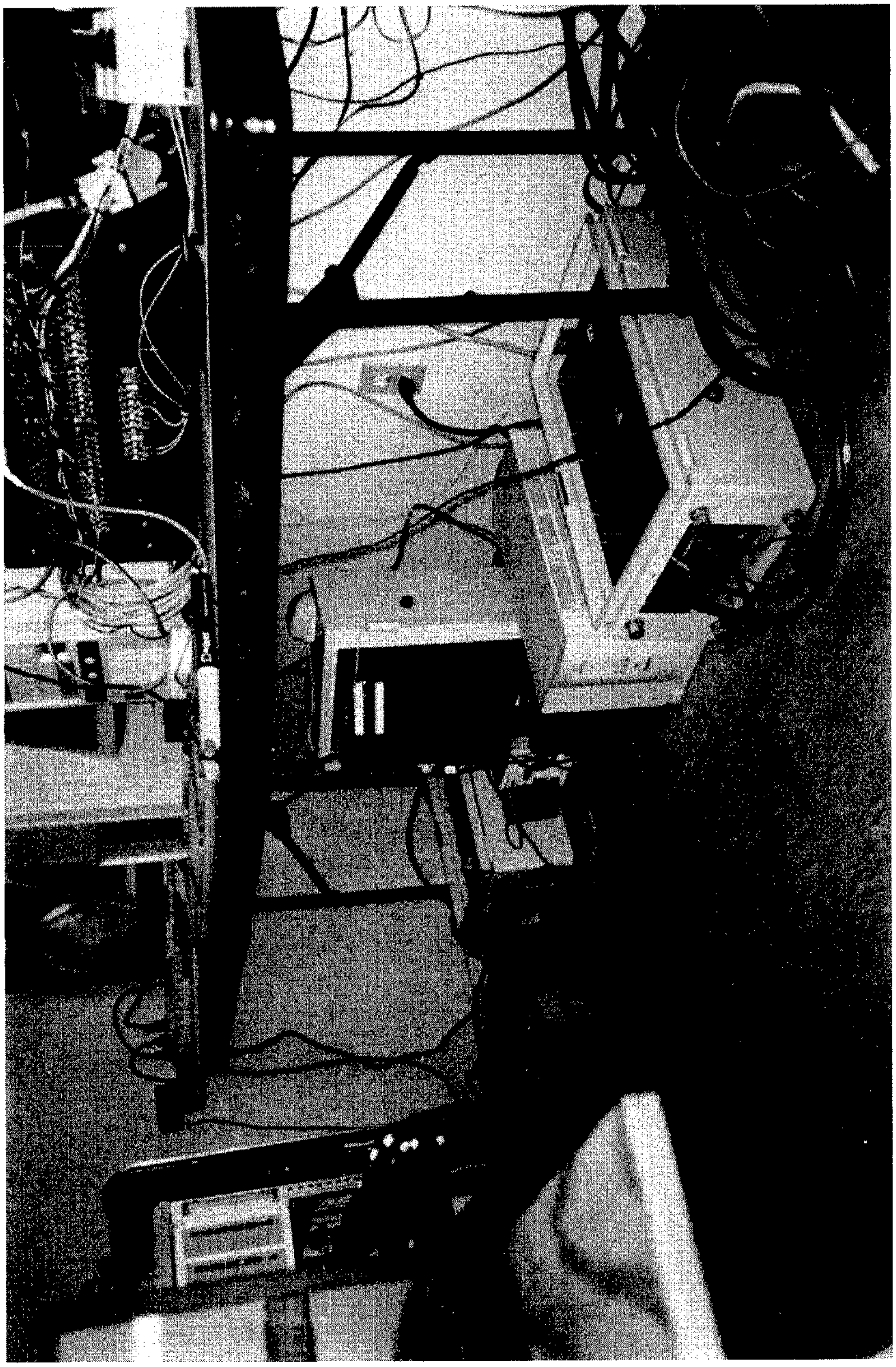


Figure 9-60. Sumitomo Detector Electronics and Uninterruptable Power Supply on Floor of Trailer

Figure 9-61. Chevrolet Corsica With Styrofoam Sheet Tied to Vehicle Top

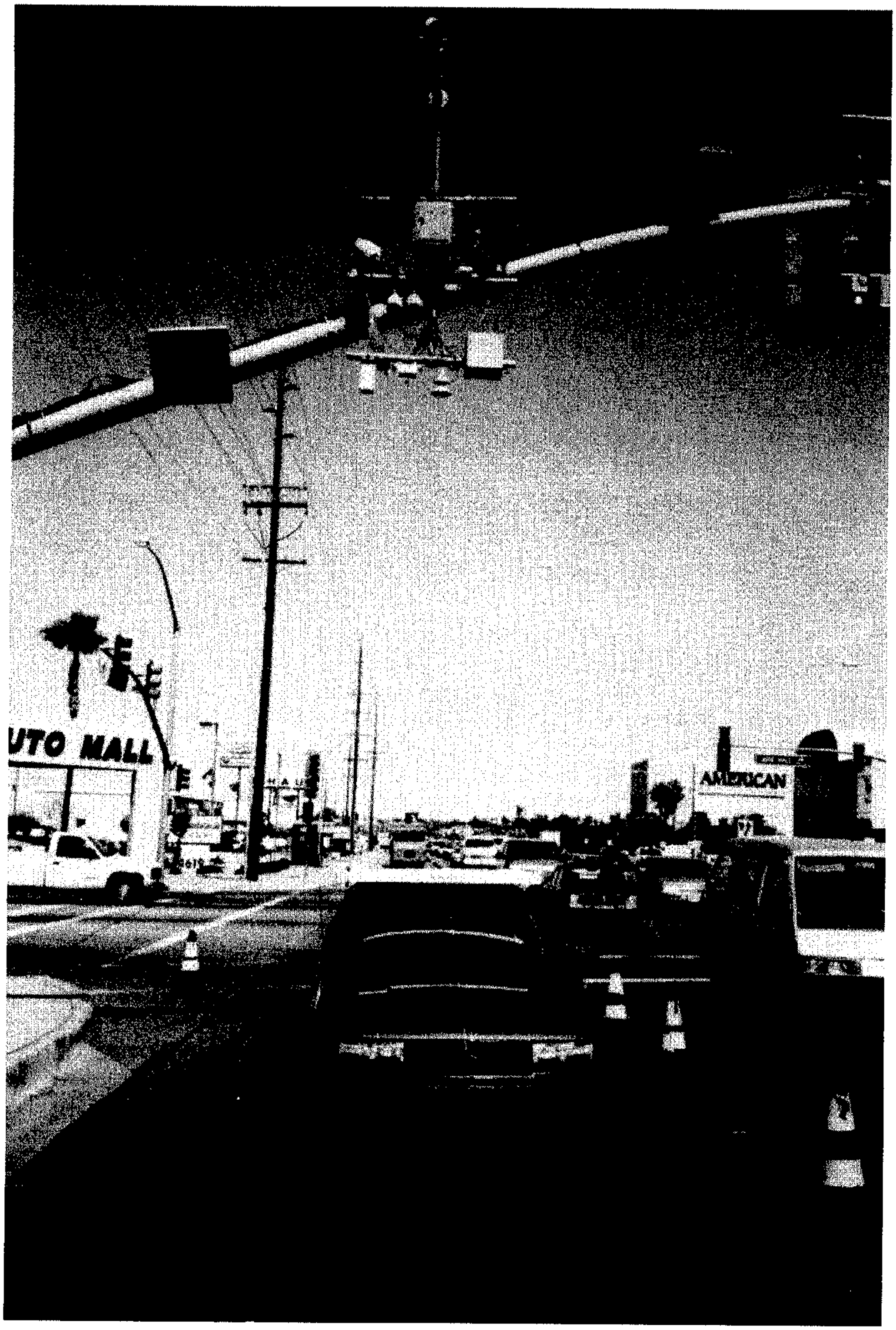


Figure 9-62. Corsica With Styrofoam Sheet Parked Under Detector Array

Table 9-5. Quantity of Data Acquired

Location	Date	Runs	Data Collected (MB)
Minneapolis Freeway	Winter 1993	15	200
Minneapolis Surface Street	Winter 1993	7	32
Orlando Freeway	Summer 1993	28	670
Orlando Surface Street	Summer 1993	21	200
Phoenix F	Autumn 1993	32	868
Tucson Surface Street	Winter 1994	34	815
Tucson Surface Street	Winter 1994	31	577 (with 3M 2020 high sampling rate amplifier)
Tucson Surface Street	Winter 1994	16	1500 (from three-axis magnetometer array)
Phoenix Freeway	Summer 1994	31	1060

10. TASK H

GENERATE FIELD TEST RESULTS

10.1 FIELD TEST OBJECTIVE

The primary objective of the field tests was to quantify the performance of traffic detector technologies with respect to the types and accuracy of data they provide under a variety of traffic flow and environmental conditions. In order to assess the data collected during the field tests, a methodology for reducing the data and presenting the results was established.

10.2 DATA COLLECTION AND ANALYSIS PROCESS

The detector data collection and analysis follows a four-step process: (1) acquisition, (2) conversion, (3) extraction, and (4) analysis. A flow chart describing the process is shown in Figure 10-1.

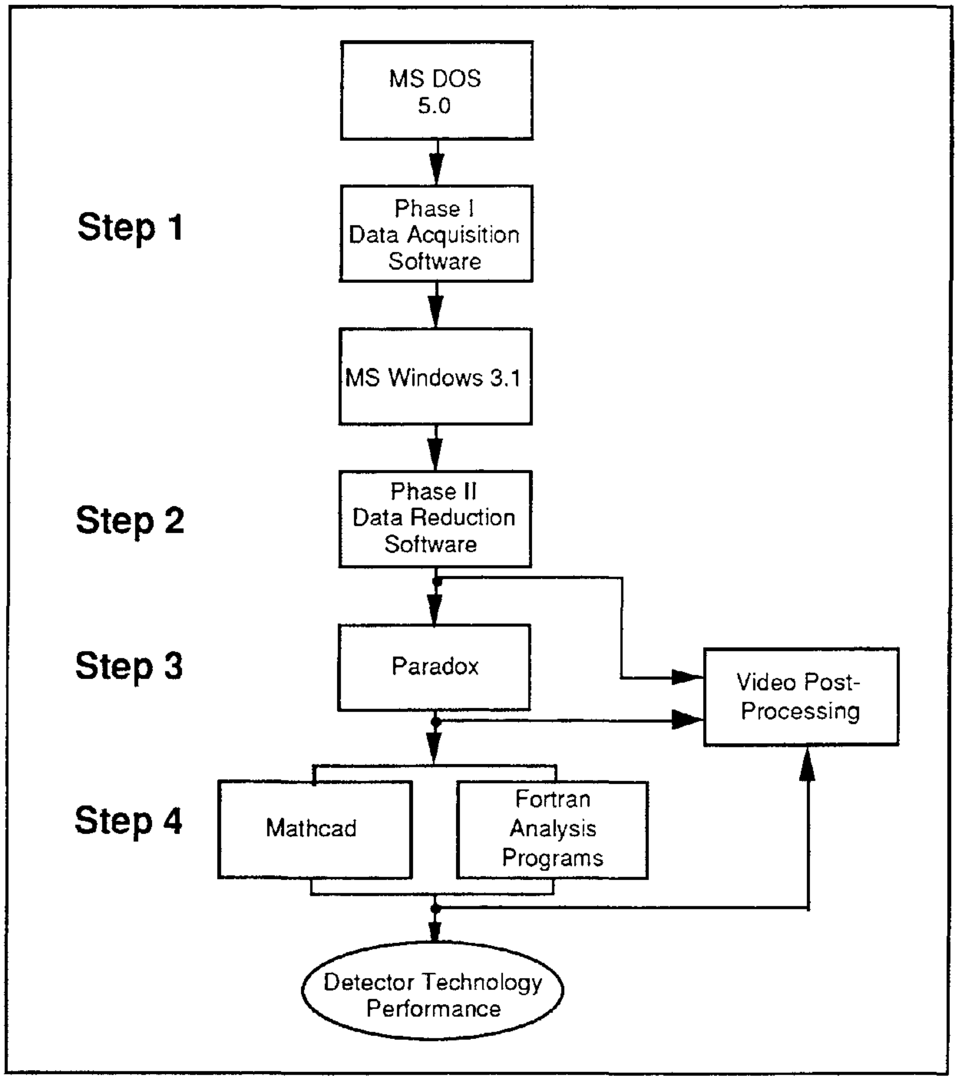


Figure 10-1. Data Collection and Analysis Process

10.2.1 Acquisition Phase

During data acquisition, all data available from each detector (shown in Tables 4-9 and 9-2) were recorded using a data logger. The data logger was designed to collect four types of output data: (1) Form C relay contact closures, (2) pulses from optically isolated outputs, (3) RS-232 serial transmissions, and (4) analog data in the form of output voltages. These detector outputs were time-stamped and recorded in real time. Video index numbers or PG numbers, generated by the personal computer video cassette recorder (PC-VCR) at the rate of one per second, were recorded to allow data and video synchronization in post-processing Steps 3 and 4. Form C relay and optically isolated output transitions (the rising and falling edges of the detector output pulse) were recorded by the Phase I Data Acquisition Software which also computed the time interval between them. The interval represents the vehicle presence defined as the time duration over which the detector output indicates a vehicle in its sensing area. The analog data were recorded through the same interface as the relay data. Serial data were recorded as they were generated through a Digiboard interface with the PC. The Phase I raw data files utilize a naming convention in which the first eight characters are numeric and represent the month, day, and military time at the beginning of the run. The raw data file is always given a .DAT extension. For example, a run conducted on April 11, beginning at 4:30 p.m., is designated 04111630.DAT as shown below:

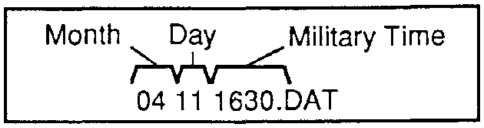


Figure 10-2 contains an excerpt from a typical raw data file.

```
06:06 18 56 079 KS59
07:06 18 56 079 LS64
08:06 18 56 079 FS57
01:06 18 56 079 OPTO FREQ 3 254 318
02:06 18 56 079 MMT 002038FA FFFFFFF7 0523 0000
* translated -> MMT H00 M08 S47 M934 Q0000 00000000,00001000,00000000
05:06 18 56 084 PG00008
06:06 18 56 084 NS66
07:06 18 56 084 JS62
08:06 18 56 084 LS60
01:06 18 56 084 OPTO PULSE 9 255 33
02:06 18 56 084 MMT 00203AC0 FFFFFFF3 0514 0000
* translated -> MMT H00 M08 S48 M048 Q0000 00000000,00001100,00000000
06:06 18 56 084 LS67
07:06 18 56 084 HS63
08:06 18 56 084 FS50
19:06 18 56 090 MMT 0023FBD1 FFFFFFFF 0540 0000
* translated -> MMT H00 M09 S49 M556 Q0000 00000000,00000000,00000000
01:06 18 56 090 OPTO FREQ 3 254 206
02:06 18 56 090 MMT 00203AC2 FFFFFFFB 0525 0000
* translated -> MMT H00 M08 S48 M048 Q0000 00000000,00000100,00000000
```

Figure 10-2. Raw Data File Excerpt

Figure 10-3 shows the data field assignments as they appear in the raw data files. The first number in a data line gives the channel or COM PORT number that is assigned to that device or output type. Channel 1 (designated 01), is dedicated to relay outputs and analog signals. Channels 2 and 19 are assigned to optically isolated detector outputs. Channels

3 and 4 are not used. Channels 5 through 20 were dedicated to RS-232 serial interfaces (the Channel 19 Opto Rack that contains provisions for 24 optically isolated inputs is connected to the data logger through the Digiboard, a device that serves as the interface from RS-232 output devices to the PC). The next four fields contain a time stamp that records the instant at which that event occurred (in hours, minutes, seconds, and hundredths of seconds according to the PC clock). The next fields contain data that are specific to the particular device or output type. Much of the data are of little use to the analyst in this form and must be translated in Step 2, using Phase II data reduction software, into a format that is more intuitive and easier to examine.

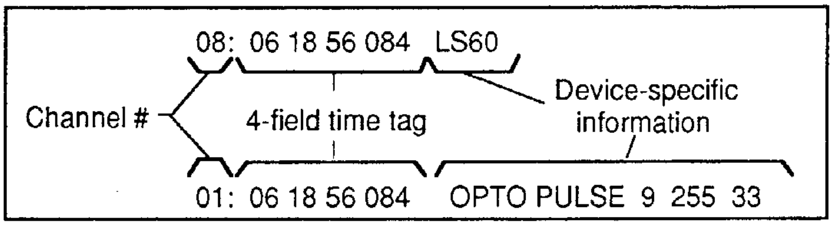


Figure 10-3. Data Field Assignments in Raw Data Files

10.2.2 Data Conversion Phase

The remainder of the steps shown in the data flow diagram are performed in post-processing. The second step applies the Phase II Data Reduction Software to convert the raw data recorded in the acquisition phase into detector-specific information presented in a comma-delimited text format as illustrated in Figure 10-4. The output of the Phase II software is referred to as a log file and is given a .LOG extension.

```
242,6,11,51,610,85192,7,,-145,153,94,35,"VP1b",3,1,1158250,567818448,,,,,,,,,,
243,6,11,51,610,85192,7,,-145,153,94,35,"MG2a",1,1,100000,,,,,,,,,,,
244,6,11,51,610,85192,7,,-145,153,94,35,"VP1b",1,1,384250,568662448,,,,,,,,,,
245,6,11,51,610,85192,7,,-145,153,94,35,"MG1a",1,1,304000,219571448,,,,,,,,,,
246,6,11,51,610,85192,7,,-145,153,94,35,"IL1b",2,1,95000,219800198,,,,,,,,,,
247,6,11,51,610,85192,7,,-145,153,94,36,"M4b",1,1,411000,219489948,,,,,,,,,,
248,6,11,51,610,85192,7,,-145,153,94,36,"M4b",2,1,181250,219811698,,,,,,,,,,
249,6,11,51,610,85192,7,,-145,153,95,36,"IL1a",2,1,98000,219908698,,,,,,,,,,
250,6,11,51,610,85192,7,,-145,153,95,36,"MG2a",2,1,110000,,,,,,,,,,,
251,6,11,51,610,85192,7,,-145,153,95,36,"IR1a",2,1,610000,,,,,,,,,,,
252,6,11,51,610,85192,7,,-145,153,95,36,"M6b",2,1,640750,568775698,,,,,,,,,,
253,6,11,52,820,85193,7,,-145,153,95,36,"M5a",3,1,,,,26,,,,,,,,
254,6,11,52,820,85193,7,,-145,153,95,36,"IL1a",3,1,108250,569604198,,,,,,,,,,
255,6,11,52,820,85193,7,,-145,153,95,36,"M5a",1,1,294500,220315198,,,,,,,,,,
256,6,11,53,200,85194,7,,-145,153,95,36,"VP4a",5,,,,1,54,0,,,,2,59,,,
257,6,11,53,200,85194,7,,-145,153,95,36,"M5a",2,1,107500,220609198,,,,,,,,,,
258,6,11,53,200,85194,7,,-145,153,96,36,"M1a",1,1,1110000,,,,,,,,,,,
259,6,11,54,140,85195,7.0625,,-138,136,96,37,"VP3a",5,,,,0,0,,0,0,,0,,,,
260,6,11,54,140,85195,7.0625,,-138,136,96,37,"VP3a",5,,,,0,0,,0,0,,1,,,,
261,6,11,54,140,85195,7.0625,,-138,136,96,37,"M2b",1,1,880000,,,,,,,,,,,
262,6,11,54,790,85195,7.0625,,-138,136,97,38,"M5a",3,1,,,,33,,,,,,,,
263,6,11,55,10,85196,7.0625,,-138,136,97,38,"M6b",1,,,,,,,28,,,1,,,,
```

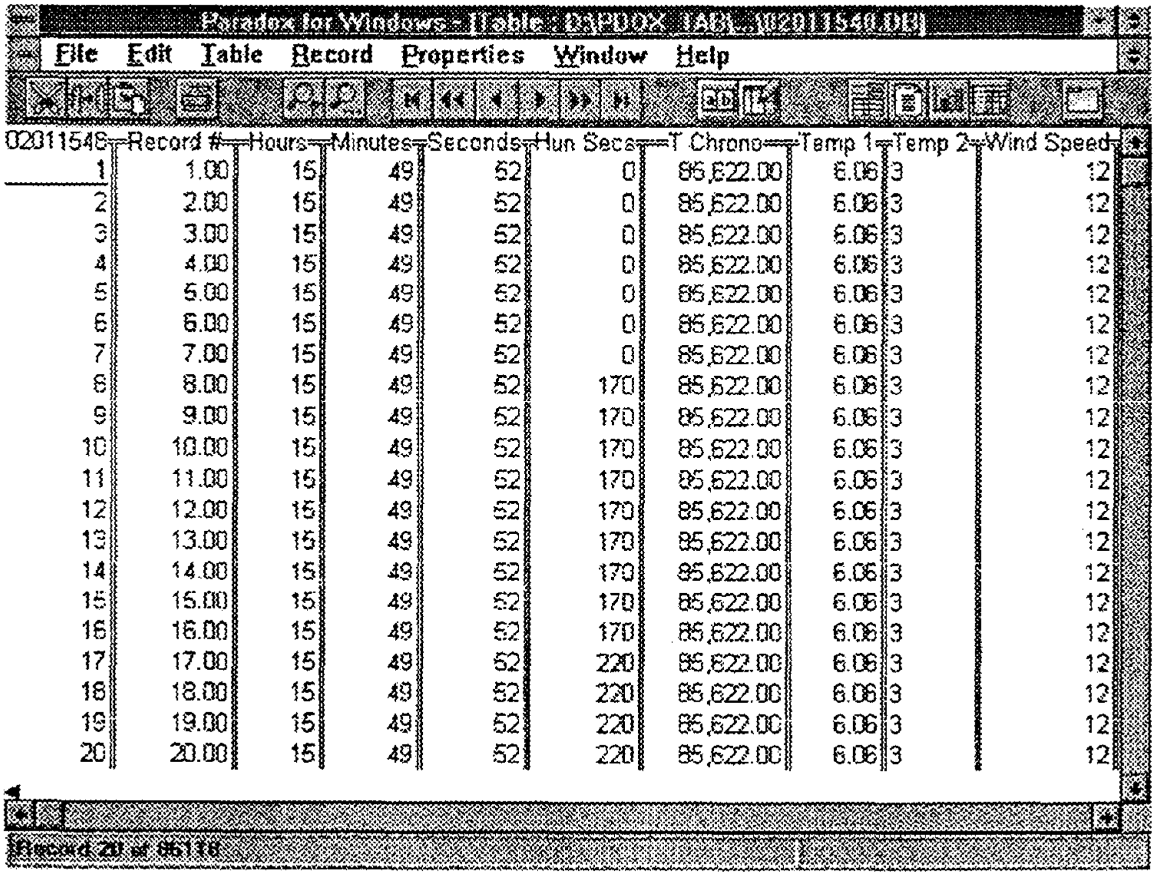
Figure 10-4. Comma-Delimited LOG File

The serial strings recorded during the acquisition phase are parsed and the device-specific parameters are stripped out by the Phase II software and placed into the appropriate data fields. The data field structure is discussed in 10.3.1.

10.2.3 Extraction Phase

The third step in the data collection and analysis process extracts specific data features from the log files. This step can be divided into two parts: (1) the importation of the log file's comma-delimited text into a more accessible database format, and (2) the utilization of database software that allows the user to extract specific parameters that are pertinent to a particular analysis. The database software used was Paradox for Windows.

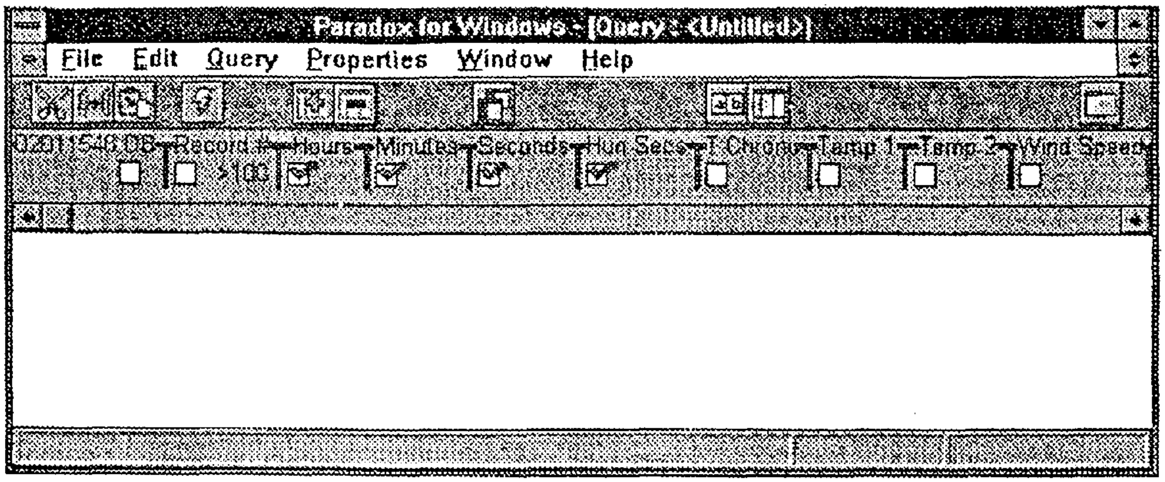
Paradox has an IMPORT command that accepts the text file created in Step 2 (log file) and converts it into a Paradox database format. These files have a .DB extension. Figure 10-5 shows an example of a .DB (database) file. Once a database file has been created, the QUERY command can be used to filter out desired detector outputs and/or data parameters and extract them from the master database file. An example of a Paradox QUERY is given in Figure 10-6. The result of the QUERY is an ANSWER table. This table can be exported in a comma-delimited format and read as a text file during the analysis phase.



02011548	Record #	Hours	Minutes	Seconds	Hun Secs	T Chrono	Temp 1	Temp 2	Wind Speed
1	1.00	15	49	52	0	85,622.00	6.06	3	12
2	2.00	15	49	52	0	85,622.00	6.06	3	12
3	3.00	15	49	52	0	85,622.00	6.06	3	12
4	4.00	15	49	52	0	85,622.00	6.06	3	12
5	5.00	15	49	52	0	85,622.00	6.06	3	12
6	6.00	15	49	52	0	85,622.00	6.06	3	12
7	7.00	15	49	52	0	85,622.00	6.06	3	12
8	8.00	15	49	52	170	85,622.00	6.06	3	12
9	9.00	15	49	52	170	85,622.00	6.06	3	12
10	10.00	15	49	52	170	85,622.00	6.06	3	12
11	11.00	15	49	52	170	85,622.00	6.06	3	12
12	12.00	15	49	52	170	85,622.00	6.06	3	12
13	13.00	15	49	52	170	85,622.00	6.06	3	12
14	14.00	15	49	52	170	85,622.00	6.06	3	12
15	15.00	15	49	52	170	85,622.00	6.06	3	12
16	16.00	15	49	52	170	85,622.00	6.06	3	12
17	17.00	15	49	52	220	85,622.00	6.06	3	12
18	18.00	15	49	52	220	85,622.00	6.06	3	12
19	19.00	15	49	52	220	85,622.00	6.06	3	12
20	20.00	15	49	52	220	85,622.00	6.06	3	12

Record 20 of 86118

Figure 10-5. Database File



0201154B.DB	Record #	Hours	Minutes	Seconds	Hun Secs	T Chrono	Temp 1	Temp 2	Wind Speed
☐	☐ >100	☑	☑	☑	☑	☐	☐	☐	☐

Figure 10-6. Paradox QUERY Illustration

10.2.4 Analysis Phase

The final step in the data analysis process involves the manipulation of the parameters extracted from the database file into a form that lends itself to interpretation by an analyst. This was accomplished by two different means. In the first, simple linear processes (such as the accumulation of vehicle counts over time) were modeled using a commercially available math analysis program called Mathcad that displayed tabular or graphical results quickly and easily. The program's simple user interface, however, restricts the ability to perform recursive looping, limiting its effectiveness when dealing with some of the more complex operations needed to adequately analyze traffic data and trends.

For this reason, a second approach utilizing application-specific FORTRAN programs were applied. The FORTRAN programs provided the capability to examine the data in greater detail. They are described in Section 10.4. The FORTRAN output can be imported into any number of commercially available graphical analysis programs and plotted. The graphing software used in this study was Kaleidagraph for the Macintosh platform.

10.3 TRAFFIC PARAMETER CALCULATION

In order to utilize the field test data to quantify detector performance, it is necessary to display detector attributes in terms of parameters that are commonly used and understood within the traffic-management community. These include count accuracy, vehicle speed, vehicle flow (sometimes referred to as volume), and lane occupancy. Some devices output such parameters directly; however, it is often necessary to calculate them using the available and sometimes rudimentary output data appearing in the .LOG files described in Table 10-1.

10.3.1 Parameter Descriptions

Field 1: Record Number

Assigns a sequential, integer record number to the events in chronological order.

Fields 2-5: PC Time Stamp

Assigns a four-field time tag to each event at the conclusion of the event (at falling edge of the waveform for pulse outputs). The event is stamped with the hour, minute, second, and hundredth of seconds that it was recorded using the time from the PC clock. The hundredths of seconds mark is converted into thousandths of seconds in the LOG file.

Table 10-1. Detector Output Data Fields as They Appear in .LOG and .DB Files

Field #	Field Name	Description
1	Record Number	Sequential record number
2	Hours	Event time tag (hours)
3	Minutes	Event time tag (minutes)
4	Seconds	Event time tag (seconds)
5	Hun Secs	Event time tag (hundredths of seconds)
6	T Chrono	Elapsed chronological time (seconds)
7	Temp 1	Temperature Probe 1 reading (degrees C)
8	Temp 2	Temperature Probe 2 reading (degrees C)
9	Wind Speed	Wind speed (mi/h)
10	Wind Dir	Wind direction
11	Frame # VCR1	Tape index number for VCR1
12	Frame # VCR2	Tape index number for VCR2
13	Det ID	Detector identification acronym
14	Det Int #	Detector interface number
15	V detect	Vehicle detect (unity when vehicle is detected)
16	V presence	Vehicle presence time (microseconds)
17	Spd Trp Timing	Speed trap timing
18	V count	Vehicle count
19	V speed	Vehicle speed (mi/h or km/h)
20	V type	Vehicle type (classification)
21	V occ	Vehicle occupancy
22	V volume	Vehicle volume
23	Special Field 1	Device-specific output #1
24	Special Field 2	Device-specific output #2
25	Special Field 3	Device-specific output #3

Field 6: T Chrono

Elapsed chronological time in seconds since the data logger last began operation (not necessarily since the beginning of a run). In most instances, the data logger hardware ran continuously whether or not data were being recorded, thus *T Chrono* usually is not equal to zero at the beginning of a run.

Fields 7-8: Temp 1 and Temp 2

When available, two separate temperature probes were employed to measure the temperature in centigrade. Fields 7 and 8 are reserved for these values.

Fields 9-10: Wind Speed and Wind Direction

An anemometer was used to provide wind speed and wind direction readings at 5-second sampling intervals.

Fields 11-12: Frame # VCR1 and # VCR2

Tape address numbers were assigned every second for both PC-VCRs. These are used in post-processing to synchronize video to the displayed data on a monitor. A single VCR was used in Minnesota and Florida. A second was added for the Arizona tests to record the video from two cameras that provided inputs to the video image processors.

Field 13: Detector ID

Contains the detector identification acronyms described in the Appendix H site hookup files.

Field 14: Detector Interface Number

Many detectors provided multiple outputs. The interface number distinguishes between these outputs in post-processing. A detailed listing of the detector interface numbers appears in the site hookup files in Appendix H.

Field 15: V detect

A value of unity appears in this field for all recorded events to aid in the accumulation of counts in Mathcad.

Field 16: V presence

Vehicle presence time in microseconds. Presence is defined as the time duration over which the detector output indicates a vehicle in its sensing area. It roughly corresponds to the time a vehicle occupies a detector's detection zone. Long electronic hold times can cause considerable errors in the presence measurement. Where adjustable, detector hold times were set to the minimum value. Even then, the presence measurement was sometimes in error when the traffic flow was heavy and the detector could not reset to record the passage of the next vehicle.

Field 17: Speed Trap Timing

Provides high resolution time stamp in 250-microsecond resolution increments. Obtained from the crystal oscillator on the Midwest Micro Tek (MMT) processor board in the data logger.

Field 18: V count

Shows cumulative vehicle count, usually over a manufacturer-specified integration interval, from detectors that output count from an RS-232 interface.

Field 19: V speed

Vehicle speed from devices that give direct speed output via a serial interface, such as radar or a video image processor. The analyst must note the units in which speed is recorded as some of the foreign devices output speed in metric units (km/h).

Field 20: V type

This field is used for detectors having a vehicle classification capability usually based on a user-selected length. The vehicle types displayed do not necessarily utilize standard classification definitions, so the vehicle type may differ from detector to detector.

Field 21: V occ

Field reserved for direct lane occupancy outputs from serial interface.

Field 22: V volume

Direct vehicle volume (or flow) data from serial interface.

Field 23: Defined as appropriate for specific detectors under evaluation.

Field 24: Defined as appropriate for specific detectors under evaluation.

Field 25: Defined as appropriate for specific detectors under evaluation.

10.3.2 Count Accuracy

One of the key goals of this program is to assess traffic parameter measurement accuracies from various detectors. A parameter of importance to the traffic management community is vehicle counts. In order to adequately compute count accuracies, a reference value must be established against which to compare the detector outputs. The determination of the count reference requires that the actual or "true" count is known. Since a video record of all the data collection runs exists, the video can be used for determining count reference values; however, it is not practical to have an observer ground truth all 500+ hours of video collected during the field tests.

A compromise was reached whereby vehicles were manually counted by a human observer for a representative time interval using samples from each test site. The results were compared against each detector utilized in that test. The detector that had the best accuracy for each test site was then used as the reference against which the accuracies of the other detectors were judged. In most cases, at least one detector could be found that was accurate to within ± 0.5 percent.

It is possible to perform detailed accuracy analyses on a particular detector output by using the video and data synchronization capability built into the Phase II software. Various types of detector parameter data can be overlaid onto the video monitor and synchronized to correspond with video events. This capability allows any number of detailed examinations to be performed in post-processing at the convenience of the analyst.

10.3.3 Speed

Another parameter employed in traffic analysis is vehicle speed. Speed can either be measured directly by a Doppler device or computed by means of a speed trap utilizing multiple detectors or multiple zones within a single detector. It is more difficult to ground truth speed than vehicle counts. One must know not only that an event has occurred, but how fast the vehicle was traveling. Another complication is the correlation of the measured or computed speed with a particular vehicle.

This problem was solved by using the Detector Systems Model 613 loop amplifier in conjunction with the Model 600A LoopComm vehicle transmitter mounted on a probe vehicle. The transmitter outputs a unique code that identifies the vehicle when it passes over an inductive loop. The vehicle is identified by a pulse output from the Model 613 loop amplifier. The pulse assists the analyst in assigning a particular vehicle speed to a unique vehicle (namely the probe vehicle) during post-processing. The test operator, when making the speed run, noted the time of day and speed that he was traveling from the vehicle's speedometer and recorded them in an engineering logbook. This gives the analyst an approximate time from which to find the output pulse and compare the speed outputs from the detectors. The exact time is noted in the database file based on the occurrence of the Model 613 pulse output.

Before the Model 613 loop detector was available, the test operator drove a probe vehicle through the detection zones with the vehicle marked in some visual way to aid in locating it on the video tape during post-processing. This approach is difficult to use because no unique signals automatically appear to identify the probe vehicle in the Paradox database file.

10.3.4 Flow

Vehicle flow is defined as the number of vehicles passing a fixed point in a given lane over some time interval (typically expressed in vehicles per hour per lane). Computing flows every several minutes and plotting the resulting values versus time of day was used to illustrate the measurement of the dynamic nature of traffic volume.

10.3.5 Density

Vehicle density is defined as the number of vehicles per lane per unit distance (typically 1 mile [1.6 km]). Most traffic detectors are incapable of monitoring long stretches of road; therefore, the most practical way to provide vehicle density is to calculate it from available detector data rather than measuring it directly. The density in vehicles per mile was expressed as the ratio of vehicle flow (in vehicles per hour) to average vehicle speed (in miles per hour). This allows the analyst to examine instantaneous vehicle densities.

10.4 FORTRAN PROGRAMS

Several FORTRAN programs were written to assist in the data reduction task. These programs manipulate the data extracted from the database into forms that are suitable for graphical presentation. Many of the parameters commonly used in traffic analysis were not directly output from the detectors. Instead they had to be calculated from the parameters that were available. The FORTRAN programs compute parameters such as vehicle counts, flow, speed, and density.

Below are the individual program names, brief descriptions of the programs, and a list of inputs and outputs. The detailed program code is contained in Appendix K.

10.4.1 COUNT.FOR

Accumulates vehicle counts from a single detector output. Each count carries with it the time stamp recorded during the actual data collection session, so the COUNT.FOR output yields vehicle counts versus time of day. Outputs from several detectors can be plotted on the same graph to provide a visual comparison of the cumulative vehicle counts from detectors that monitored the same lane of traffic.

Inputs:

- Eight-digit numerical file name with .CI extension (########.CI)
- Four-field PC clock time tag for each vehicle detection:
  - Hours
  - Minutes
  - Seconds
  - Hun Secs

Outputs:

- The same eight-digit numerical file name with .CO extension (########.CO)
- Text file yielding time in decimal hours and cumulative vehicle count for each vehicle detection

10.4.2 INT_CNT.FOR

Computes vehicle count accuracies and statistical measures of effectiveness over some user-defined time interval. Vehicle counts are accumulated over the desired time interval for two different detector outputs from the same lane of traffic. The first set of vehicle detections are from the detector that has been ascertained to yield the best count accuracy (usually inductive loops). These counts are used as the "truth" that the other detector counts are compared against. The program computes the count difference and the percentage difference between the values from the two detectors for each time interval. The mean of the count difference over all time intervals of the run and the standard deviations of the count difference and the percentage count difference are also calculated.

Inputs:

- Eight-digit numerical file name with .ILI extension (########.ILI)
- Eight-digit numerical file name with .CI extension (########.CI)
- Four-field PC clock time tag for each vehicle detection:
  - Hours
  - Minutes
  - Seconds
  - Hun Secs

Outputs:

- Eight-digit numerical file name with .CO extension (########.CO)

10.4.3 DENSITY.FOR

Computes lane density, average speed, and vehicle flow for a user-defined time interval for detectors that occur in pairs within a given lane. The high-resolution time tags used for these pairs of events come from the speed trap times that are generated by a crystal oscillator with 250-microsecond resolution. Speeds are computed between the speed traps by computing the time change between events and dividing by the speed trap spacing. Density is computed as the ratio of vehicle flow to average speed over some integration time interval. Flow, speed, density, and time of day are output into a text file.

Inputs:

- Eight-digit numerical filename with .DI extension (########.DI)
- Four-field PC clock time tag for each vehicle detection:
  - Hours
  - Minutes
  - Seconds
  - Hun Secs
- Detector Interface Number (e.g., lead loop = 1, following loop = 2)

- Speed trap time tag reference value

Outputs:
- Eight-digit numerical filename with .DO extension (########.DO) and parameters

- Integration interval number
- Time of day (hours)
- Vehicle flow (vehicles/hour)
- Average speed over interval (mi/h)
- Lane density (vehicles/mile)

10.4.4 OVF.FOR

Computes lane occupancy versus vehicle flow for a user-defined time interval. Lane occupancy is calculated as the percentage of time that a detector output is in the active or "high" state over a user-defined time interval. Occupancy is commonly used as a surrogate for lane density and is dependent upon a detector's count accuracy, size and shape of the detection footprint on the ground, and the hold time of the detector electronics.

Inputs:
- Eight-digit numerical filename with .IN extension (########.IN)

- Four-field PC clock time tag for each vehicle detection:

  Hours
  Minutes
  Seconds
  Hun Secs

- Vehicle presence time (seconds)

Outputs:
- Eight-digit numerical filename with .OFO extension (########.OFO) and parameters

- Time of day (hours)
- Lane occupancy (percent)
- Vehicle flow (vehicles/hour)

10.4.5 DENS_TOD.FOR

Computes density, speed, and vehicle flow over a user-defined integration interval.

Inputs:
- Eight-digit numerical filename with .DI extension (########.DI)

- Four-field PC clock time tag for each vehicle detection:

  Hours
  Minutes
  Seconds
  Hun Secs

- Detector interface number

Outputs:
- Eight-digit numerical filename with .DO extension (########.DO) and parameters

- Time of day (hours)
- Vehicle flow (vehicles/hour)
- Average speed (mi/h)
- Lane density (vehicles/mile)

10.4.6 DENS_232.FOR

Computes the same parameters as DENS_TOD.FOR, but uses directly measured speed inputs from detectors having RS-232 serial outputs.

Inputs:
- Eight-digit numerical filename with .DI extension (########.DI)

- Four-field PC clock time tag for each vehicle detection:

  Hours
  Minutes
  Seconds
  Hun Secs

- Measured vehicle speed (mi/h)

Outputs:
- Eight-digit numerical filename with .DO extension (########.DO) and parameters

- Time of day (hours)
- Vehicle flow (vehicles/hour)
- Average speed (mi/h)
- Lane density (vehicles/mile)

10.4.7 GP_COUNT.FOR

Outputs vehicle counts versus time of day for the Tucson surface-street site. Counts are only noted for through-traffic, i.e., during the signal green phase.

Inputs:
- Eight-digit numerical filename with .GPI extension (########.GPI)
- Four-field PC clock time tag for each vehicle detection:

  Hours
  Minutes
  Seconds
  Hun Secs
- Eight-digit numerical filename with .GP extension (########.GP)
- Four-field PC clock time tag for each falling edge of the green signal phase:

  Hours
  Minutes
  Seconds
  Hun Secs
- Presence time for green phase (green duration)

Outputs:
- Eight-digit numerical filename with .GPO extension (########.GPO)
- Vehicle counts accumulated over the green signal phases during the period of the run.

10.4.8 OCC.FOR

Computes lane occupancy values over a user-defined integration time interval. Presence values are accumulated for a given detector output over the integration interval chosen by the user. The accumulated presence is divided by the integration interval, yielding the percentage of the time that a given detector is in the active state during the integration window. Strictly speaking, the resulting value is not exactly the percentage of the time that a vehicle resided in the detection zone as the computed value is also a function of the electronic hold time of the detector.

Inputs:
- Eight-digit numerical filename with .IN extension (########.IN)
- Four-field PC clock time tag for each vehicle detection:

  Hours
  Minutes
  Seconds
  Hun Secs
- Vehicle presence (seconds)

Outputs:
- Eight-digit numerical filename with .OUT extension (########.OUT)
- Time of day (hours)
- Lane occupancy (percent)

10.4.9 SVF.FOR

Computes flow and average speed over a user-defined integration interval.

Inputs:
- Eight-digit numerical filename with .SFI extension (########.SFI)
- Four-field PC clock time tag for each vehicle detection:

  Hours
  Minutes
  Seconds
  Hun Secs
- Measured vehicle speed (mi/h)

Outputs:
- Eight-digit numerical filename with .SFO extension (########.SFO) and parameters
- Time of day (hours)
- Accumulated interval count
- Vehicle flow (vehicles/hour)
- Average speed over interval (mi/h)

10.5 VIDEO/DATA SYNCHRONIZATION USING THE PC-VCR

The Phase II software provides the capability to overlay a variety of information onto the video monitor so that relevant parameters can be superimposed over the ground truth or any recorded video segment during post-processing. Video/data synchronization enables the analyst to visually correlate the actions of individual vehicles with the measured or computed traffic parameters associated with them. The analyst may also revisit the field test data at his leisure and concentrate his attention on the performance of a particular detector.

An example of the utility of video/data synchronization is as follows. Perhaps the results of a certain run indicate that a video image processor is noticeably undercounting vehicles. Displaying the accumulated counts for that particular device in conjunction with the recorded video may indicate that the VIP was failing to detect dark-colored automobiles, possibly due to a problem in the brightness threshold setting. Or perhaps the VIP is overcounting and analysis shows that the device was detecting shadows from vehicles in adjacent lanes, or maybe a magnetometer is double- or triple-counting tractor-trailer rigs. Such trends will become evident when examined using this tool.

Using the video/data synchronization portion of the Phase II software requires the following items:

(1) Copy of the raw data file (example, 02110625.DAT).

(2) A file VCR.LOG containing the detector output data or attributes the analyst wishes to overlay.

Up to 10 attributes can be displayed on the video monitor. The numbers in Figure 10-7 represent the location of the 10 data items displayed in the video.

Each line of the VCR.LOG file consists of a video tape index number that exists both in the raw data file and on the tape itself (these are the reference markers that synchronize the video and the detector output data) and a maximum of 10 attributes. The structure of each line is:

> Tape Index PG #, Attribute 1, Attribute 2, ..., Attribute 10

The first field must contain the tape index numbers. The remaining fields (up to 10) may contain whatever information the analyst wishes to display, the order being up to the analyst. Microsoft Excel is a useful tool for manipulating the data columns. VCR.LOG must be in a comma-delimited format.

1	2
3	4
5	6
7	8
9	10

Figure 10-7. Configuration of Displayed Detector Data Attributes

10.6 A QUALITATIVE VIEW ON DETECTOR INSTALLATION AND APPLICATIONS TO TRAFFIC MANAGEMENT

In addition to the quantitative results from the field evaluations, several qualitative features, such as ease of use, setup difficulty, and reliability impact detector deployment.

Each detector has its own unique mounting requirements that may affect its suitability for a particular application. A broad spectrum of mounting locations were encountered during the *Detection Technology for IVHS* field tests. They allowed an assessment of the operation and deployment of the detectors under a wide range of traffic flow, environmental, and mounting conditions.

The mounting locations of the detectors were somewhat constrained due to the large number of detectors. Some of them were designed to look directly downward at nadir and, as such, were not obstructed by other detectors mounted below them. These devices were, therefore, located at the bottom of whatever mounting fixture was used. Doppler devices, which included some microwave detectors and some ultrasonic detectors, and the infrared detectors were mounted at an incidence angle between nadir and 90 degrees. The location of such a detector on a structure with a catwalk was high enough to avoid interference by the metal walkway grating and hand rails. Video image processors sometimes specified a higher optimum camera height than was obtainable on an existing overpass or sign-bridge structure. In these cases, the camera was mounted as high as possible.

The specific data output by each detector were shown in Tables 4-9 and 9-2, and the output type (discrete or serial) was shown in Table 8-4.

10.6.1 Ultrasonic Detectors

Sumitomo SDU-200 (RDU-101) Ultrasonic Doppler Detector (U-1)

This detector was inadvertently identified as a model SDU-200 at the start of the program. We later learned that the correct model identification was RDU-101. A dual horn transducer (one to transmit, one to receive) is provided along with electronics enclosed in a rugged cabinet. The device outputs separate pulses for long and short vehicles and these were recorded using the data logger's relay inputs. In theory, the sum of the long and short vehicle pulses should add to the total vehicle count, however, in practice, these outputs were but a small percentage of the true vehicle count. This detector also provided a digitized 8-bit speed output that was not compatible with the data logger's input types; therefore, the field tests were unable to evaluate this feature. One difficulty with this product is its 100-Volt AC power input, which requires a stepdown transformer to supply the specified input voltage.

Sumitomo SDU-300 Ultrasonic Presence Detector (U-2)

This device consists of a single transducer head and remote electronics packaged similarly to that of the SDU-200. The head is oriented directly downward over traffic, such that its footprint is circular and directly underneath the transducer. Three different heads are available to control the size of the footprint. Setting the sensitivity and gain to correspond to the mounting height requires an oscilloscope. Once the proper settings are obtained, the SDU-300 is a reliable, rugged device that yields vehicle counts and presence.

Microwave Sensors TC-30C Ultrasonic Presence Detector (U-3)

This unit is extremely simple to mount and use. Once supplying power, setup time takes no more than 10 to 15 minutes. The compact detector package houses all of the detector electronics, including simple potentiometer adjustments for gain, range, and hold time. The detector has a light-emitting diode (LED) on the back of the housing that can be used to visually correlate the passing of a vehicle with the output of the detector during setup.

10.6.2 Microwave Detectors

Microwave Sensors TC-20 Medium Beamwidth Motion Detector (M-1)

The TC-20 is a low-cost, compact motion detector that operates on the Doppler principle. Its effectiveness in the field tests was limited by its inability to operate as a presence detector since it can only detect moving vehicles. Even then, its minimum electronic hold time was too long to accurately count vehicles in a high-speed, high-density traffic environment. Its primary function is to detect the arrival of vehicles approaching a signalized intersection, not to count individual vehicles or measure their presence times. The device is easy to mount and wire. The response to vehicle flow direction is changeable by moving a pair of jumpers. The output is a simple relay contact closure.

Microwave Sensors TC-26 Medium Beamwidth Motion Detector (M-2)

The TC-26 is a more sophisticated version of the TC-20. In addition to the relay output, the TC-26 provides five optically isolated speed bin outputs. The speed bin outputs utilize a +5 VDC transistor-to-transistor logic (TTL) level and provide a coarse speed indication without the need for an RS-232 serial line. Numerous difficulties were encountered in the field regarding the speed bins, such as spurious toggling of one or more bins. The response to traffic flow direction is easily set by means of a switch located inside the detector housing.

Whelen TDN-30 Narrow Beamwidth Motion Detector (M-4)

This device is a self-contained Doppler speed detector with two optically isolated outputs to emulate loops and a serial output for direct speed measurement. The direction of traffic flow is changed by means of a jumper setting. The lightweight, 1-foot (0.3-m) cube-shaped detector is easy to mount. The Whelen detectors experienced two problems during the testing effort: water seepage into the unit and loss of the serial communication data on several occasions. Power to the detector had to be cycled at the start of a run before the serial communication began. The latter problem could be serious if these devices were deployed in a traffic management application and a power grid went down. The detectors have since been redesigned with new housing and new seals to prevent the water leakage problem. The communication problem can be remedied, perhaps, with the introduction of a new RS-232 transmitter chip. When operating properly, the detectors appeared to provide high-accuracy count and speed data, and their serial data protocol was one of the easiest to decode.

Whelen TDW-10 Wide Beamwidth Motion Detector (M-5)

The TDW-10 is a wide-beam version of the TDN-30. The two units share common electronics. A jumper setting distinguishes between wide-beam and narrow-beam electronics operation, but the TDW-10 has a wide-beam antenna that distinguishes it from the narrow-beam version. The TDW-10 can monitor up to three or four lanes of traffic (all lanes must be moving in the same direction), depending on the mounting geometry and the width of the lanes, but it merges the data from the lanes into one detection zone.

Electronic Integrated Systems RTMS-X1 Microwave Radar Presence Detector (M-6)

The RTMS is unique among the microwave detectors employed in these tests due to its true presence-sensing and multizone vehicle detection capabilities. All of the other microwave detectors are Doppler devices that key off of vehicle movement, whereas the RTMS can detect motionless vehicles. The unit can be deployed in a forward-looking or side-looking mode. It can also be used to look diagonally across an intersection. Detection parameters and location of the detection zones are set remotely by means of a software interface. This allows the user to perform a portion of the setup procedure without closing lanes. This device has 12 optically isolated outputs that can be used to determine vehicle queues in the forward-looking mode, or to monitor up to 8 separate lanes in side-looking mode. A single side-looking detector can monitor lanes traveling in opposite directions.

10.6.3 Infrared Detectors

Schwartz Electro-Optics Model 780D1000 Autosense I Laser Radar (IR-1)

This active infrared radar transmits two rows of laser beams in the near IR spectrum across a lane and detects the reflected energy when the beams impinge upon a passing vehicle. The unit has both relay and serial outputs. It could only detect approaching vehicles until late in the testing process, when the unit's firmware was modified to detect either approaching or departing traffic. Problems were experienced with the serial communication hardware early in the program. An RS-232 chip manufactured by a different supplier was eventually inserted to replace the original one and the unit's reliability improved.

Eltec Model 842 Passive Infrared Presence Detector (IR-2)

The 842, by virtue of its role as a presence detector, has a long electronic hold time. Its primary function is to provide intersection control. This affected its ability to accurately count vehicles in heavy traffic because the falling edge of its output pulse often did not occur prior to the entrance of another vehicle into the detection zone. Consequently, the vehicle count from the 842 was lower than that from other detectors. However, keep in mind that this detector was not designed for vehicle counting, although the detector was used in this manner. This device has a simple relay closure output.

Eltec Model 833 Passive Infrared Detector (IR-3)

The Eltec 833 is designed for traffic signal control and vehicle counting applications. The unit tested in the field had a much shorter hold time than the 842, making it a better candidate for high-speed, high-traffic-volume counting. The relay in the original unit was configured with a normally closed output. Over a period of time, this caused the relay contacts to burn and the unit eventually failed. After repair, it was configured to operate in the normally open mode and no further problems were experienced throughout the remainder of the field tests.

Grumman Imaging IR Traffic Sensor (IR-4)

This system uses high-resolution, passive infrared imaging over a wide field of view. Its infrared spectral operating region provides an advantage in adverse weather over video image processors that operate in the visible spectrum. The product employs a focal plane cooler to increase thermal sensitivity. Typically, coolers are not known for their longevity and devices that have them require more power than uncooled devices. However, the power requirement may not be limiting in traffic management applications. The unit can be used for both high-speed traffic management and controlling signalized intersections.

10.6.4 Video Image Processors

Econolite Autoscope 2003 (VIP-1)

The Autoscope 2003 is a wide-area vehicle detection system that uses video imaging as an alternative to inductive loops in multiple lanes and multiple directions of traffic. It accepts inputs from up to four video cameras and provides vehicle presence, flow, time headways, occupancy, speed, and classification based on vehicle length. Vehicle detection is provided either from loop detector compatible outputs on an external interface module (EIM) or from a serial output. The traffic data can be accumulated into 10-second to 1-hour intervals for individual lanes or multiple lanes. The full capability of the Autoscope could not be explored in the field tests because the output serial data protocol was not made available to the engineers performing the tests. This did not allow correlation of the parameters computed from the EIM loop detector compatible outputs with the serial output parameters computed by the Autoscope 2003. However, output detections from the EIM were time-tagged and recorded in order to calculate vehicle count and speed.

Econolite recommends using a Burle Model TC 650EA camera that incorporates automatic gain control circuitry and auto-iris to minimize difficulties caused by blooming from vehicle headlights during nighttime operation. It has 383-line resolution with a 510x492 pixel CCD array.

Computer Recognition Systems Traffic Analysis System (TAS) (VIP-2)

The TAS is based on automatic machine vision technology and edge detection algorithms. It performs traffic flow analysis by tracking vehicles on multi-lane highways; monitoring up to three lanes of traffic; and computing statistical traffic flow parameters such as average speed, lane occupancy, and lane density. It provides vehicle classification based on user-supplied lengths, traffic parameters based on vehicle class, and speed alarm notification. The standard package includes setup software.

Traficon CCATS-VIP 2 (VIP-3)

The CCATS-VIP 2 uses detection zones to monitor traffic flow. It is capable of monitoring up to four lanes of traffic from a single camera. This device incorporates graphical data interpretation and a display package that outputs total number of vehicles and number per lane, gap time between vehicles, lane occupancy, vehicle classification (up to three types) based on length, mean length of all detected vehicles, and alarms at lower and upper thresholds set by the user. This unit is neatly housed in a compact package. The software version evaluated in the field tests experienced problems detecting dark-colored vehicles in shadowed areas. Newer software supposedly corrects the problem.

Sumitomo IDET-100 (VIP-4)

The IDET-100 employs vehicle edge detection algorithms to compute traffic volume, vehicle type, and speed for up to four lanes of two-way traffic simultaneously. Vehicles can be tracked even as they change lanes.

Traffic data are reported by lane via an RS-232 interface. Data include vehicle detection with a claim of 90-percent accuracy, vehicle type (small or large), velocity in kilometers per hour, vehicle status (moving, recently stopped, or parked), and the pulse width of the detection signal.

EVA 2000 (VIP-5)

The EVA 2000 monitors up to four lanes of traffic from a single camera. The VIP tracks vehicles and provides traffic volume, average speed, density, occupancy, average spatial headway, and vehicle counts, each on a per lane and vehicle type (two types are supported) basis. The EVA 2000 can track individual vehicles even when they cross lanes.

10.6.5 Acoustic Array

AT&T SmartSonic TSS-1 (A-1)

This passive acoustic array was used in only two of the seven field test sites (Phoenix freeway in Autumn 1993 and Tucson surface street in Winter-Spring 1994). The detector was large, heavy, and cumbersome; its very size and weight presenting a challenge to the crew charged with its installation. Since the completion of the field tests, AT&T has produced a next-generation version of the unit in a dramatically smaller package (approximately half the size and weight). One of the attractive features of the AT&T acoustic array is its ability to emulate inductive loop outputs. The electronics card for the acoustic array fits into a Type 170 rack and, therefore, can be exchanged with existing loop amplifier electronics.

10.6.6 Magnetic Detectors

Midian Self-Powered Vehicle Detector (SPVD) Magnetometer

The SPVD is a system that detects the presence of a vehicle by measuring its magnetic field from beneath the roadway surface. As its name implies, the power for this unit is entirely self-contained within the SPVD. Traffic data and device status are transmitted to a roadside receiver by means of a radio frequency (RF) link that uses an antenna built into the housing of the buried magnetometer. An external antenna, connected to a receiver with a coaxial cable, is required to receive the data. The receiver may be located in a controller cabinet and may serve as the interface with a traffic management system.

3M Microloop Magnetometer (L-1)

The 3M Microloop probe is a small, cylindrical transducer that transforms changes in magnetic field intensity into inductance changes which can be sensed by loop detector electronics. The probes are inserted into 1-inch (25.4-mm) holes 16 to 24 inches (406.4 to 609.6 mm) beneath the road surface.

Each instrumented lane requires from one to three microloop probes, the number being a function of the lane width and the height of the vehicles to be detected. These devices are advertised to perform in high-iron environments, such as on or under bridge decks.

10.7 PRESENTATION OF DATA ANALYSIS RESULTS

Since reducing all the data collected during the field tests was beyond the scope of this phase of the project, a representative sample of the data was analyzed to reflect the different sites and different traffic and weather encountered. The results, therefore, represent a wide spectrum of conditions chosen to stress the performance of the detectors under test. Figure 10-8 shows the structure in which the detector performance results are presented. The numbers appearing in parentheses in the boxes correspond to the section numbers in this chapter. The runs analyzed and the characteristics associated with them are given in Table 10-2. The column labeled Hookup Configuration refers to Appendix H, where the connections of the detector outputs to the data logger are shown along with the input power connections to the detectors.

Table 10-2. Runs Analyzed in this Report

Run	Site	Traffic Flow	Weather	Hookup Configuration
02081127	MN Freeway	Departing	Cold, overcast	Hookup 4A
02091626	MN Freeway	Depart & Approach	Cool, overcast	Hookup 4A
02110625	MN Freeway	Departing	Cold, light flurries	Hookup 1A
03091019	MN Street	Departing	Cold, snow	Hookup 6
03101343	MN Street	Departing	Cold, clear	Hookup 6
07221647	FL Freeway	Approaching	Hot, humid	Hookup I-4
07231329	FL Freeway	Approaching	Warm, heavy rain	Hookup I-4
07280615	FL Freeway	Approaching	Hot, humid	Hookup I-4
09071553	FL Street	Departing	Hot, humid	SR 436
09141730	FL Street	Departing	Hot, humid	SR 436
11090822	AZ Freeway	Approaching	Mild, dry	Phoenix 93
11221359	AZ Freeway	Approaching	Mild, dry	Phoenix 93
07281536	AZ Freeway	Approaching	Hot, dry	Phoenix 94
08041552	AZ Freeway	Approaching	Hot, dry	Phoenix 94
03101008	AZ Street	Departing	Warm, dry	Tucson
04121633	AZ Street	Departing	Warm, dry	Tucson
04131703	AZ Street	Departing	Warm, dry	Tucson

The detectors are referenced in the graphs and tables that give their performance by their model numbers. This designation was chosen so that specific designs and operating characteristics could be correlated with performance. A generic designation, such as microwave, does not account for the antenna beamwidth, hold time, or signal processing scheme that differ from device to device. These parameters must be noted, as in Tables 4-1 to 4-6 and 8-4, and taken into account to properly interpret the field test results.

Table 10-3 summarizes the ground truth from selected runs. Vehicles were counted manually by an observer from the video imagery of the traffic flow collected during the field tests. Ground truth data were tabulated for intervals ranging from 45 minutes to 2 hours, usually in 15-minute increments to reduce the error rate. A broad spectrum of traffic and weather conditions are represented. These values serve as the reference against which other detector outputs are compared when count accuracies and errors are reported. Some video was ground truthed multiple times in order to assess the accuracy and repeatability of the value recorded by the human observer. The results were typically repeatable to within ±0.25 percent.

It is not possible to precisely compare outputs from every detector represented in the field tests with the ground truth value because the

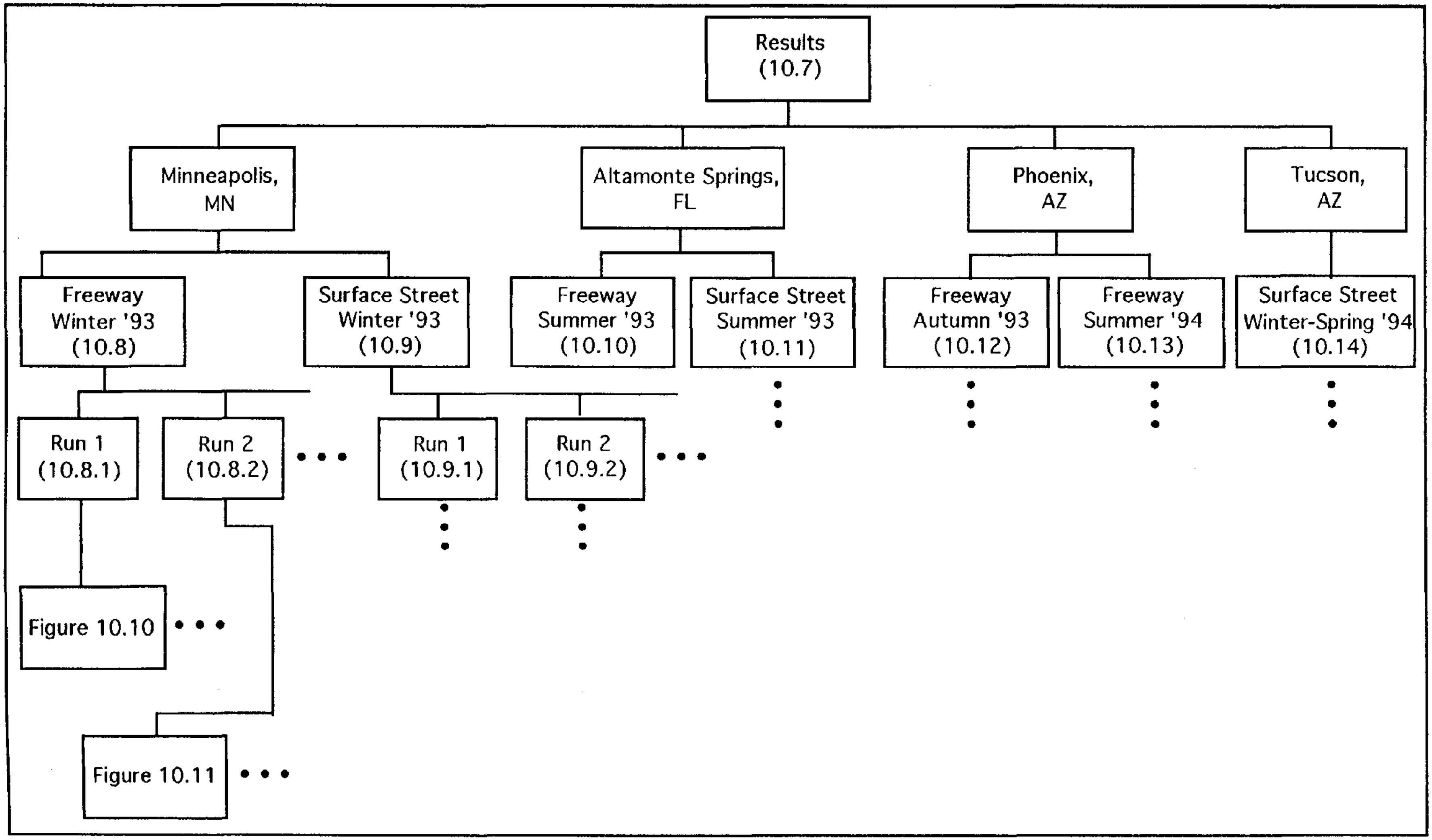


Figure 10-8. Roadmap for Detector Performance Results

sensing areas associated with each device do not exactly coincide with one another. Therefore, frequent lane changes can cause anomalies in the counts recorded by devices monitoring different sections of the same lane. Although care was taken to select sites and detector mounting locations that minimized this problem, lane changing was unavoidable at the Tucson surface-street site. However, a software program was created to filter out the great majority of anomalies resulting from vehicles sweeping across multiple lanes when completing their turning movements. This is discussed in greater detail in Section 10.14.2.

Table 10-3. Vehicle Count Ground Truth Runs

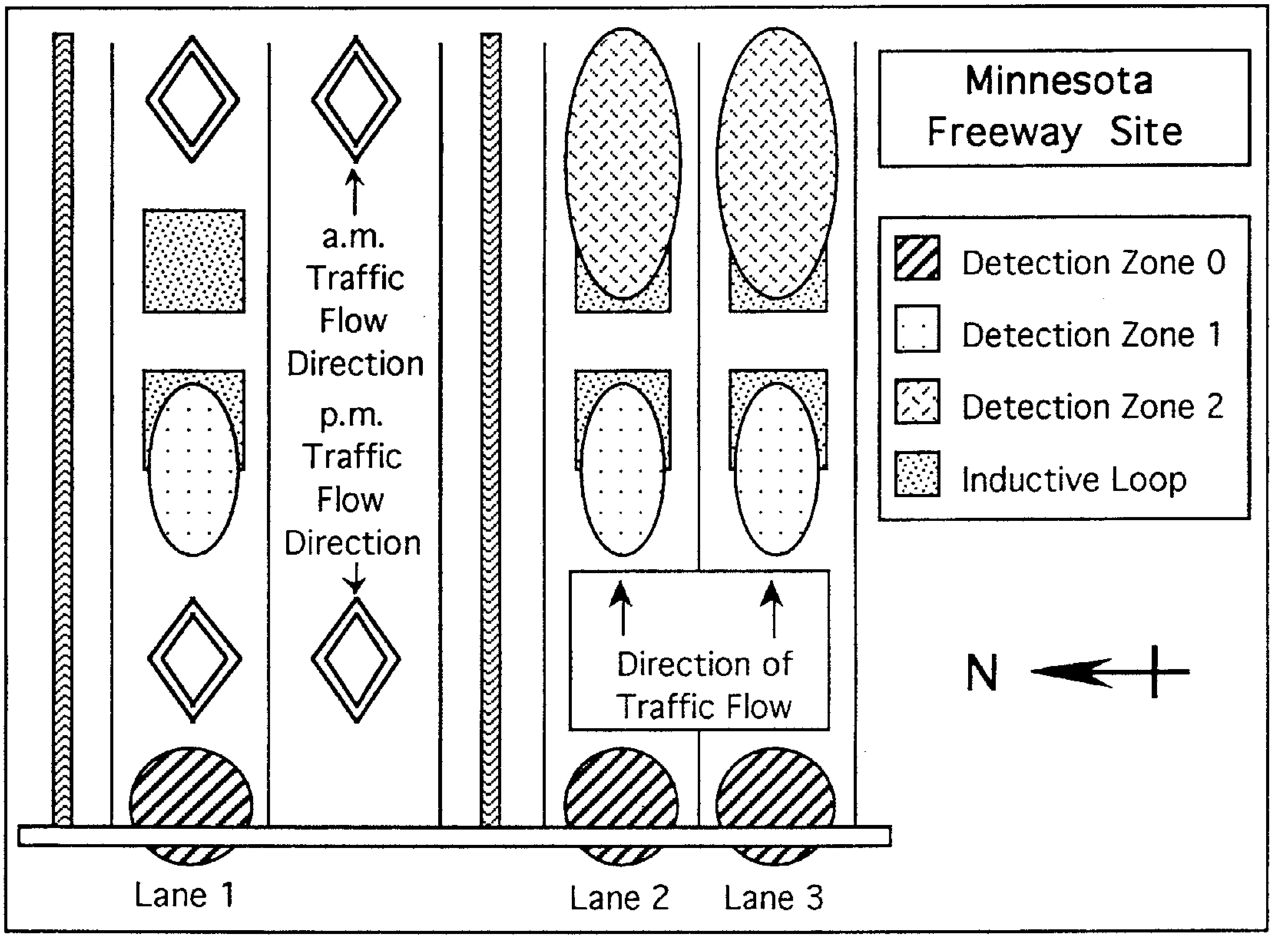
Run	Site	Weather	Start Time	Stop Time	Vehicle Counts		
					Lane 1	Lane 2	Lane 3
02011159	MN Fwy	Cool, sunny	1201	1300	*	1127	1890
02091626	MN Fwy	Cool, overcast	1815	1900	*	846	1476
02110625	MN Fwy	Cold, light flurries	0700	0800	*	1816	1862
03091019	MN Street	Cold, snow	1200	1400	245	316	–
03101343	MN Street	Cold, windy	1630	1730	413	421	–
07150617	FL Fwy	Hot, humid	0745	0845	1215	944	1108
07211633	FL Fwy	Warm, rain	1700	1800	1013	1102	501
07231329	FL Fwy	Warm, heavy rain	1330	1426	959	1052	524
07280615	FL Fwy	Hot, humid	0730	0900	2281	2193	1360
09071553	FL Street	Hot, rain	1630	1830	1815	1778	–
09080725	FL Street	Hot, humid	0730	0930	1091	866	–
09081241	FL Street	Hot, humid	1300	1500	1716	1661	–
09141730	FL Street	Hot, humid	1800	2000	1512	1434	–
11090822	AZ Fwy	Mild, dry	0900	1000	750	1033	–
11221359	AZ Fwy	Sunny, dry	1600	1700	1603	1554	–
12021502	AZ Fwy	Mild, dry	1700	1800	1436	1423	–
12090620	AZ Fwy	Cool, dry	0625	0740	1.656	1951	–
07281536	AZ Fwy	Hot, dry	1900	2000	658	828	–
08041552	AZ Fwy	Hot, dry	1700	1800	1307	1399	–
04121633	AZ Street	Warm, dry	1700	1800	–	500	429

* Lane 1 on I-394 MN freeway was a reversible HOV lane. The video camera did not monitor the traffic in this lane.

10.8 MINNESOTA FREEWAY DATA

This site was located on eastbound I-394 at Penn Avenue in Minneapolis, Minnesota. The detector layout configuration is shown in Figures 9-2 and 9-4. The I-394 freeway site was unique in that it had a pair of reversible HOV lanes as described in Section 9.1. One of these lanes was instrumented with detectors as were the two non-reversible eastbound lanes. All of the overhead detectors monitoring the HOV lane were directional devices, operating on either approaching or departing traffic, but not both at the same time. For this reason the lane 1 HOV overhead detector data were obtained only for evening runs when traffic flowed westward toward the detectors that were configured to monitor oncoming vehicles.

Figure 10-9 shows the approximate location of the sensing areas corresponding to the overhead devices and the physical locations of the inductive loops in each of the three



Zone	Lane 1		Lane 2		Lane 3	
	Symbol	**Model**	**Symbol**	**Model**	**Symbol**	**Model**
0	IR1	Schwartz 780D1000	U3	MW Sensors TC-30C	U2 IR2 IR3	Sumitomo SDU-300 Eltec 842 Eltec 833
1	IL1A-2 M1B M2B	Inductive Loop 2 (PM) MW Sensors TC-20 MW Sensors TC-26	IL1B-2 M2A M4 VP1A-3 VP2A-1	Inductive Loop 1 MW Sensors TC-26 Whelen TDN-30 Autoscope 2003 VIP TAS VIP	IL1C-2 M1A VP1A-1 VP2A-2	Inductive Loop 1 MW Sensors TC-20 Autoscope 2003 VIP TAS VIP
2	IL1A-1 M5A	Inductive Loop 1 (PM) Whelen TDW-10	IL1B-1 VP1A-4 VP2A-3	Inductive Loop 2 Autoscope 2003 VIP TAS VIP	IL1C-1 VP1A-2 VP2A-4 M5B	Inductive Loop 2 Autoscope 2003 VIP TAS VIP Whelen TDW-10

Figure 10-9. Detection Zones on I-394 in Minneapolis, MN

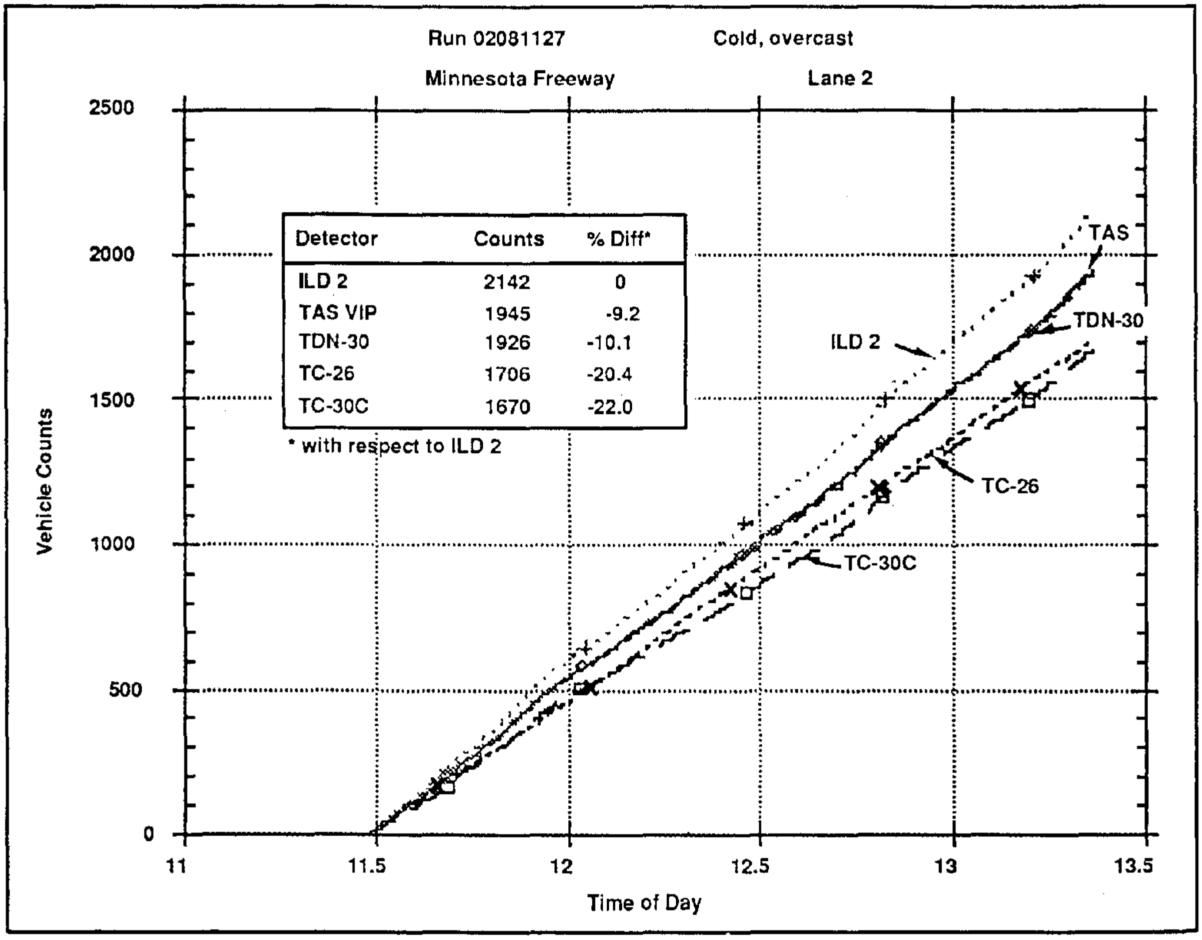
instrumented lanes. The symbol column shows the detector mnemonic and interface designation for the relay and optically isolated detector outputs. Serial interfaces are not included in this table because they typically contain data that apply to several detection zones. The serial interfaces are included in the hookup files in Appendix H. Detection Zone 0 contains the footprints of the detectors that were oriented directly downward (or nearly so) toward nadir. Detection Zone 1 contains the westernmost inductive loops in each lane and the footprints of many of the Doppler microwave detectors. Zone 2 contains the easternmost loops in each of the monitored lanes. Two video image processors were evaluated at the Minneapolis freeway site, the Autoscope 2003 from Econolite and the Traffic Analysis System (TAS) from Computer Recognition Systems (CRS). Data from two optically isolated outputs, representing the traffic count in each of the eastbound lanes, were recorded for each VIP. No serial outputs from either VIP were recorded at this site.

10.8.1 Run 02081127

This run is typical of light mid-day traffic on the I-394 freeway. The sky was overcast and the air temperature at noon was 24°F (-4.4°C).

Vehicle Counts vs. Time of Day

Figure 10-10 shows accumulated vehicle counts in lane 2 over approximately 2 hours for two Doppler microwave detectors (Microwave Sensors TC-26 and Whelen TDN-30), an ultrasonic detector (Microwave Sensors TC-30C), a video image processor (CRS TAS), and an inductive loop. Count variations on the order of 20 percent were experienced by the TC-26 and TC-30C when compared with counts from the second loop in the lane. The TAS and TDN-30 each undercounted by about 10 percent in this midday run.



Detector	Counts	% Diff*
ILD 2	2142	0
TAS VIP	1945	-9.2
TDN-30	1926	-10.1
TC-26	1706	-20.4
TC-30C	1670	-22.0

* with respect to ILD 2

Figure 10-10. Comparison of Detector Vehicle Counts in Lane 2 During Light Traffic on Minneapolis Freeway Site

The difference between the counts from the TC-26 and the loop are attributed to the relatively long hold time of the TC-26. This resulted in an average TC-26 "on" time of 2.10 seconds per vehicle as compared to 0.14 second for the loop. The standard deviation of the TC-26 on time was 1.76 seconds.

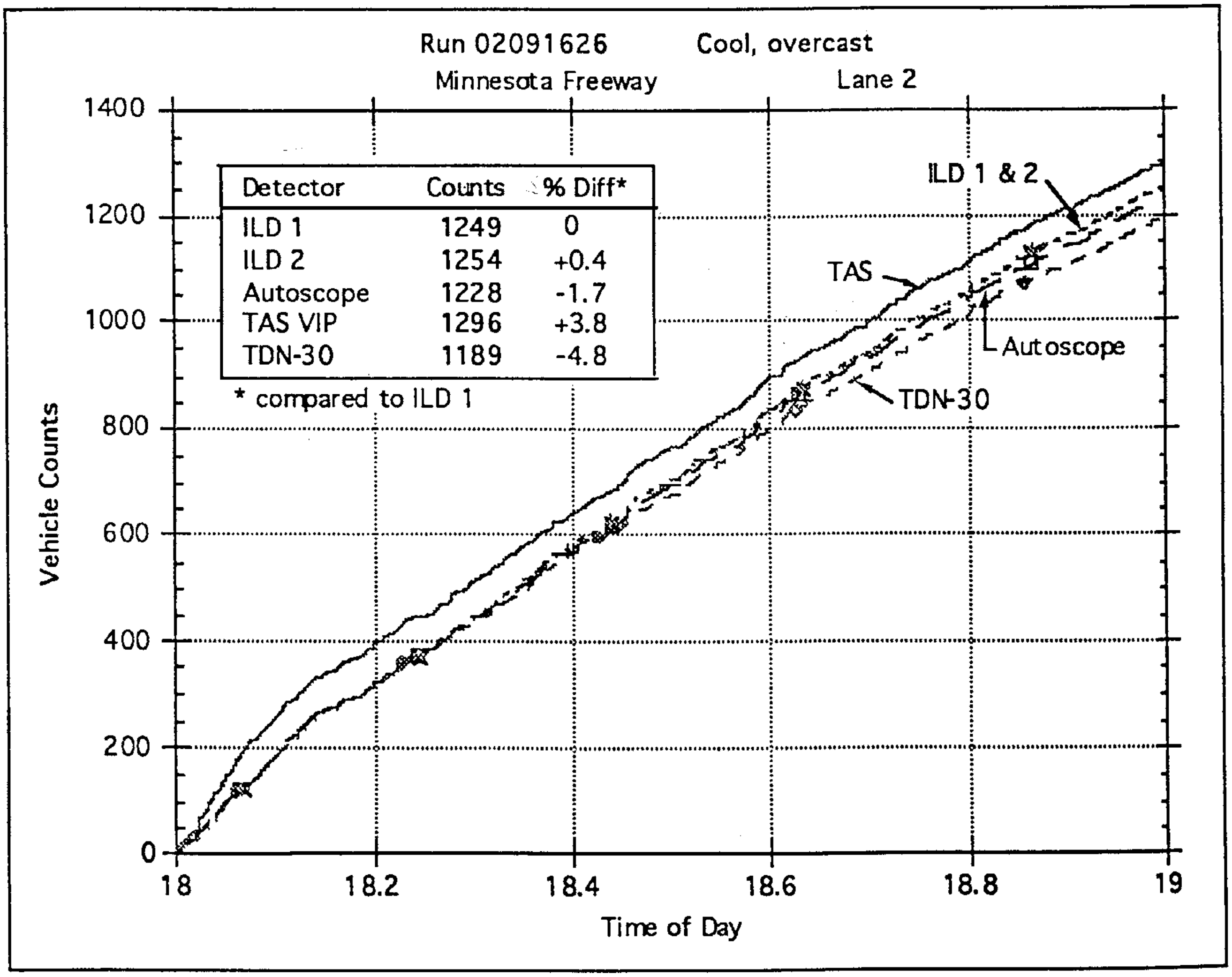
Although ground truthing from other I-394 runs shows the inductive loop to be consistently among the most accurate detectors, the loop showed a tendency to overcount slightly (by less than 0.5 percent), while the microwave and ultrasonic detectors tended to undercount. Therefore, the percent difference in counts with respect to the loop may be slightly greater than the true percent error associated with video-based ground truthing. However, even video-based ground truthing would not eliminate the majority of the large percent differences noted in the figure. The TAS VIP tended to undercount, except during dark-to-light and light-to-dark transitions, when it overcounted.

10.8.2 Run 02091626

On this portion of a nighttime run on the I-394 freeway, the count from one of the loops in lane 2 was used as the reference with which to compare counts from other detectors. The temperature was 32°F (0°C) at 6:00 p.m.

Vehicle Counts vs. Time of Day

Figure 10-11 relates vehicle counts to time of day for three detector technologies. Represented are inductive loops, Autoscope 2003 VIP, TAS VIP, and the Whelen TDN-30 narrow-beam microwave Doppler detector.



Detector	Counts	% Diff*
ILD 1	1249	0
ILD 2	1254	+0.4
Autoscope	1228	-1.7
TAS VIP	1296	+3.8
TDN-30	1189	-4.8

* compared to ILD 1

Figure 10-11. Comparison of Detector Vehicle Counts in Lane 2 During Nighttime Darkness on Minneapolis Freeway Site

Percent differences were computed for the vehicle counts given by the first inductive loop, Autoscope, TAS, and TDN-30 with respect to the second loop in the lane. The second loop was chosen as the reference because its detection zone more closely coincided with those of the VIP and the microwave detector.

The actual percent errors of the Autoscope and microwave detectors with respect to video-based ground truth are slightly less than the computed percent difference with respect to the loop, because the Autoscope and microwave detectors tend to undercount, whereas the inductive loops, although typically accurate to within 0.5 percent, tend to overcount. Therefore, a comparison with the video-based ground truth count could reduce the percent error by up to 1 percent. Conversely, the percent error (with respect to video-based ground truth) attributable to the TAS VIP is slightly greater than the 3.8 percent difference computed with respect to the loop because the TAS overcounted. The TAS counts are seen to be increasing with respect to the other detectors until shortly after 6 p.m. After this time, the TAS counts closely track those from the inductive loops.

The TAS does allow the operator to adjust a variety of setup and calibration parameters, a feature that theoretically should give more optimal performance in a true operational traffic management scenario. A factor that may have contributed to the observed performance of the TAS was the inability to position an ambient light monitoring zone sufficiently off the roadway due to the camera mounting height and location. Because of the zone's location, its ambient light monitoring function may have been affected by the headlights from oncoming vehicles.

10.8.3 Run 02110625

This run is representative of heavy volume morning rush hour traffic flow into Minneapolis. The temperature at the start of the run was 18°F (-7.8°C). Light flurries fell during the run. The first two figures from this run compare accumulated vehicle counts from the detectors, while the next three show speed, flow, and density, respectively, versus time of day. The sixth figure compares the vehicle speeds in adjacent lanes, while the last figure demonstrates the inverse relation between speed and flow that was observed in lane 2.

Vehicle Counts vs. Time of Day (Ground Truth Interval)

Figure 10-12 displays the vehicle counts in lane 2 (the leftmost of the two eastbound I-394 lanes) for a 1-hour ground truth interval as measured by five detectors. The detectors shown are the Econolite Autoscope 2003 VIP, CRS TAS VIP, Whelen TDN-30 narrow-beam microwave Doppler detector, Microwave Sensors TC-30C ultrasonic detector, and the second 6-foot by 6-foot (1.8-m by 1.8-m) inductive loop in the lane controlled by Detector Systems' 222B driver. The 7:00 a.m. to 8:00 a.m. counts generated by the detector outputs were compared to the ground truth count tabulated manually from video imagery during the post-processing analysis. The counts from the five detectors are within 0.3 to 1.6 percent of the ground truth value in this heavy traffic volume run. The TAS VIP overcounts early in the hour and undercounts for the rest of the hour, resulting in a 98.8-percent overall count accuracy.

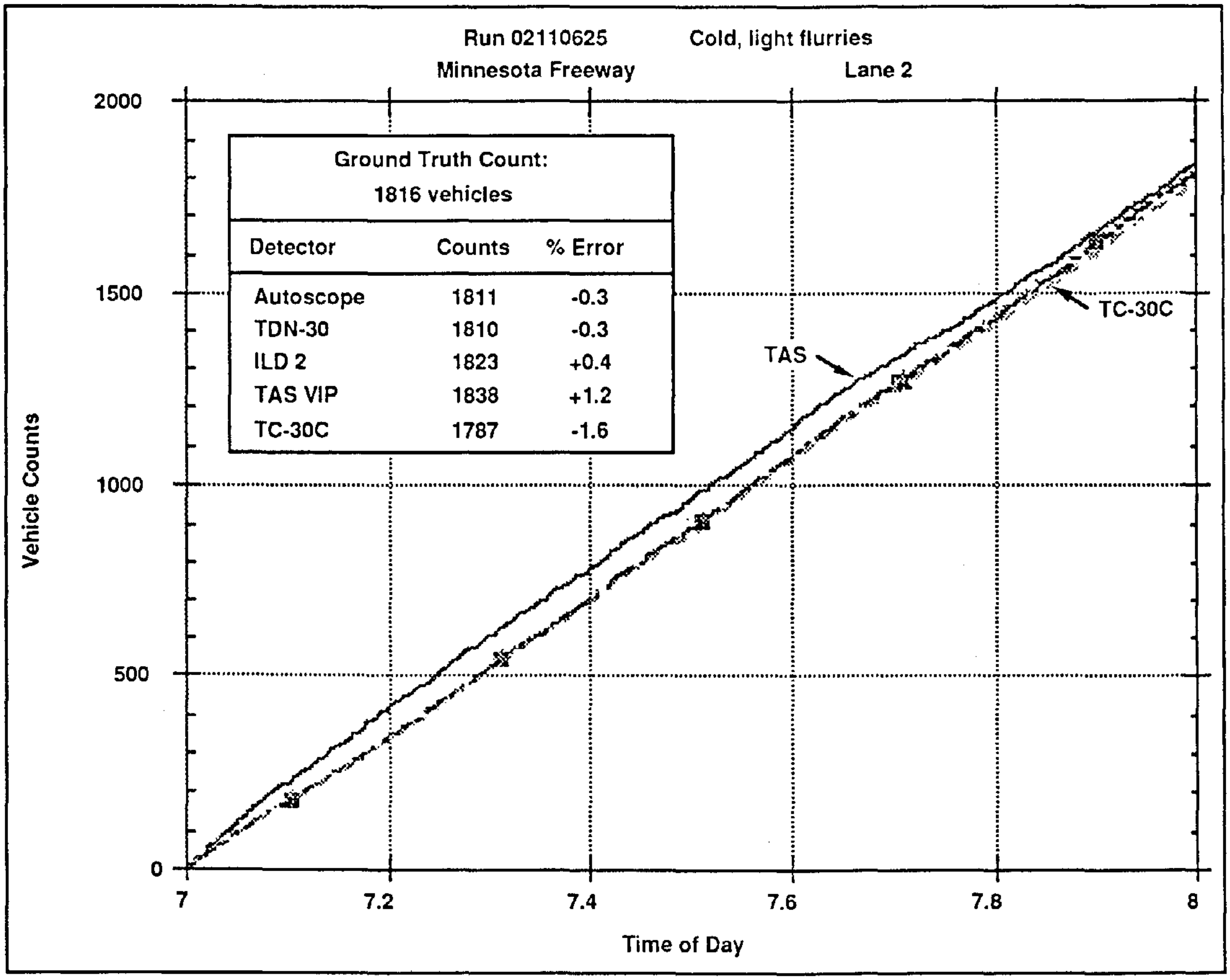
Vehicle Count vs. Time of Day Over 4 Hours

Figure 10-13 shows accumulated vehicle counts in lane 2 as a function of time of day for the approximately 4-hour run. The counts from two Doppler microwave detectors (TDN-30 and TC-26), one ultrasonic detector (TC-30C), and a video image processor (TAS) are compared with those from the second inductive loop in the lane. Percent differences were computed using the inductive loop count over the 4-hour interval as the reference.

The TDN-30 count is within 0.9 percent of the loop, the TC-30C is within 3.7 percent, and the TAS is within 0.6 percent. The on time of the TC-30C averaged 0.29 second as compared to 0.14 second for the loop. The TC-26 significantly undercounted because of the long electronic hold time characteristic of this detector. The on time of the TC-26 averaged 5.47 seconds. The standard deviation of the TC-26 on time was 6.77 seconds and for the TC-30C it was 0.08 second.

The long hold time of the TC-26 caused missed detections when vehicles were closely spaced, such as in this heavy traffic volume run. The undercount is explained as follows. The TC-26 generates an electronic pulse when a vehicle is detected. If a second vehicle enters the detection zone before the falling edge of the original pulse occurs, then the TC-26 remains in the active state and does not detect the second vehicle as a separate event. Thus, an entire platoon of vehicles may trigger only a single detection pulse. The undercounting is more prevalent during heavy traffic when intervehicle gap times are at their minimum. The almost 5.5-second on time supports the hypothesis that the TC-26 is combining the detection of several vehicles into a single output count.

The TAS VIP began the run overcounting vehicles until just after 7 a.m. This may be due to the VIP having difficulty transitioning from dark-to-light ambient lighting conditions. After this time, the TAS showed a tendency to undercount. However, the net result, a 99.4-percent counting accuracy with respect to the loop, is misleading. Had the run ended earlier than approximately 10:20 a.m., the percent difference would have been greater because the undercount interval would not have been long enough to compensate for the initial overcount interval. For example, if the run ended at 8 a.m., the TAS would show a percent difference of approximately +24 percent.



Ground Truth Count:
1816 vehicles

Detector	Counts	% Error
Autoscope	1811	-0.3
TDN-30	1810	-0.3
ILD 2	1823	+0.4
TAS VIP	1838	+1.2
TC-30C	1787	-1.6

Figure 10-12. Vehicle Counts and Ground Truth in Lane 2 from I-394 Minneapolis Freeway Site

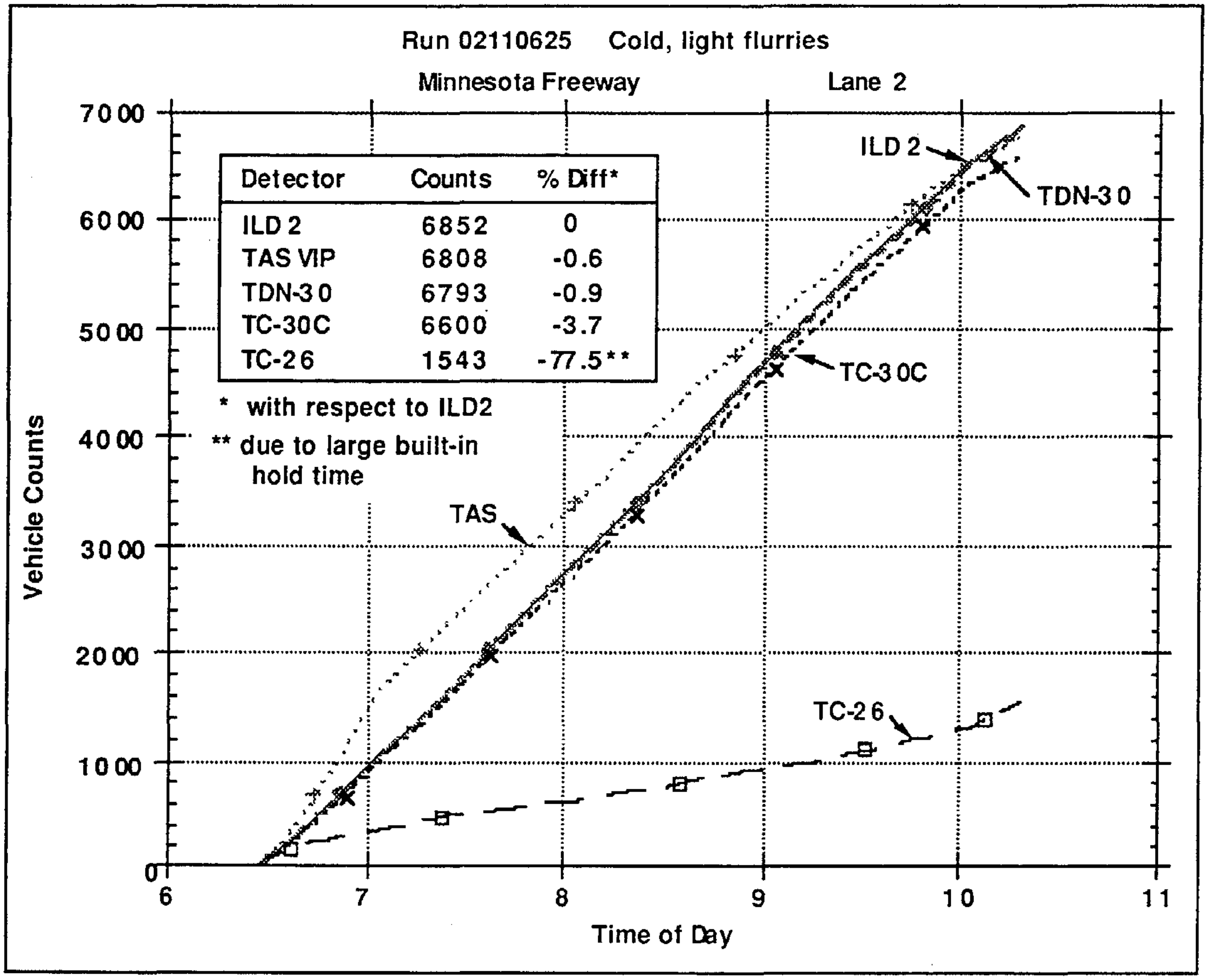
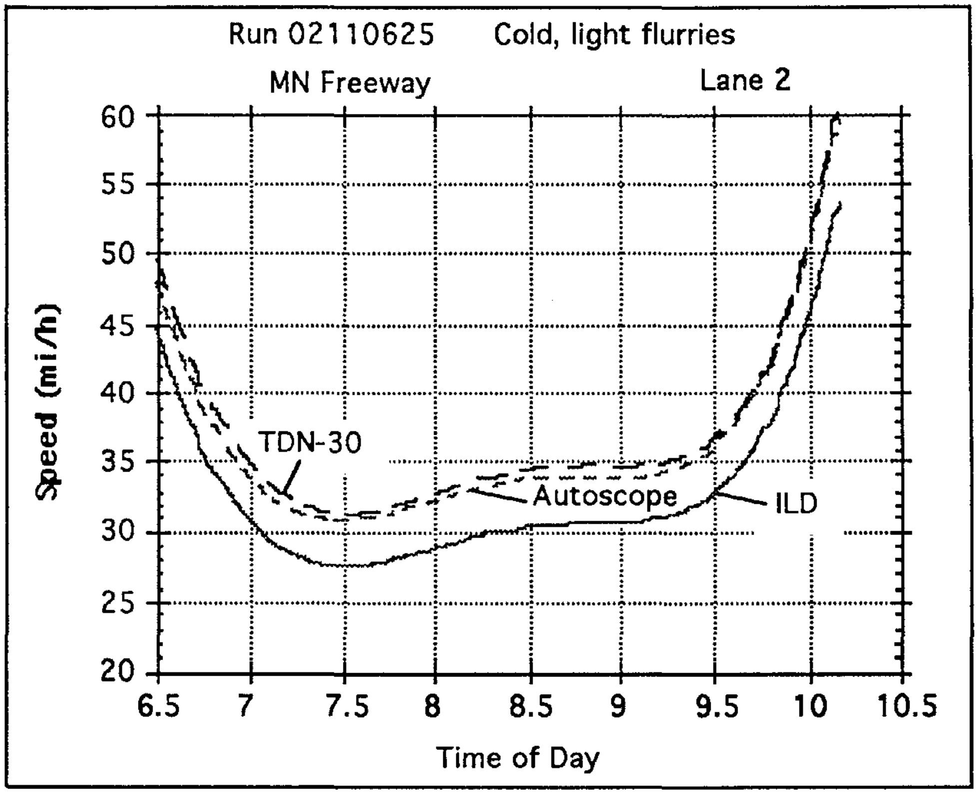


Figure 10-13. Vehicle Count Comparison Over 4-Hour Run Duration in Lane 2 on I-394 Minneapolis Freeway Site

Speed vs. Time of Day

The data in Figure 10-14 represent the entire duration of the run for all practical purposes (approximately the first 5 minutes of the run were omitted due to a "stacking up" of events in a buffer while the software began its initialization process). The plots of vehicle speed in lane 2 versus time of day were fitted with a fifth-order polynomial to the actual data in order to smooth out the spiky, discrete nature of the actual speeds. The plotted speeds are values obtained by averaging data from the TDN-30, Autoscope 2003, and a pair of inductive loops over 5-minute intervals. The three curves are consistent in their shape, with the only discernible difference being the magnitude of the speed. Speed was measured directly by the Whelen TDN-30 microwave detectors and output via an RS-232 interface to the data logger. The speeds calculated from the loops and the Autoscope VIP used the falling-edge time tag associated with each of two detection zones and knowledge of the spacings between those zones. The speeds noticeably decrease between 6:30 and 7:00 a.m. and resume free-flow conditions between 9:30 and 10:00 a.m.



1 mi/h = 1.61 km/h

Figure 10-14. Comparison of Speed Data in Lane 2 from I-394 Freeway Site

The lower speed calculated from timing of pulses generated by the two-loop speed trap is attributed to a pair of factors. The first is the sequential scanning feature used in the Detector Systems 222B loop amplifier electronics. The two loops (driven by a single, two-channel card) are alternately turned off and on so as to minimize interference due to crosstalk. This may have caused timing problems that had a significant impact on the speed calculations. One can envision the lead loop being in the off state when a vehicle passes over it. Then when the loop is energized, the leading edge of the detection pulse does not necessarily correspond to the entrance of the vehicle into the loop's detection zone.

The second difficulty stems from the width of the vehicle detection pulse. According to the loop amplifier's specification, the pulse width is 125 ± 25 milliseconds. This pulse width (and the associated 20-percent uncertainty) is quite long when compared to the 170 milliseconds necessary for a vehicle traveling at a freeway speed of 60 mi/h (96.6 km/h) to traverse the 15-foot (4.6-m) center-to-center spacing between the two loops. The maximum percentage error in speed attributed to the pulse-width uncertainty for a vehicle traveling at 60 mi/h (96.6 km/h) is approximately 30 percent.

Flow vs. Time of Day

Figure 10-15 demonstrates the relationship between vehicle flow in lane 2 and time of day. The flow has units of vehicles per hour. These plots indicate an inverse proportionality of flow with speed; that is, as the speed increases (as depicted in Figure 10-14), the flow decreases. This decrease in traffic flow is attributed to a pronounced decline in demand beginning at around 9:30 a.m. The three different types of technology demonstrated here yield comparable results.

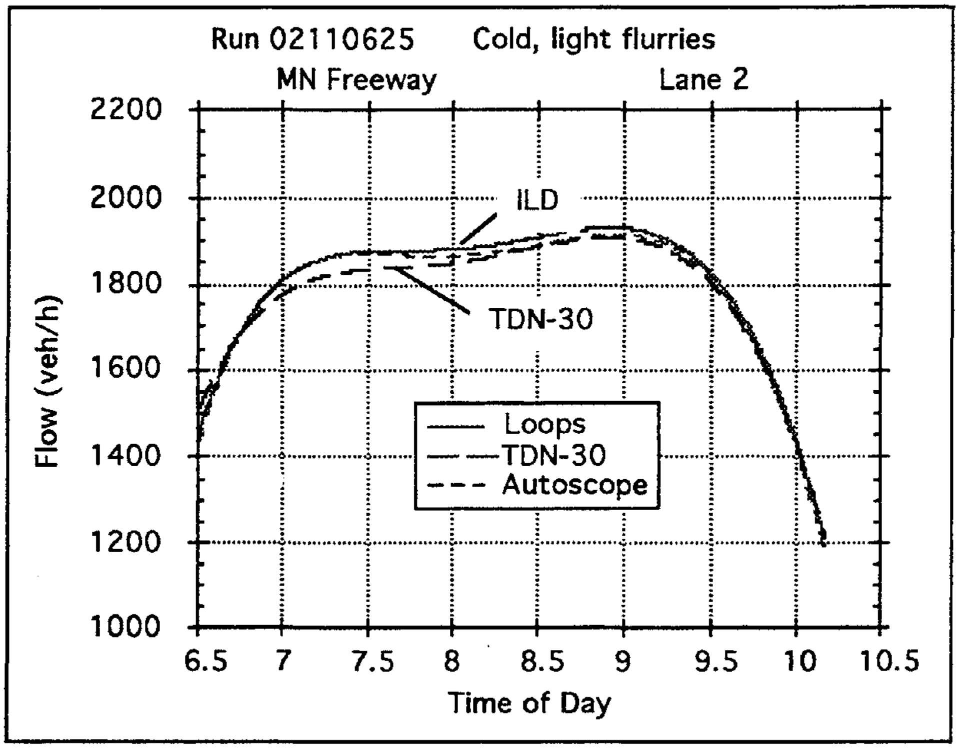
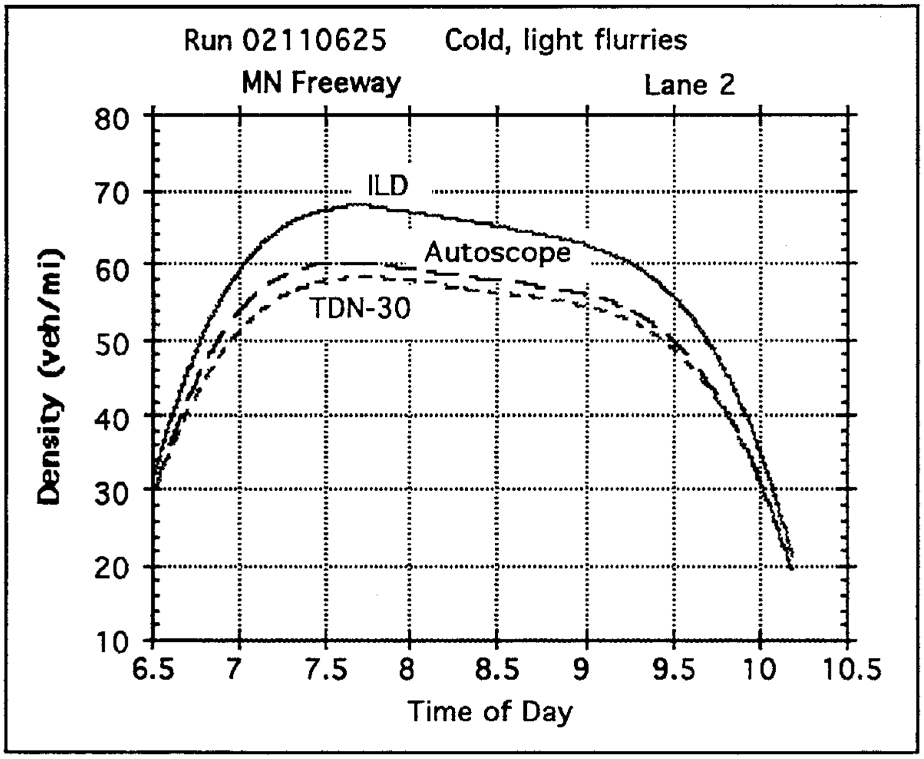


Figure 10-15. Comparison of Flow Data in Lane 2 from I-394 Freeway Site

Density vs. Time of Day

Figure 10-16 demonstrates the relationship between lane density in lane 2 and time of day. The lane density is the number of vehicles present within a 1-mile (1.6-km) distance in a given lane. Since it is not practical to measure this parameter directly without a wide-area detector, density is calculated from the available traffic data instead. The density is, therefore, computed as the ratio of vehicle flow (in vehicles per hour) to average speed (in miles per hour) over some integration interval. The density values in this example were calculated over 5-minute integration times. The interval can be defined by the user in the DENSITY.FOR program. The density plots bear out the assertion made in the preceding description of vehicle flow that the increase in speed between 9:30 and 10:00 a.m. and the corresponding decrease in vehicle flow indicate a decrease in demand during that time window.

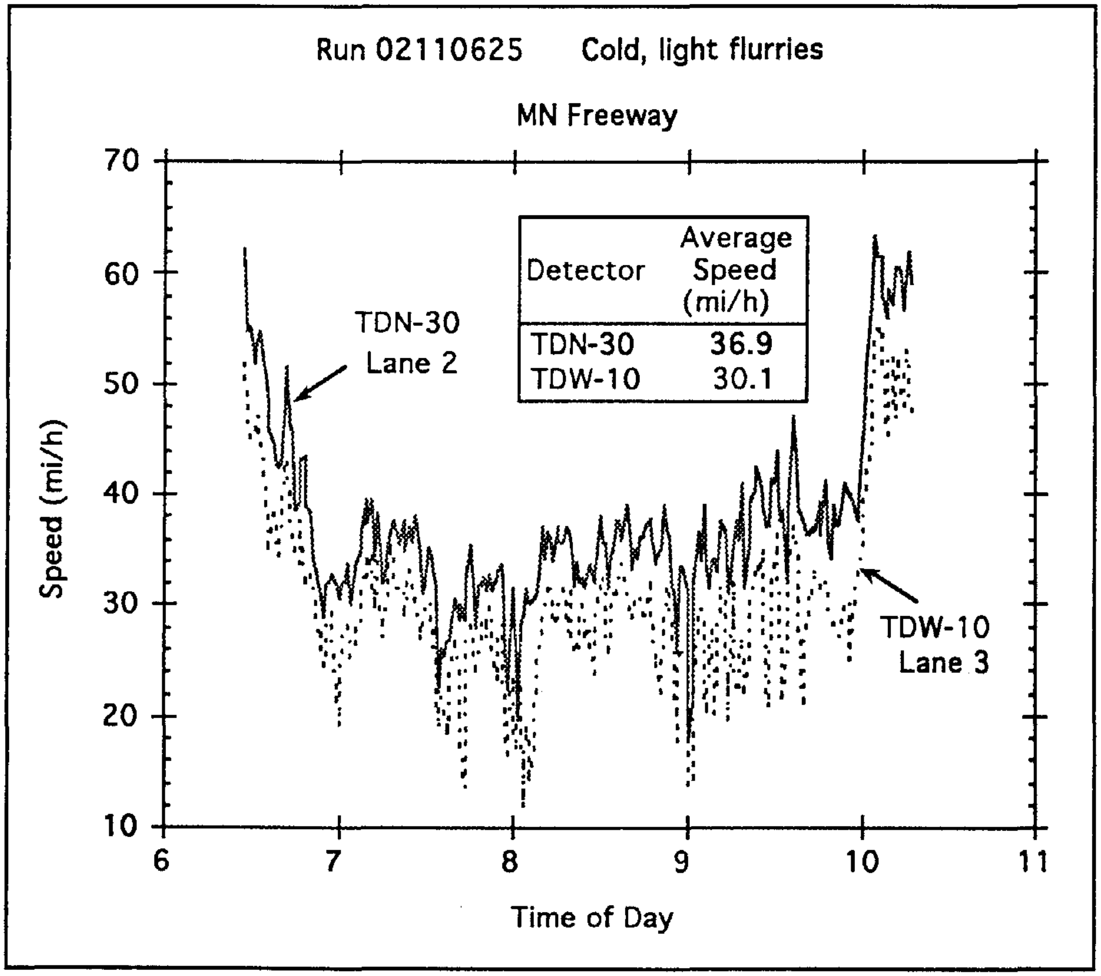


1 mi = 1.61 km

Figure 10-16. Density in Lane 2 as Computed From Data Collected at I-394 Freeway Site

Comparison of Speed From Two Detectors Monitoring Multiple Traffic Lanes

Figure 10-17 shows the relationship of speed as measured by two detectors located in adjacent traffic lanes 2 and 3. The vehicle speeds from each device were collected over a 1-minute integration interval and the average speed over that interval was computed. The uniformity in the shapes of the curves is a good indication that the detectors are correctly monitoring the traffic trends as they actually occurred. An average of the reported speeds was computed over the entire run. The TDN-30 in lane 2 (the leftmost of the two eastbound through lanes) reported an average speed of 36.9 mi/h (59.4 km/h) for the session, while the TDW-10 reported an average of 30.1 mi/h (48.4 km/h) in the right lane. The traffic in the right lane was observed, on average, to move slightly slower than the left lane. This was due to merging traffic both before and after the Penn Avenue off/on-ramp to I-394.

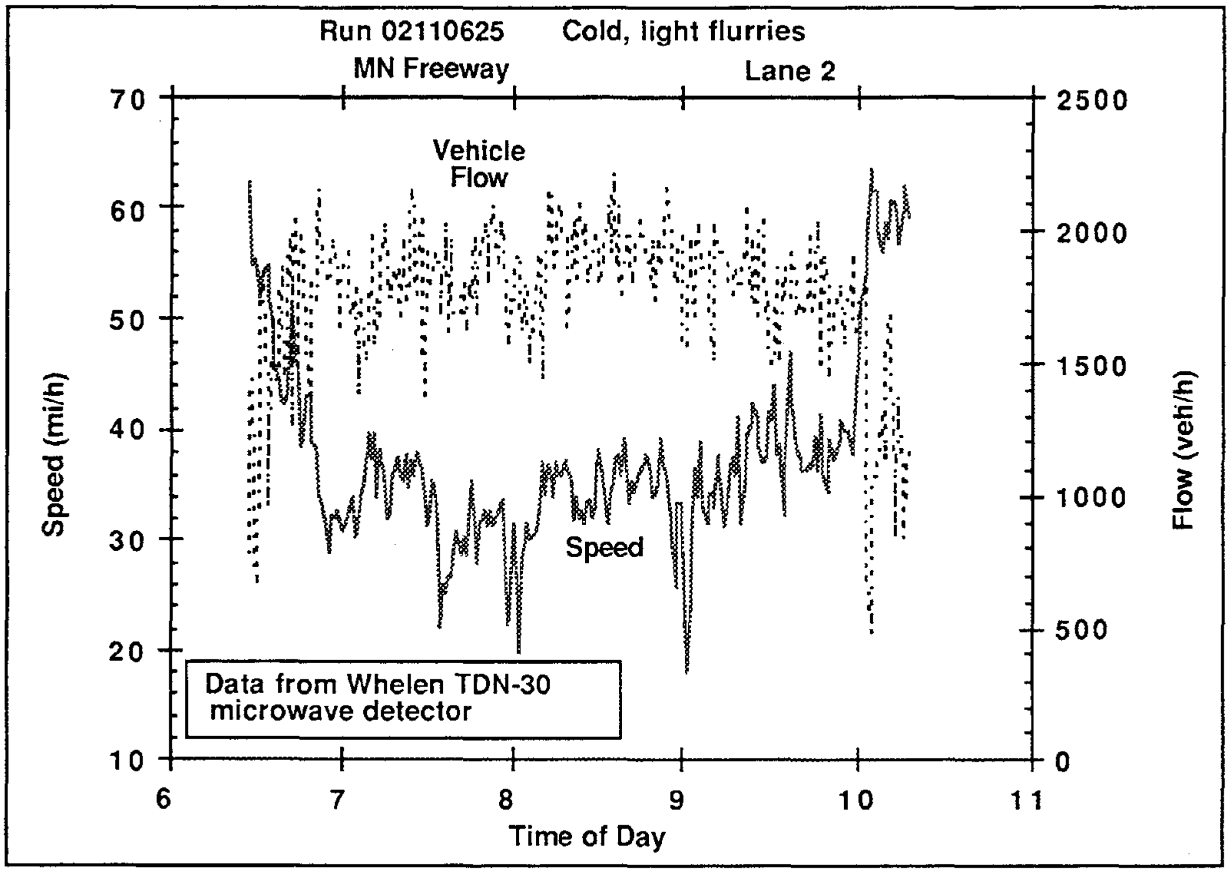


1 mi/h = 1.61 km/h

Figure 10-17. Speed Comparison of Doppler Microwave Detectors Located in Adjacent Lanes on I-394 Freeway Site, Minneapolis, MN

Comparison of Speed and Vehicle Flow

Figure 10-18 shows the inverse relationship between speed and flow in lane 2 during a typical morning rush hour at the I-394 freeway site. This is indicative of the types of data parameters that can be computed using simple, commercially available detectors. The data in this example was from the Whelen TDN-30 Doppler microwave detector. The speeds were recorded in real time from the radar's serial interface. Average speeds and vehicle flows were computed in post-processing using a 1-minute integration interval. These computations could be made locally in real time to support traffic management applications such as freeway incident detection or interconnected intersection control on surface streets.

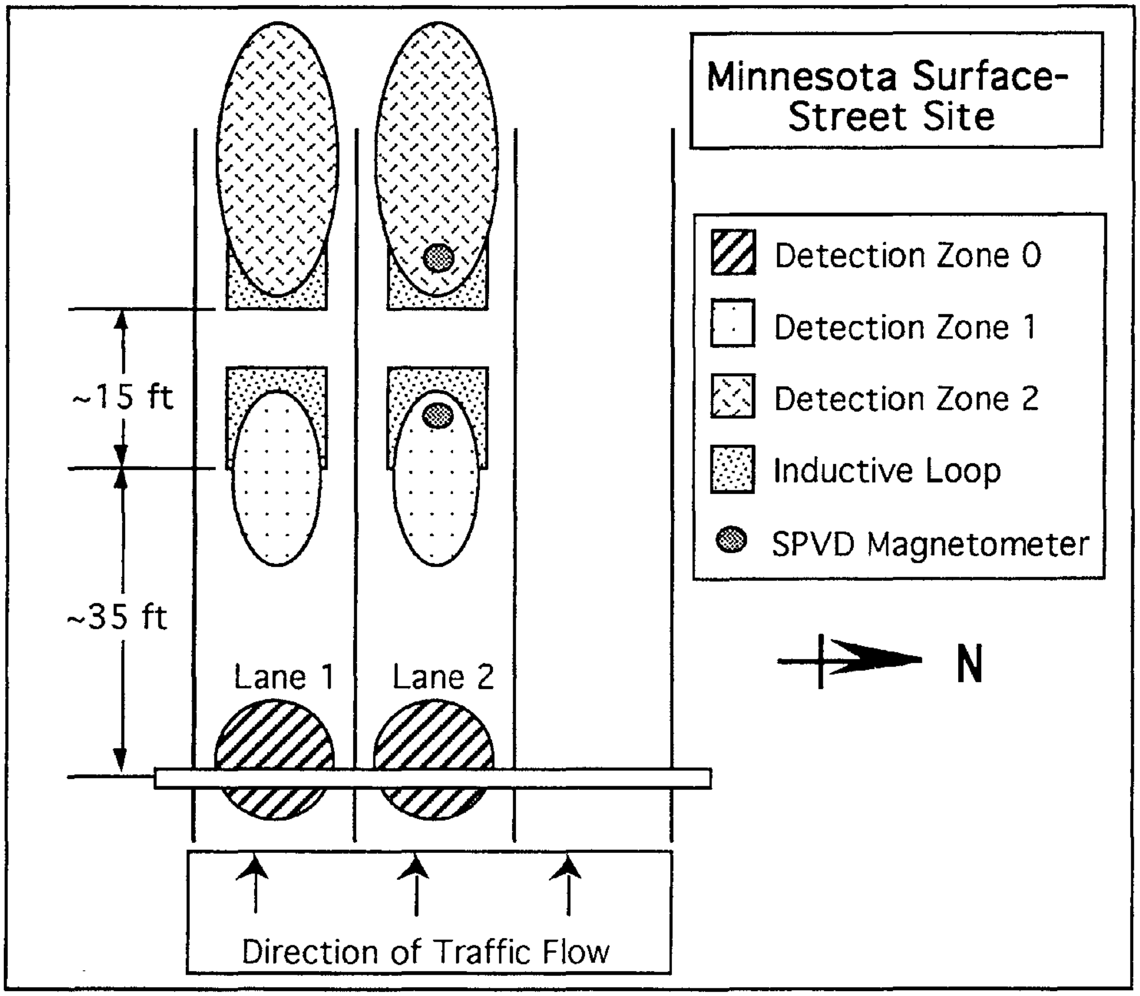


1 mi/h = 1.61 km/h

Figure 10-18. Comparison of Speed and Vehicle Flow in Lane 2 on I-394 Freeway Site in Minneapolis, MN

10.9 MINNESOTA SURFACE-STREET DATA

This site was located on Olson Highway (TH-55) at East Lyndale Avenue North in Minneapolis, Minnesota. The approximate locations of the detection zones are shown in Figure 10-19. The inductive loops generally coincided with the detectors having footprints in Zone 1 and Zone 2 at this site. Given the number of diverse technologies represented in these tests, it is difficult to calculate the precise location of the detection zones corresponding to the different detectors because they rarely coincide, whether they are transducer beam footprints, electromagnetic fields, or optical fields of view. (Theoretical detector footprint sizes and locations as a function of mounting heights and incidence angle are given in Appendix F.) However, if the amount



1 ft = 0.305 m

Zone	Lane 1		Lane 2	
	Symbol	**Model**	**Symbol**	**Model**
0	U2A U3A IR2	Sumitomo SDU-300 Microwave Sensors TC-30C Eltec 842	U2B IR3	Sumitomo SDU-300 Eltec 833
1	M4B IL1A-1 VP1A-4	Whelen TDN-30 Inductive Loop Autoscope VIP	M4A M6A-2 IL1B-1 VP1A-2 MG2A-1	Whelen TDN-30 EIS RTMS-X1 (fwd-looking) Inductive Loop Autoscope 2003 VIP SPVD Magnetometer
2	M2B IL1A-2 VP1A-3	Microwave Sensors TC-26 Inductive Loop Autoscope VIP	M6A-3 IL1B-2 VP1A-1 MG2A-2 M5A	EIS RTMS-X1 (fwd-looking) Inductive Loop Autoscope 2003 VIP SPVD Magnetometer Whelen TDW-10

Figure 10-19. Detection Zones on Olson Highway in Minneapolis, MN

of lane changing is minimal, detector zone location in a particular lane should have little effect on vehicle count when the count is collected over a long time.

10.9.1 Run 03091019

The March 9 run was notable because of the appreciable amount of snowfall. The run was extended to 6 hours to gather as much data under these conditions as possible.

Counts in Multiple Detection Zones

The counts from detectors having multiple detection zones in lane 2 are compared in Figure 10-20. If there are a negligible number of vehicles changing lanes, then the counts from the two detection zones in the lane should be approximately equal. The figure illustrates the good agreement that generally exists between the inductive loops. The SPVD magnetometer in Zone 2 is within 1 percent of the inductive loop count. The lower value of the SPVD count in Zone 1 was likely due to electronic noise on the receiver input line generated by the computer and other electronics in the trailer. In later runs, the SPVD receiver was connected to its own AC power circuit to alleviate this problem. The RTMS radar counted well in Zone 1. In Zone 2, the footprint widened and most likely picked up vehicles in adjacent lanes. The poorer performance of Autoscope in Zone 1 was probably due to imprecise calibration during setup of the zones by the Autoscope personnel.

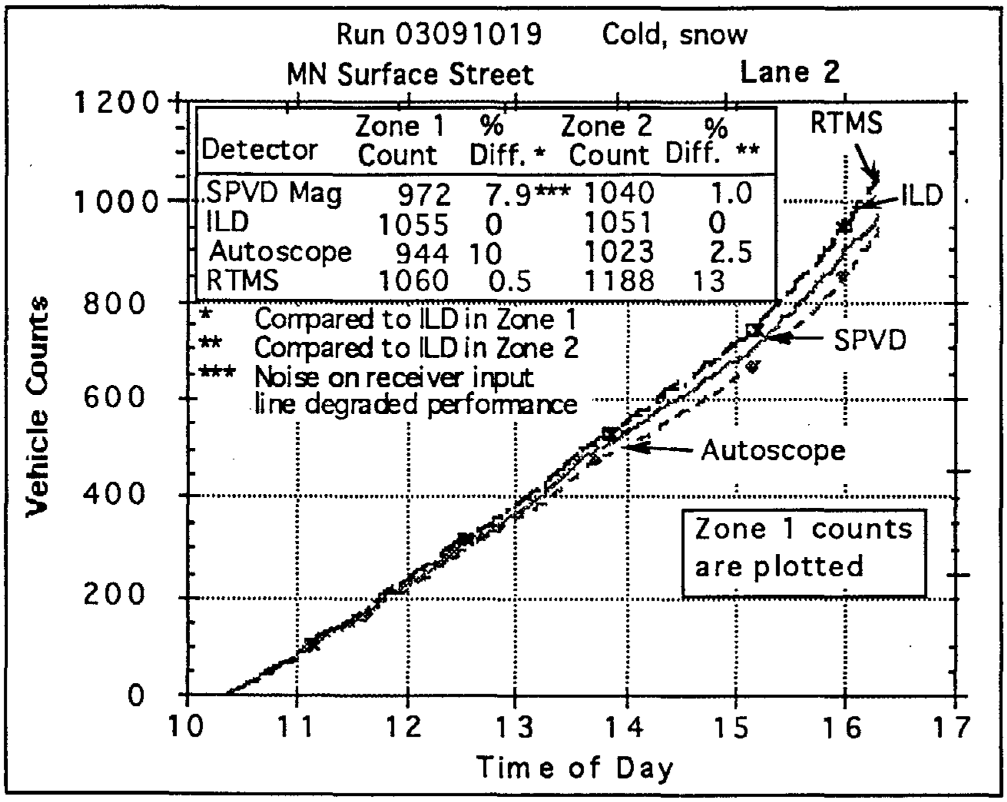
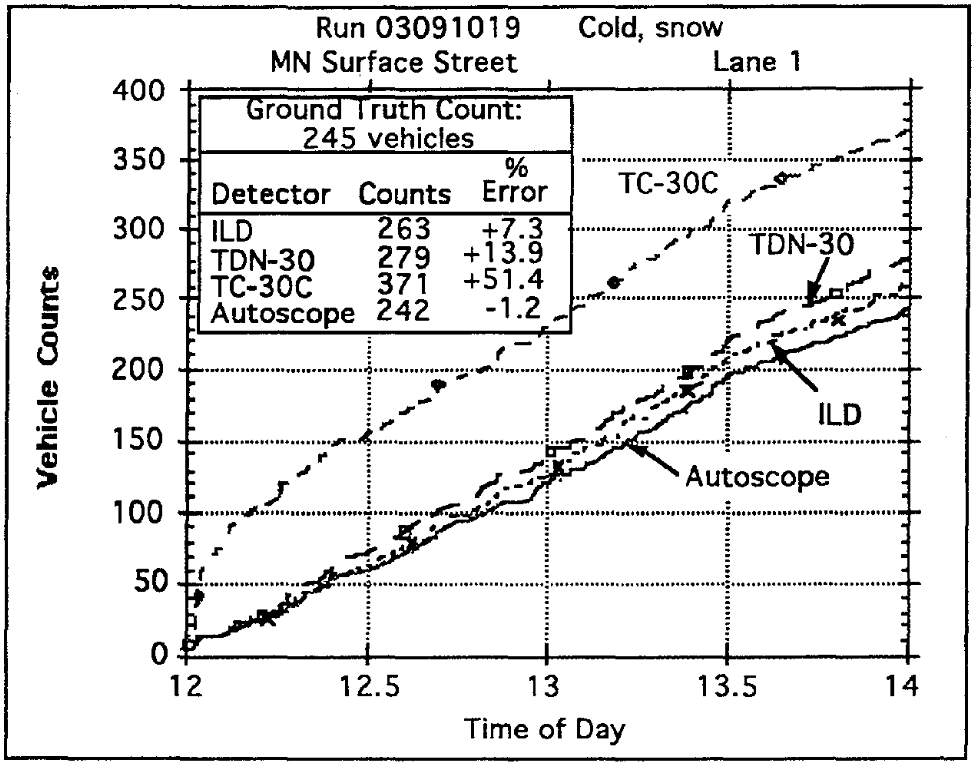


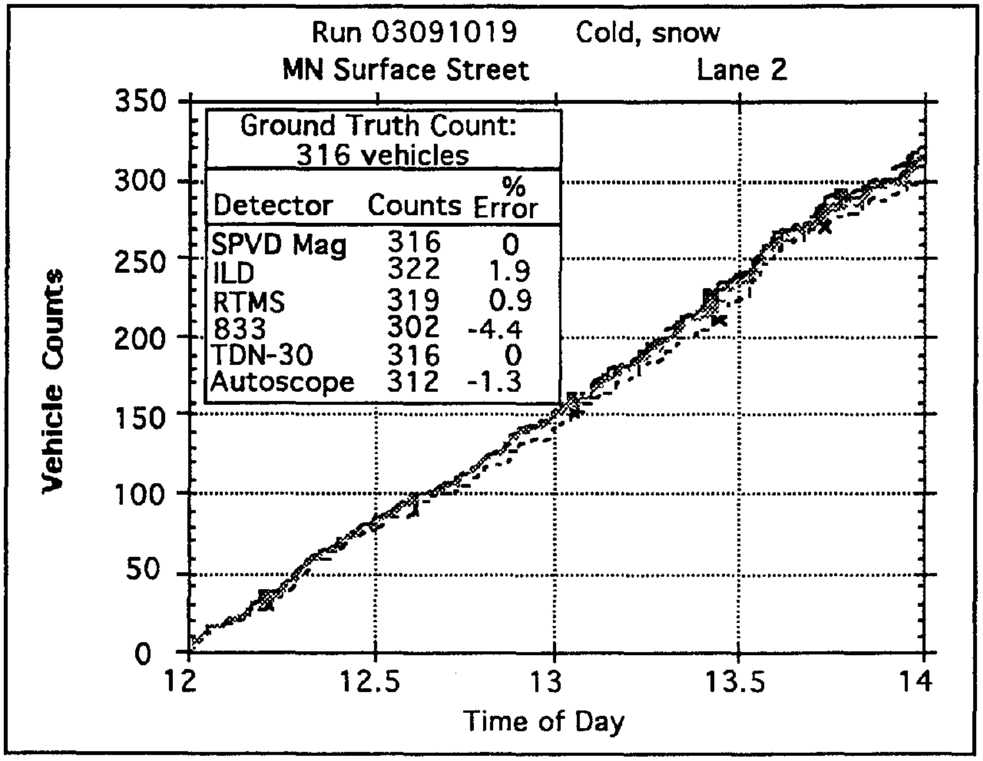
Figure 10-20. Vehicle Counts From Detectors With Multiple Detection Zones in Lane 2 of the Olson Highway Site

Figures 10-21 and 10-22 show the vehicle count data output by the detectors compared with ground truth obtained by manually counting the vehicles in lanes 1 and 2, respectively, on the video imagery of a 2-hour interval. The lane 2 results appear within manufacturers' specifications. The poorer performance of the TDN-30 in lane 1 when compared to lane 2 may be due to moisture accumulation in the lane 1 unit. Possible explanations for the large error in the TC-30C's count include cold weather-



Detector	Counts	% Error
ILD	263	+7.3
TDN-30	279	+13.9
TC-30C	371	+51.4
Autoscope	242	-1.2

Figure 10-21. Comparison of Detector Vehicle Counts with Ground Truth in Lane 1 of the Olson Highway Site



Detector	Counts	% Error
SPVD Mag	316	0
ILD	322	1.9
RTMS	319	0.9
833	302	-4.4
TDN-30	316	0
Autoscope	312	-1.3

Figure 10-22. Comparison of Detector Vehicle Counts with Ground Truth in Lane 2 of the Olson Highway Site

related effects or reflection of signals from the snow flurries. However, the exact cause of the overcount could not be deduced.

10.9.2 Run 03101343

This session was conducted 1 day after the run discussed in the previous section. Vehicle counts were ground truthed in post-processing for a 1-hour period between 4:30 and 5:30 p.m. when peak traffic occurred. Table 10-4 shows the counts and associated percent errors from several detectors in two lanes. The most consistent performers in each lane were the inductive loops, registering 98- to 99-percent accuracies in both lanes. The Autoscope 2003 video image processor showed good results in the second detection zone of each lane (although slightly undercounting as it had in Run 03091019), but poorer accuracies for both lead detection zones. The count accuracies of the TDN-30 microwave detectors were also within specifications in both lanes. The rest of the detectors did not perform as well as these. The 833 passive IR detector that undercounted during the snowy, low-traffic Run 03091019, overcounted during this run, which had approximately three times the traffic volume.

Table 10-4. Count Accuracies for Run 03101343 on Olson Highway Surface-Street Site in Minneapolis, MN

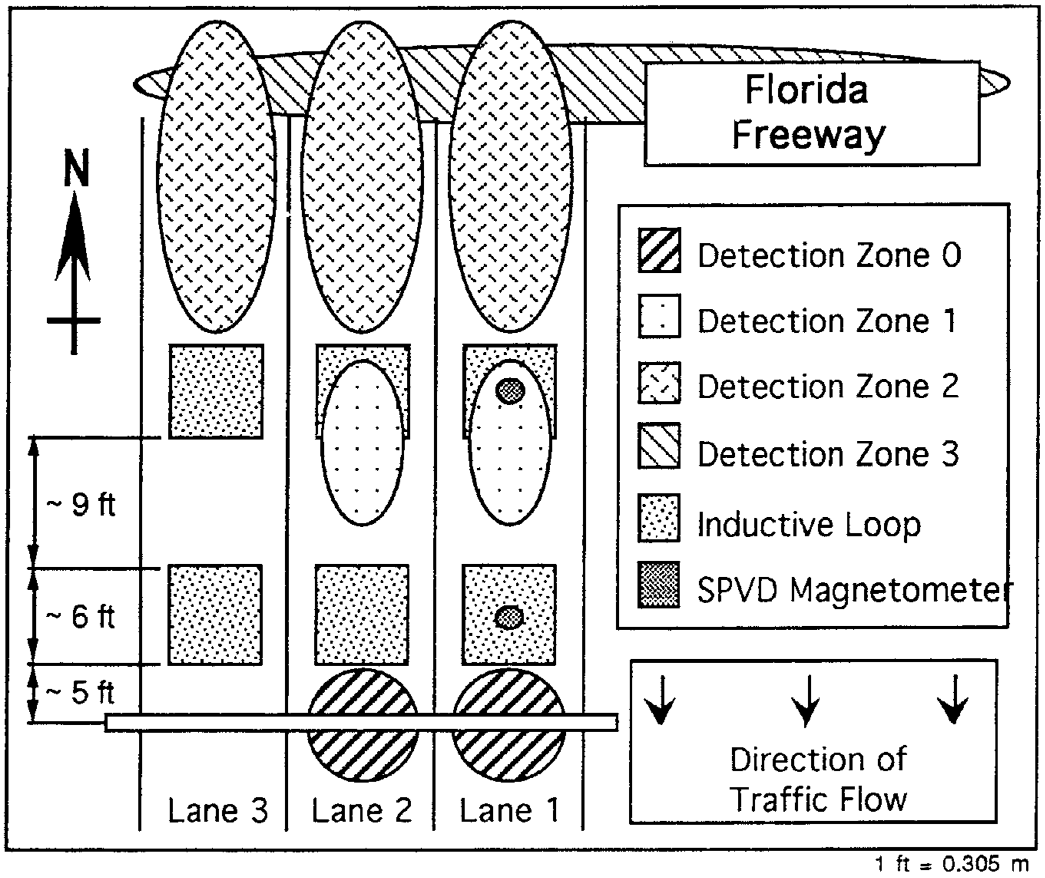
Lane 1			Lane 2		
Detector	**Count**	**% Error**	**Detector**	**Count**	**% Error**
ILD 1	418	1.2	SPVD Mag 1	340	-19.2
ILD 2	421	1.9	SPVD Mag 2	616	46.3
TDN-30	401	-2.9	ILD 1	426	1.2
TC-30C	467	13.1	ILD 2	425	1.0
TC-26	463	12.1	TDN-30	404	-4.0
Autoscope 1	383	-7.3	RTMS-X1 (1)	460	9.3
Autoscope 2	411	-0.5	RTMS-X1 (2)	521	23.8
			833	490	16.4
			Autoscope 1	379	-10.0
			Autoscope 2	412	-2.1
Ground Truth	413		Ground Truth	421	

10.10 FLORIDA FREEWAY DATA

Traffic moving south was monitored in all three lanes of the westbound I-4 freeway just north of SR 436, which runs over the freeway. The overhead detector layout and video image processor detection zones are shown in Figures 9-17 and 9-19, respectively. A pair of inductive loops were installed in each of the three lanes. SPVD magnetometers were inserted in the center of the loops in lane 1 (leftmost lane). The detection zone locations are shown in Figure 10-23.

Detection Zone 0 contained footprints from detectors oriented toward or near nadir in lanes 1 and 2. These included a TC-30C ultrasonic detector from Microwave Sensors and a Schwartz 780D1000 Autosense I laser radar in lane 1. Lane 2 was monitored by an Eltec Model 833 passive infrared detector, while both lanes 1 and 2 contained Sumitomo SDU-300 ultrasonic units. The second inductive loop in each pair and the second SPVD magnetometer were located in between detection Zones 0 and 1.

Detection Zone 1 contained the lead loops in each lane and the first magnetometer in lane 1. The other detectors in lane 1 were the Whelen TDN-30 and the Eltec 842. The footprints in lane 2 that were included in Zone 1 were from the Whelen TDN-30 and the



Zone	Lane 1		Lane 2		Lane 3	
	Symbol	**Model**	**Symbol**	**Model**	**Symbol**	**Model**
0	U3A U2A IL1A-2 MG2A-2 IR1	MW Sensors TC-30C Sumitomo SDU-300 Inductive Loop SPVD Magnetometer Schwartz 780D1000	U2B IR3 IL1B-2	Sumitomo SDU-300 Eltec 833 Inductive Loop	IL1C-2	Inductive Loop
1	M4B IR2 IL1A-1 MG2A-1	Whelen TDN-30 Eltec 842 Inductive Loop SPVD Magnetometer	M4A IL1B-1 U1 M6A-2	Whelen TDN-30 Inductive Loop Sumitomo RDU-101 EIS RTMS (fwd-look)	IL1C-1	Inductive Loop
2	M2B VIP1C M1B	MW Sensors TC-26 Autoscope 2003 VIP MW Sensors TC-20	M5A M6A-3 VIP1B M1A	Whelen TDW-10 EIS RTMS (fwd-look) Autoscope 2003 VIP MW Sensors TC-20	VIP1A	Autoscope 2003 VIP
3	M6A-5	EIS RTMS (side-look)	M6A-6	EIS RTMS (side-look)	M6A-7	EIS RTMS (side-look)

Figure 10-23. Detection Zones on I-4 in Altamonte Springs, FL

Sumitomo RDU-101 Doppler ultrasonic detector, and those included in the second zone were from the forward-looking RTMS-X1 true-presence microwave radar.

Five microwave detectors had footprints in Zone 2. Microwave Sensors TC-20 and TC-26 monitored lane 1, while a Whelen TDW-10, Microwave Sensors TC-20, and the first forward-looking RTMS-X1 range bin were in lane 2. A second TC-20 was mounted on a support column located in the freeway median of SR 436 and was side-fired into lane 1. The Autoscope 2003 video image processor monitored all three lanes in Zone 2.

Zone 3 overlaps Zone 2, representing the area covered by the side-looking RTMS-X1 radar mounted on a pole located on the eastbound side of the freeway near the trailer. This unit also monitored all three eastbound lanes, although ground truth is not available against which to compare these outputs.

10.10.1 Run 07221647

The run is representative of a typical evening rush hour. Westbound traffic is usually heavier in the morning when workers commute from the suburbs into Orlando. This session, as with most of the nighttime runs, continued into darkness in order to monitor the effect of the light-to-dark transition on video image processor operation.

Total Vehicle Counts

Table 10-5 shows vehicle count results collected over the entire 4-hour session. Vehicle counts were not ground truthed for this run. Instead, the percent difference was computed with respect to the first inductive loop in each of the three lanes. The loops have been shown to be accurate to within 0.5 percent in other Florida freeway runs. Thus, the percent difference computation yields a meaningful figure of merit.

Table 10-5. Vehicle Counts for Run 07221647 on Florida Freeway

Lane 1			Lane 2			Lane 3		
Detector	Count	% Diff	Detector	Count	% Diff	Detector	Count	% Diff
ILD 1	2297	0.0	ILD 1	3632	0.0	ILD 1	1586	0.0
ILD 2	2292	-0.2	ILD 2	3634	0.1	ILD 2	1587	0.1
TDN-30	1562	-32.0	TDN-30	3436	-5.4	RTMS-X1**	1451	-8.5
SPVD Mag 1	2057	-10.4	RTMS-X1(1)*	3506	-3.5	Autoscope 1	1566	-1.3
SPVD Mag 2	2035	-11.4	RTMS-X1(2)*	4290	18.1	Autoscope 2	1406	-11.3
SDU-300	2198	-4.3	RTMS-X1**	3419	-5.9	Autoscope 3	1546	-2.5
TC-20	1718	-25.2	TC-20	2582	-28.9			
TC-30C	2070	-9.9	SDU-300	3562	-1.9			
RTMS-X1**	2023	-11.9	Autoscope 1	3588	-1.2			
Autoscope 1	2234	-2.7	Autoscope 2	3247	-10.6			
Autoscope 2	2202	-4.1	Autoscope 3	3576	-1.5			
Autoscope 3	2310	0.6						
ILD 1 Ref.	2297		ILD 1 Ref.	3632		ILD 1 Ref.	1586	

* Forward-looking mode
* * Side-looking mode

The counts from the three loop pairs demonstrate consistency within 0.2 percent. The Autoscope 2003, although generally yielding counts within 3 percent of those of the loops in at least one zone, shows an inconsistency among its three detection zones in each lane. The second of these zones was set up as a speed detector. Zones 1 and 3 were set up as count detectors. The count outputs from zones 1 and 3 support a graceful transition from daylight to nighttime algorithms since the inaccuracies do not grow large over the approximately 5:00 to 9:00 p.m. run.

The first detection zone of the RTMS-X1 in lane 2 counted to within 3.5 percent of the loop value, while the second detection zone overcounted by 18 percent. This is due to the difficulty in confining the elliptical beam footprint to a single lane. This causes "splashing," which is the detection of vehicles from adjacent lanes of traffic. A second RTMS-X1, operating in a side-looking mode, gave varying accuracy results. This single unit also monitored traffic in the three east-bound lanes, but there is no other data against which to compare these results. The TC-20s in lanes 1 and 2 undercounted due to their long electronic hold times, while the TDN-30 microwave detector in lane 1 is believed to have suffered damage from water seeping into the detector electronics. The TDN-30 in lane 2 agreed with the loop count to within 5 percent. The SDU-300 ultrasonic detector achieved 96- and 98-percent agreement with the loops in lanes 1 and 2, respectively.

10.10.2 Run 07231329

This run, though quite short in duration, is important in that it occurred during a heavy thunderstorm. This allows data to be compared with those from the run of the day before (07221647) to ascertain whether or not the heavy rain made an appreciable difference on the count accuracies. Results were ground truthed for this run, which enables percent error to be calculated.

Total Vehicle Counts

The results from Table 10-6 indicate that most of the detectors suffered little or no degradation in performance due to the extreme weather conditions present during the run. The only notable exception was the SPVD magnetometer. The lead magnetometer in lane 1 undercounted by nearly 50 percent, whereas on the previous day it was 10 percent under the count from the loops. The reason for this result is not apparent since the magnetometer count accuracy in subsequent runs, as observed in the Paradox database files, was closer to the performance demonstrated in the previous Florida freeway runs. The count accuracy of the second magnetometer was within 1 percent of the value recorded on the previous day. The TC-30C ultrasonic detector was not operational due to a failure that occurred prior to the run made earlier in the morning.

Table 10-6. Vehicle Counts for Run 07231329 on Florida Freeway

Lane 1			Lane 2			Lane 3		
Detector	**Count**	**% Error**	**Detector**	**Count**	**% Error**	**Detector**	**Count**	**% Erro**
ILD 1	963	0.4	ILD 1	1057	0.5	ILD 1	522	-0.4
ILD 2	964	0.5	ILD 2	1057	0.5	ILD 2	521	-0.6
TDN-30	713	-25.7	TDN-30	1043	-0.9	RTMS-X1**	475	-9.4
SPVD Mag 1	493	-48.6	RTMS-X1(1)*	1057	0.5	Autoscope 1	511	-2.5
SPVD Mag 2	844	-12.0	RTMS-X1(2)*	1176	11.8	Autoscope 2	476	-9.2
SDU-300	938	-2.2	RTMS-X1**	1011	-3.9	Autoscope 3	493	-5.9
TC-20	609	-36.5	TC-20	696	-33.8			
TC-26	1020	+6.4	SDU-300	1033	-1.8			
RTMS-X1**	900	-6.2	Autoscope 1	1036	-1.5			
Autoscope 1	925	-3.5	Autoscope 2	1006	-4.4			
Autoscope 2	926	-3.4	Autoscope 3	1031	-2.0			
Autoscope 3	938	-2.2						
Ground Truth	959		Ground Truth	1052		Ground Truth	524	

* Forward-looking mode

* * Side-looking mode

One possible explanation for the magnetometer anomaly is RF noise due to either the lightning or, more likely, from nearby RF communications. The magnetometer receiver's frequencies of operation are not in a protected band, and spurious voice transmissions were heard from time to time during the field tests through a speaker connected to the output of the receiver.

10.10.3 Run 07280615

This run is representative of morning rush-hour conditions on westbound I-4. The session began at 6:15 a.m. and continued until approximately 10:50 a.m. The results shown in the following figures compare vehicle counts and flow among the detectors.

Counts vs. Time of Day

Figure 10-24 compares vehicle counts versus time of day for six traffic detectors located in the fast lane of the westbound I-4 freeway. The vehicle counts were ground truthed by manually counting vehicles from the video tape made of the actual run during the interval from 7:30 to 9:00 a.m. This gives a true value with which to compare the counts from the detector outputs. The figure includes data from the RTMS-X1 microwave presence radar, a TDN-30 Doppler microwave detector, an SDU-300 ultrasonic detector, an inductive loop, the 780D1000 laser radar, and the Autoscope 2003 video image processor.

A wide variation in the vehicle count is shown. The best count results were achieved by the inductive loop, followed by the Schwartz laser radar relay output, the Autoscope VIP, and the Sumitomo SDU-300 ultrasonic detector in that order. The two microwave detectors, the side-looking RTMS and the Whelen TDN-30, showed poor results for this test. The RTMS generally provides better results in the forward-looking orientation; the Whelen TDN-30's problem was likely due to a failure of a rubber seal that allowed water from a number of thunderstorms to seep into the unit. Whelen has since improved the design of their housings and seals and drilled a hole in the bottom of their case to avoid accumulation of moisture.

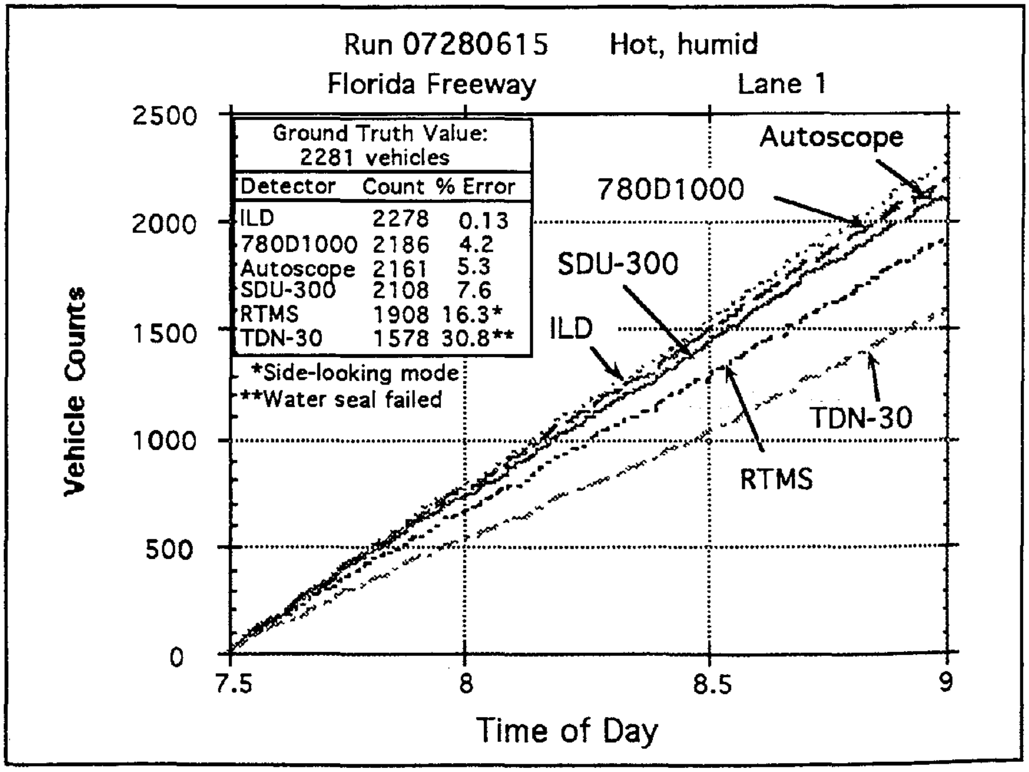


Figure 10-24. Comparison of Detector Count Data at Florida Freeway Site

Vehicle Flow vs. Time of Day

Figure 10-25 shows how the traffic flow varied during an approximate 4-hour period for the same six detectors represented in Figure 10-24. These curves are fifth order polynomial fits to the computed flow data that were calculated using 5-minute integration intervals. The plots illustrate a peak in the traffic volume occurring at 7:00 a.m. that steadily decreases until approximately 10:00 a.m. All the curves have the same basic shape, with the only discernible difference occurring in the plot representing the Autoscope 2003 video image processor. Here, the flow appears to fall off more rapidly after 8:30 a.m. for the Autoscope than for the other detectors. The reason for this is not known.

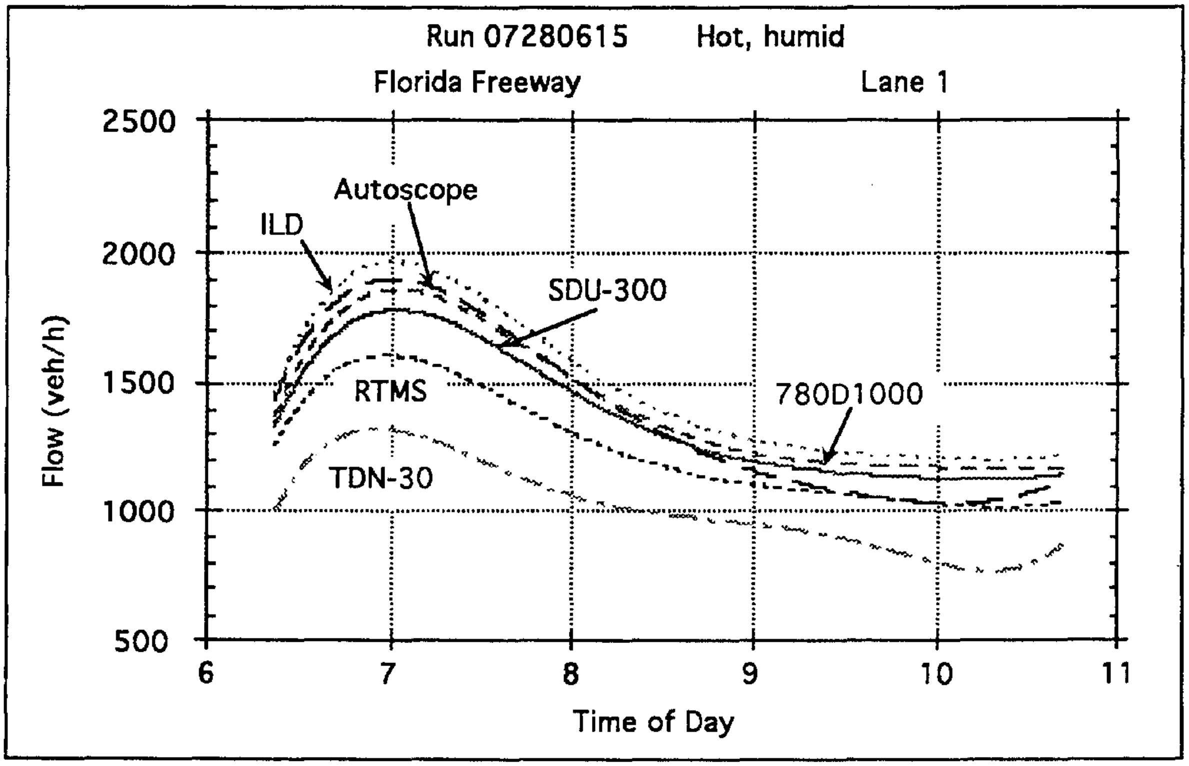


Figure 10-25. Comparison of Detector Flow Data at Florida Freeway Site

Histogram of Occupancy Computations

Figure 10-26 shows a histogram relating lane occupancy to the number of occurrences over the entire run of approximately 4 hours. Each bin of the histogram represents a 2.5-percent increment in lane occupancy, defined as the percentage of an integration interval that a detector is in an active state. Occupancy is commonly used as a surrogate for lane density. The occupancy values were computed using a 30-second integration interval. The histogram shows that this detector, representing one of the detection zones from an Autoscope 2003 video image processor, measured occupancies of 2.5 to 15 percent approximately 80 percent of the time.

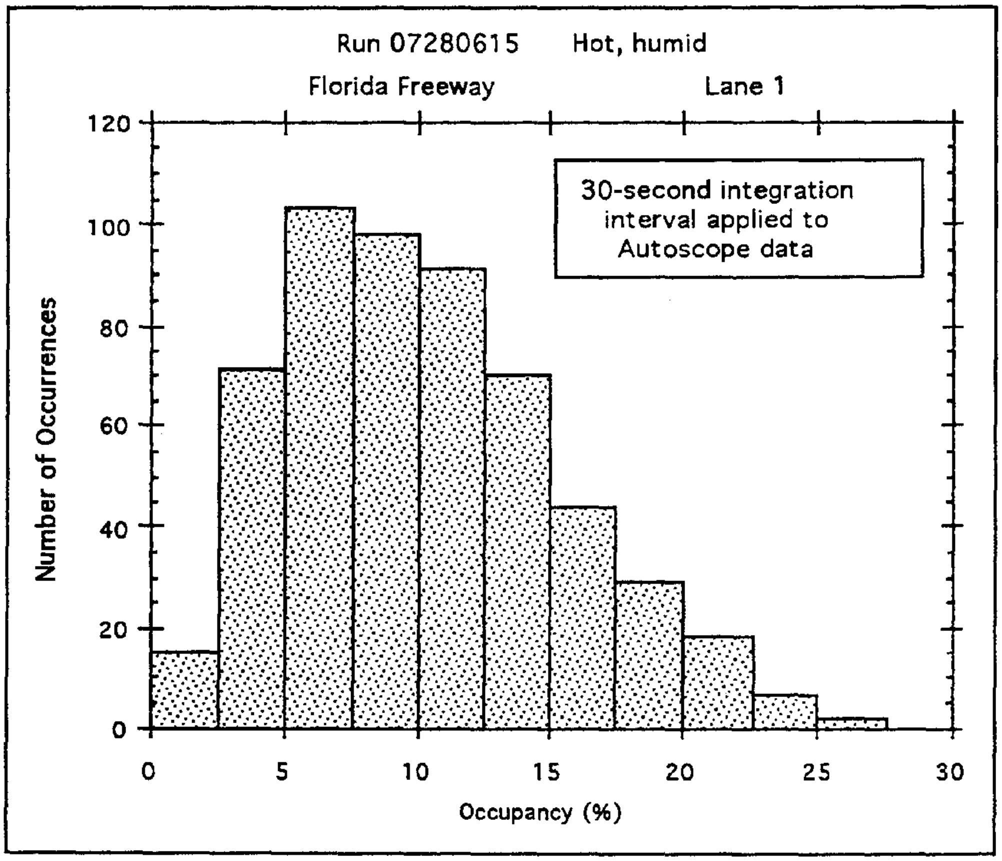


Figure 10-26. Occupancy Histogram at I-4 Freeway Site, Altamonte Springs, FL

Effect of Integration Interval on Fifth Order Polynomial Curve Fit

The effect of the integration interval on lane occupancy was computed using the Autoscope detection zone output from lane 1 of the I-4 freeway site. Occupancy was calculated by summing the vehicle presence times output by the detector interface over a selected integration interval and then dividing the sum by the interval time. This yielded the percentage of the time that the detector was in the active state over that interval. The resulting occupancy values were plotted versus time of day. The data were fitted to a fifth order polynomial curve in order to better examine the average trend that was somewhat masked by the discrete occupancy values, as shown on the left in Figure 10-27 for a 30-second interval. This process was repeated using a 5-minute integration interval in order to assess the effect of a longer integration time on the discrete data points and the fitted curve as illustrated in the right graph in Figure 10-27. Integrating the data one-tenth as often eliminated the peak values evident in the left graph. Overlaying the curves fitted to the 30-second and 5-minute integrated data showed no discernible difference in the fitted curves. This enabled the analyst to use a 5-minute integration interval in future analyses to speed up the data output process when average trends were desired. However, if peak values were needed, then the shorter integration intervals were used.

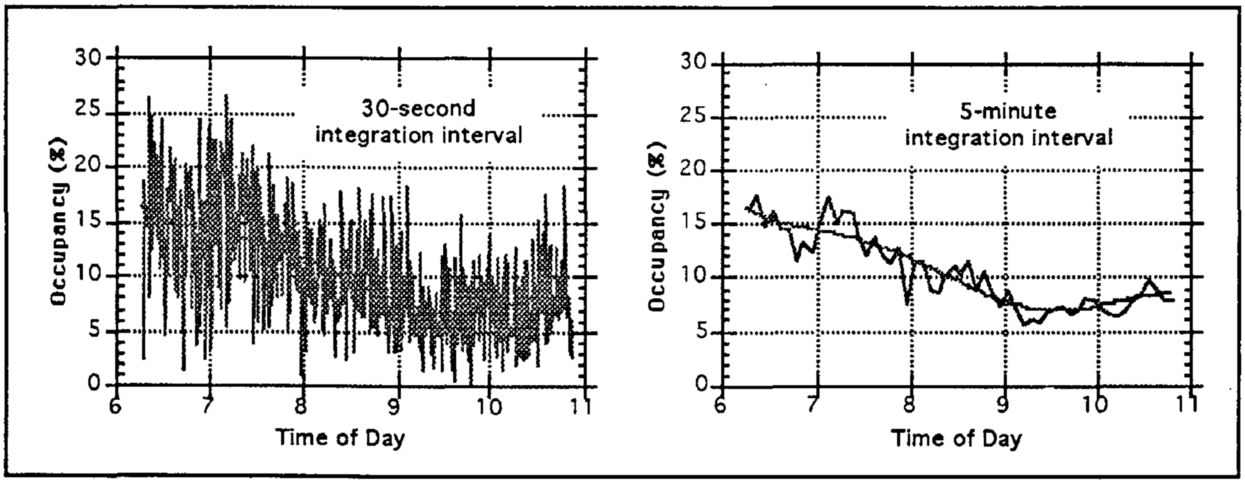
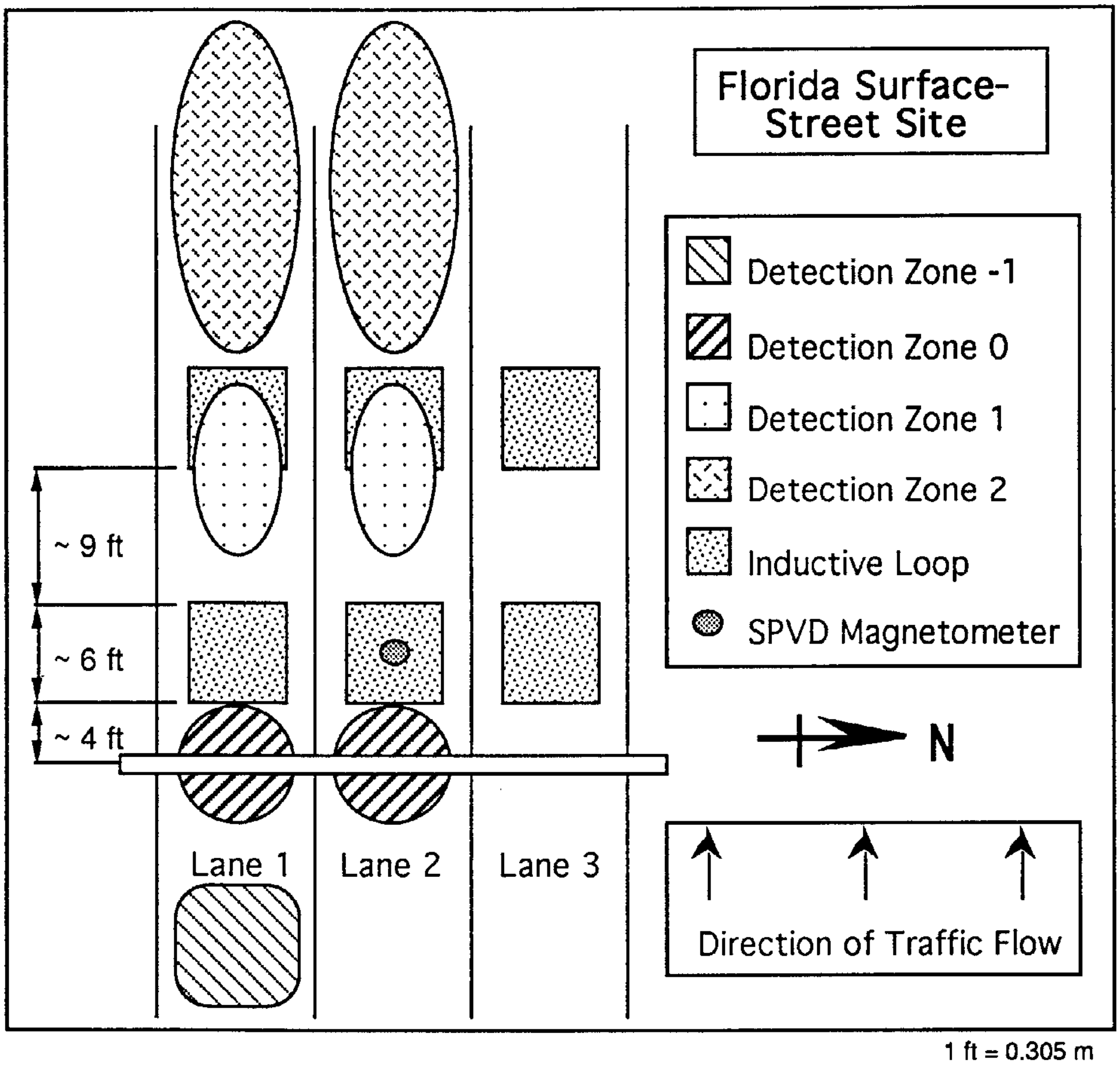


Figure 10-27. Effect of Integration Interval on Data Resolution

10.11 FLORIDA SURFACE-STREET DATA

The evaluation site on SR 436 had four concentrations of detection zones. The first zone, shown in the table accompanying Figure 10-28, is labeled detection Zone -1 due to its placement forward of the other zones. Two detectors monitored this area of lane 1 as they observed approaching traffic. The overhead detectors in the other zones observed the rear of the vehicles as they monitored departing traffic.

Detection Zone 0 contained the footprints of the detectors oriented toward nadir in lanes 1 and 2. The first pair of inductive loops were in between Zones 0 and 1. The second set of loops generally coincided with detectors having footprints in Zone 1. Zone 1 contained the viewing areas of devices that were oriented at approximately 45 degrees with respect to the plane of the roadway. These included a Whelen TDN-30 Doppler microwave detector in lane 1 and the first of the two range bins from the forward-looking RTMS-X1 true-presence microwave radar in lane 2. The furthest viewing area was detection Zone 2 that contained the approximate viewing areas of the TC-26 Doppler microwave in lane 1 and the TDW-10 Doppler microwave and second RTMS-X1 range bin in lane 2.



Zone	Lane 1		Lane 2	
	Symbol	**Model**	**Symbol**	**Model**
- 1	U1 IR1	Sumitomo RDU-101 Schwartz 780D1000		
0	U2A U3A IR2 IL1A-1	Sumitomo SDU-300 Microwave Sensors TC-30C Eltec 842 Inductive Loop	U2B IR3 IL1B-1	Sumitomo SDU-300 Eltec 833 Inductive Loop
1	M4B IL1A-2	Whelen TDN-30 Inductive Loop	MG2A-1 M6A-2 IL1B-2	SPVD Magnetometer EIS RTMS-X1 (fwd-looking) Inductive Loop
2	M2B	Microwave Sensors TC-26	M6A-3 M5A	EIS RTMS-X1 (fwd-looking) Whelen TDW-10

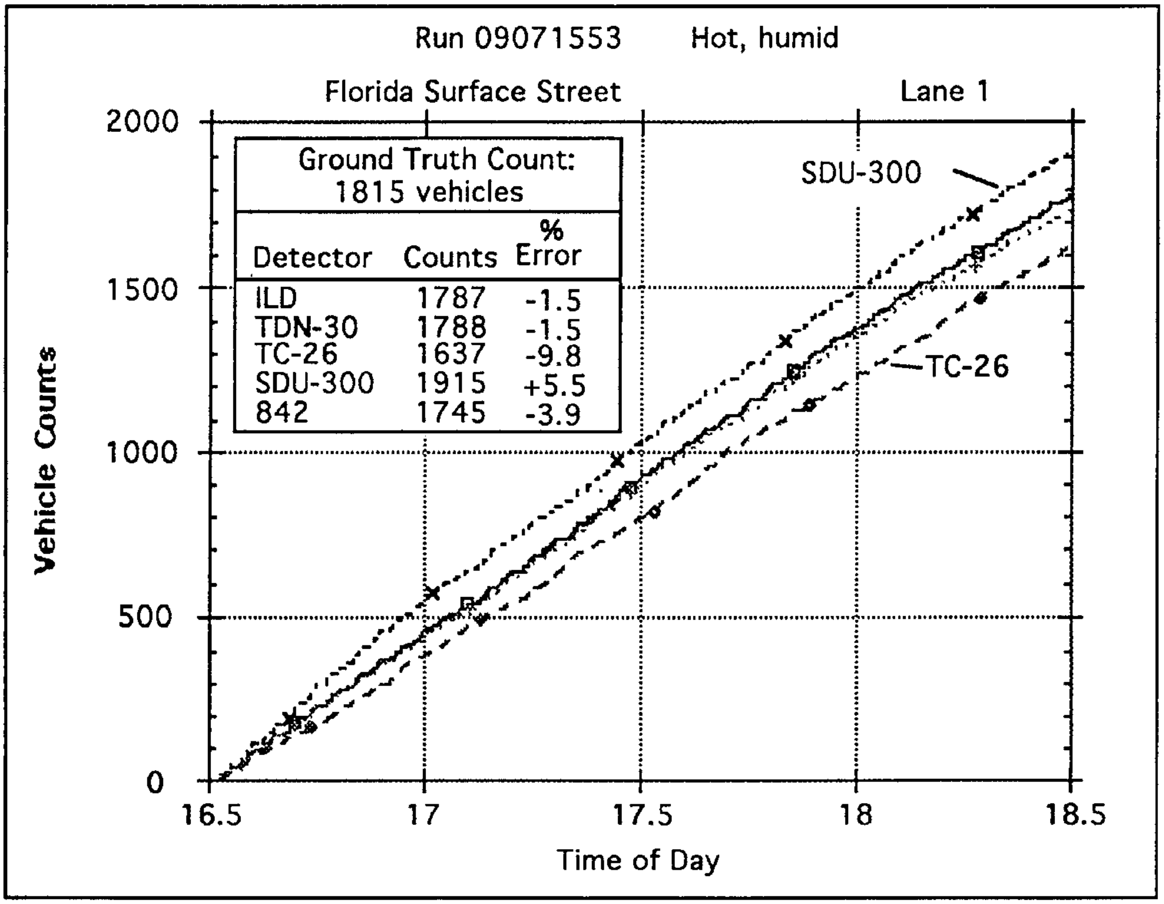
Figure 10-28. Detection Zones on SR 436 in Altamonte Springs, FL

10.11.1 Run 09071553

The weather during the run was hot and humid with heavy rain starting at about 5:15 p.m., tapering to thunder showers around 5:30.

Vehicle Counts in Lane 1 vs. Time of Day

Both the TDN-30 and the loops had a 1.5-percent error with respect to the ground truth value of vehicle count in lane 1 as shown in Figure 10-29. In fact, all detectors, with the exception of the TC-26, performed within manufacturers' specifications. The TC-26 is not designed for a vehicle-counting application because of its long hold time. It is designed for signal control and detection of vehicles approaching an intersection that are within its field of view.



Ground Truth Count: 1815 vehicles

Detector	Counts	% Error
ILD	1787	-1.5
TDN-30	1788	-1.5
TC-26	1637	-9.8
SDU-300	1915	+5.5
842	1745	-3.9

Figure 10-29. Comparison of Vehicle Count Data on Lane 1 of Florida Surface-Street Site

Vehicle Counts in Lane 2 vs. Time of Day

Figure 10-30 contains the vehicle count data from lane 2. The count from the forward-looking RTMS-X1 microwave detector was closer to the ground truth value during this run than was the count from the inductive loop. The larger error shown by the 833 passive infrared detector was probably due to the relatively long hold time of the device. The hold time, however, is a design parameter that generally can be adjusted by the manufacturer to suit specific applications.

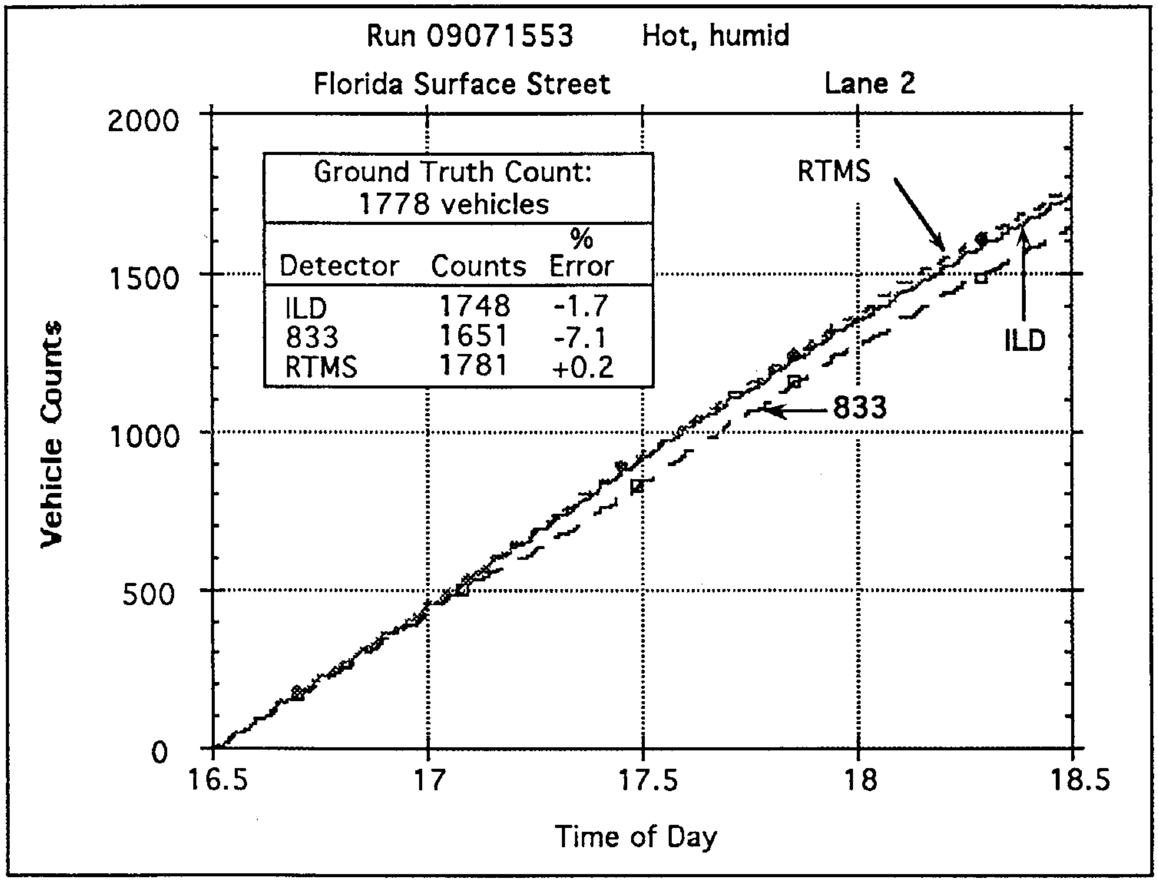


Figure 10-30. Comparison of Vehicle Count Data on Lane 2 of Florida Surface-Street Site

Vehicle Counts in Lane 2 Over 3-Minute Traffic Signal Cycle

The data in this run were analyzed to determine the short-term count accuracy of the detectors over a time period consisting of one traffic signal cycle equal to 3 minutes. The counts from the forward-looking RTMS detector were closest to the 2-hour ground truth value of 1778 vehicles. Therefore, this detector was used as the reference for the analysis of short-term count stability shown in Figures 10-31 and 10-32.

Video imagery in future analyses can be used o ground truth the count over a time interval of only one signal cycle. In this way, the detector with the best short-term accuracy can be identified and used as the reference against which to compare the counts of the other detectors.

Comparison of Vehicle Counts From Eltec 833 With RTMS-X1

Figure 10-31 shows the short-term stability of the vehicle count obtained with the Eltec 833 and the RTMS-X1 in lane 2 (middle lane). The data span almost a 6-hour period. They were accumulated over 3-minute intervals corresponding to the cycle time of

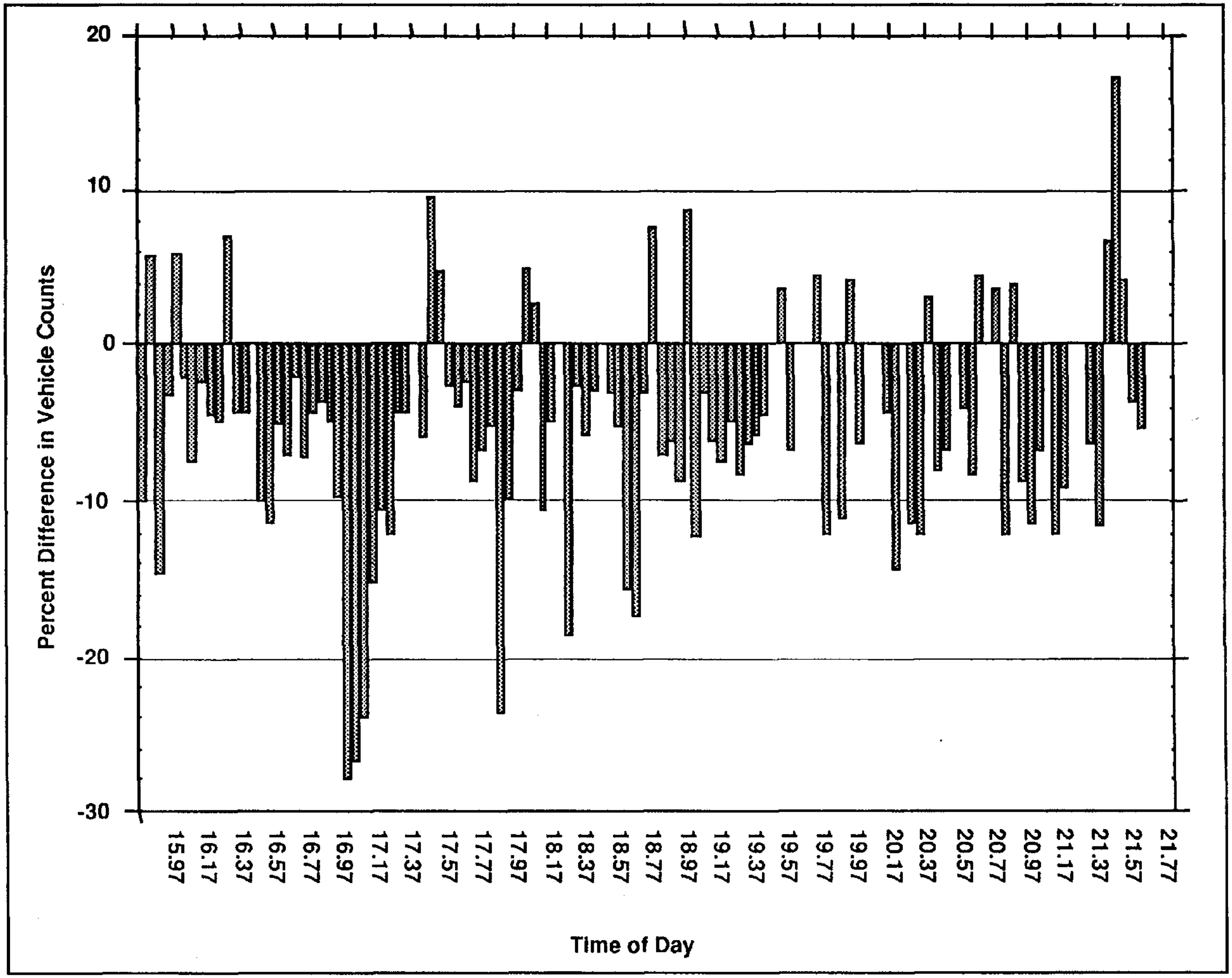


Figure 10-31. Percentage Difference In Vehicle Counts Between Eltec 833 and RTMS-X1 Over 3-Minute Traffic Signal Cycles

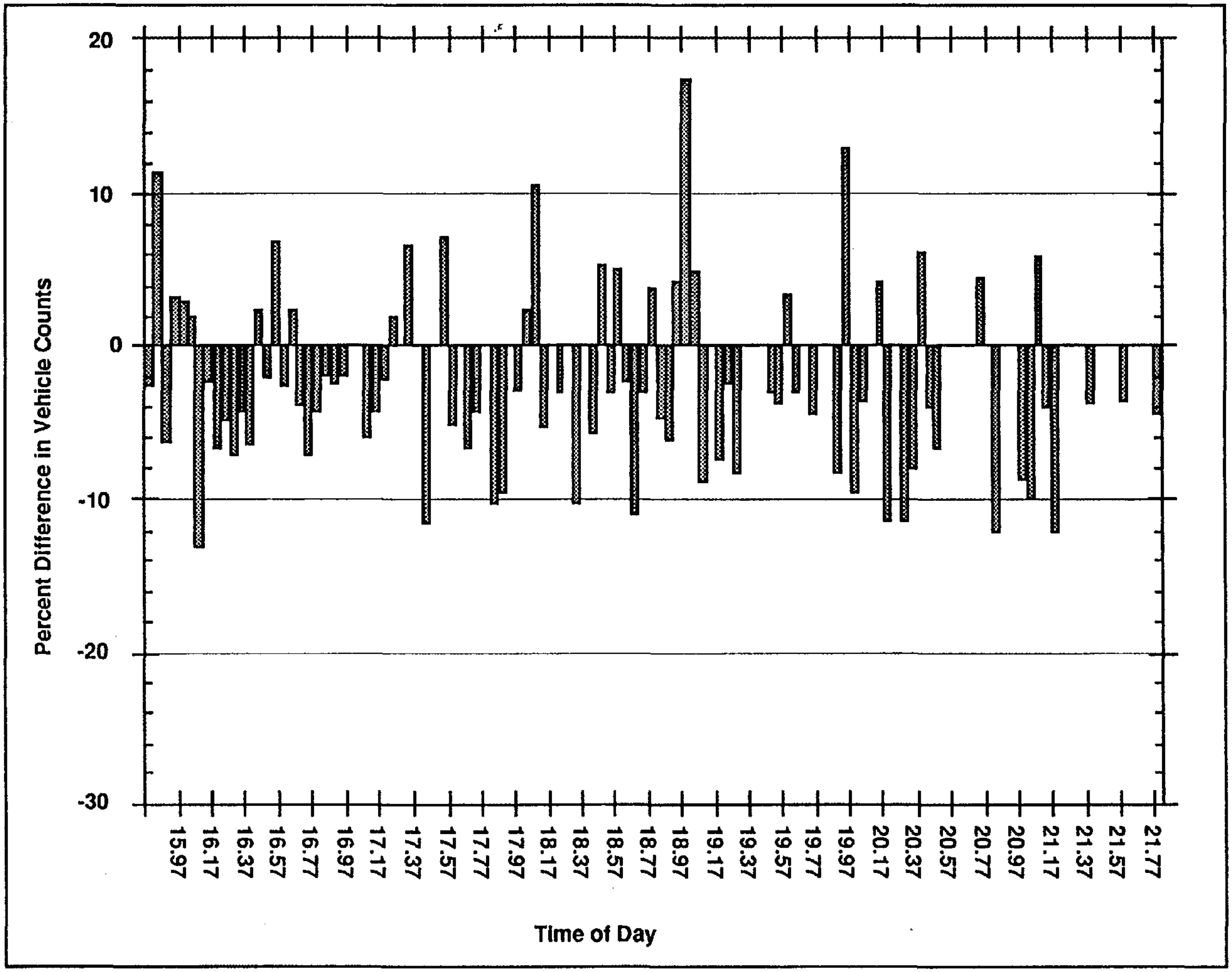


Figure 10-32. Percentage Difference In Vehicle Counts Between Inductive Loop and RTMS-X1 Over 3-Minute Traffic Signal Cycles

the traffic signals at this intersection. The average value of the count difference was -1.94 counts and the standard deviation of the count difference was 2.83 counts. The standard deviation of the percent difference values was 7.22 percent. The Eltec 833 consistently undercounted as evidenced by the predominance of negative percent differences when compared with the RTMS counts. This indicates that the Eltec 833 IR detector is either missing some vehicles entirely (due to insufficient detector sensitivity to distinguish the thermal contrast between the vehicle and the road surface), or failing to discriminate between closely spaced vehicles.

Comparison of Vehicle Counts From Inductive Loop With RTMS-X1

Figure 10-32 shows the short-term stability of the vehicle count obtained with the first inductive loop and the RTMS-X1 in lane 2 (middle lane). The average value of the count difference was -0.75 counts per interval and the standard deviation of the count difference values was 1.73 counts. The standard deviation of the percent difference values was 5.35 percent. These results show that the loop did not consistently overcount or undercount with respect to the RTMS.

10.11.2 Run 09141730

The weather during this run was warm, humid, and clear. The duration of the session was approximately 3.5 hours with video ground truthing performed for a 2-hour window between 6:00 and 8:00 p.m.

Vehicle Counts vs. Time of Day

Vehicle counts were tabulated for the 6 p.m. to 8 p.m. ground truth period for the detectors in lanes 1 and 2. The results are shown in Table 10-7. There are some differences between these results and those obtained from run 09071553 conducted 1 week earlier. The TC-26 microwave detector and Eltec 833 passive infrared detector undercounted by 9.8 and 7.1 percent, respectively, during the run of September 7, but overcounted by 9.9 and 8.2 percent, respectively, during this run. The Eltec 842 passive infrared detector undercounted by approximately 22 percent more than it did during the September 7 run. Conversely, the SDU-300 ultrasonic detector in lane 1 overcounted by 5.5 percent on September 7 and undercounted by 1.6 percent during this run. The inductive loops, TDN-30 microwave detector, and RTMS-X1 true-presence microwave radar all showed reasonable consistency in their respective count accuracies when compared to the run conducted 1 week prior. Further analysis needs to be performed to determine trends or patterns that may explain the inconsistency in the results. This entails overlaying the detection information for a given detector onto the video imagery and examining each missed or false detection.

Table 10-7. Vehicle Counts for Run 09141730 on Florida Surface Street

Lane 1			Lane 2		
Detector	**Count**	**% Error**	**Detector**	**Count**	**% Error**
ILD 1	1476	-2.4	ILD 1	1411	-1.6
ILD 2	1467	-3.0	ILD 2	1386	-3.3
TDN-30	1487	-1.7	RTMS-X1 (1)	1468	2.4
TC-30C	*	-	RTMS-X1 (2)	1523	6.2
TC-26	1661	9.9	833	1552	8.2
780D1000	* *	-	SDU-300	* * *	-
842	1125	-25.6	TC-20	873	-39.1
SDU-200	1131	-25.2			
SDU-300	1488	-1.6			
Ground Truth	1512		Ground Truth	1434	

* Mounting height exceeded manufacturer's maximum operating range

* * Not functioning

* * * Detector electronics were not calibrated for the large operating range at this site

10.12 PHOENIX AUTUMN 1993 FREEWAY DATA

The Phoenix I-10 freeway site was characterized by five detection zones over three lanes of westbound traffic. The five zones are shown in Figure 10-33. In keeping with the convention established for the Florida surface-street runs, Zone -1 was assigned to the area on the opposite side of the sign structure from that monitored by the other detectors. The AT&T passive acoustic array and the Eltec 833 passive infrared detector in Zone -1 monitored departing traffic because AT&T preferred to have their array face departing traffic, and the 833 provided counts to compare with those from the acoustic array. Because of the location of these footprints, video ground truth was not available for these detectors. However, due to the small amount of lane-changing observed at this location, the count variation with respect to the other lane 2 detectors is expected to be minimal.

Zone 0 contained footprints from detectors that are oriented at or near nadir. The Eltec 842 passive infrared device was mounted north of lane 1 as shown in Figure 9-30, but was side-looking into Zone 0 of lane 1. The second inductive loop in each lane and the second SPVD magnetometer in lane 2 were located between Zones 0 and 1.

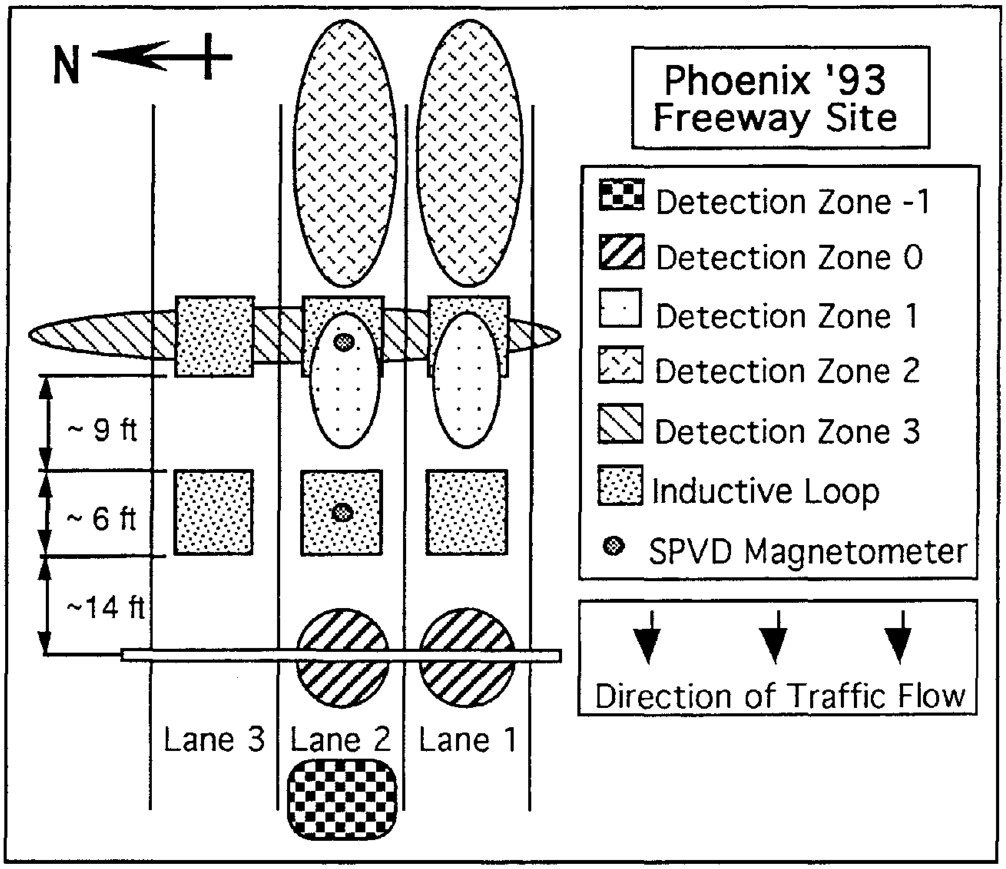
Zone 1 contained the lead loops in each of the three lanes and the lead magnetometer in lane 2. Most of the beam footprints from the forward-looking microwave detectors were found in Zone 1, with the exception of the first RTMS-X1 range bin located in Zone 2. The footprints of the wide-beam Whelen TDW-10 radar and Autoscope were also in Zone 2. Zone 3 overlaps Zone 1 and represents the area covered by the side-looking RTMS-X1 microwave detector mounted on a pole on the north side of the freeway.

The inductive loops failed to operate properly throughout the Phoenix 1993 tests. The lead loop in lane 2 was affected the most and consistently registered false detections due to crosstalk between adjacent loops. The problem persisted in spite of trying many different types of loop amplifiers, adjusting the loop frequency and sensitivity settings, rechecking the electrical ground connections, and replacing the lead-in wire to the test trailer with premium quality shielded cable. Arizona DOT loop installation personnel spent a substantial amount of time attempting to ascertain the cause of the problem without success. The project was unable to obtain permission to close the freeway lanes and have the loops reinstalled.

10.12.1 Run 11090822

This was one of the first runs conducted at the Phoenix freeway site. The Autoscope VIP had not yet been installed. Vehicle counts were ground truthed for a 1-hour period between 9:00 and 10:00 a.m. for lanes 1 and 2 using the recorded video imagery. The results are shown in Table 10-8. The inductive loops and the Sumitomo SDU-300 ultrasonic detector yielded the best count accuracies in lane 1. All of the lane 1 detectors shown yielded at least 90-percent accuracies with the exception of the Eltec 842. This unit ceased to respond at all within 2 weeks from this date, so it may have been operating in an impaired state. Since the 842 was configured as a presence detector, the count accuracy suffered in high-volume applications due to the detector's long hold time.

Several detectors in lane 2 displayed good count accuracies. Both of the SPVD magnetometers and the Eltec 833 all achieved count accuracies greater than 99 percent, with the TDN-30 microwave detector and the SDU-300 ultrasonic detector close behind. The acoustic array overcounted by 21 percent. Since these tests, the sound processing algorithms in the acoustic detector have undergone a substantial amount of modification and the detector package size has been reduced considerably. The TC-20 Doppler microwave and the Eltec 842 passive infrared detectors undercounted by approximately 28 percent and 21 percent, respectively. This has been attributed to their relatively long hold times that cause undercounting in heavy traffic applications. Note that presence detection, and not vehicle counting, is the primary function of these detectors. Count accuracy could be vastly improved with a simple modification to the detector electronics that reduces hold time.



1 ft = 0.305 m

Zone	Lane 1		Lane 2		Lane 3	
	Symbol	Model	Symbol	Model	Symbol	Model
1			A1 IR3	AT&T Acoustic Array Eltec 833		
0	U3A U2A IL1A-2 IR1 IR2	MW Sensors TC-30C Sumitomo SDU-300 Inductive Loop Schwartz 780D1000 Eltec 842	U3B U2B IL1B-2 MG2A-2	MW Sensors TC-30C Sumitomo SDU-300 Inductive Loop SPVD Magnetometer	IL1C-2	Inductive Loop
1	IL1A-1 M4B M2B M6A-3 U1	Inductive Loop Whelen TDN-30 MW Sensors TC-26 EIS RTMS (fwd-look) Sumitomo RDU-101	IL1B-1 M4A M1A MG2A-1	Inductive Loop Whelen TDN-30 MW Sensors TC-20 SPVD Magnetometer	IL1C-1	Inductive Loop
2	VP1C M6A-2	Autoscope 2003 VIP EIS RTMS (fwd-look)	VP1B M5A	Autoscope 2003 VIP Whelen TDW-10	VP1A	Autoscope 2003 VIP
3	M6A-5	EIS RTMS (side-look)	M6A-6	EIS RTMS (side-look)	M6A-7	EIS RTMS (side-look)

Figure 10-33. Detection Zones on I-10 in Phoenix, AZ During Autumn 1993

Table 10-8. Vehicle Counts for Run 11090822 on Phoenix Freeway

Lane 1			Lane 2		
Detector	**Count**	**% Error**	**Detector**	**Count**	**% Error**
ILD 1	766	2.1	SPVD Mag 1	1025	-0.8
ILD 2	789	5.2	SPVD Mag 2	1032	-0.1
TDN-30	686	-8.5	ILD 1**	3030	193.3
TC-30C	697	-7.1	ILD 2	944	-8.6
780D1000	680	-9.3	TDN-30	1019	-1.4
842*	590	-21.3	TC-20*	747	-27.7
SDU-300	719	-4.1	833	1042	0.9
			Acoustic Array	1251	21.1
			SDU-300	1009	-2.3
Ground Truth	750		Ground Truth	1033	

* Designed as a presence detector

* * Crosstalk between loops in the same lane on lanes 1 and 2

10.12.2 Run 11221359

The run commenced when traffic was moderate and continued through the time of peak traffic. The weather was mild and clear. Vehicle counts were ground truthed in post-processing for the 4:00 to 5:00 p.m. interval.

Vehicle Counts vs. Time of Day

Figure 10-34 compares the vehicle counts from seven detectors in lane 2 at the Phoenix site with ground truth. All detectors, except the loops, appeared to perform within manufacturers' specifications. The poor performance of the loops at this site was traced to crosstalk between loops in the same lane. Therefore, this was the only site where the loops could not be relied on for accurate vehicle counts nor for the use of multiple-loop speed traps. When the Phoenix site was revisited in the Summer 1994, only one loop was used in lanes 1 and 2, and the crosstalk problem was not encountered. The loops in lane 3 (the rightmost through-lane) did not experience crosstalk. Unfortunately, the detectors could not be moved over lane 3 because of the presence of a large variable message sign mounted on the sign-bridge structure.

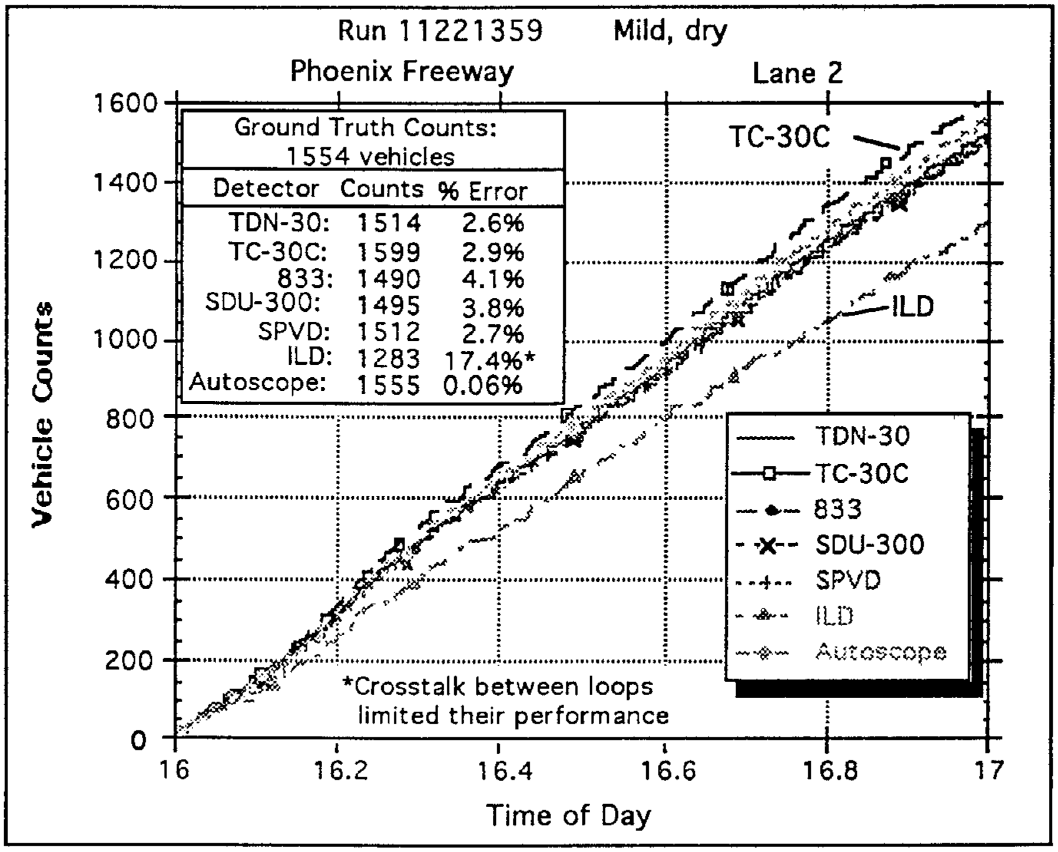


Figure 10-34. Comparison of Vehicle Count Data for Run 11221359 at Phoenix Freeway Site

Vehicle Flow vs. Time of Day

Figure 10-35 shows vehicle flow in lane 2 as calculated from the TC-30C and SDU-300 ultrasonic detectors and an SPVD magnetometer. Figure 10-36 shows vehicle flow in lane 2 based on data from the TDN-30 microwave detector, 833 passive infrared, and Autoscope 2003 video image processor. Two figures were used to show the flow data for the six detectors in order to make the individual curves more clear. The flows were computed based on 1-minute data integration intervals over a 1-hour period between 4 and 5 p.m. for which the ground truth vehicle counts were available. The result of using a 1-minute integration interval is a discrete, "spiky" curve. Shorter integration intervals, such as 30 seconds, produce flow values that reflect the microscopic movement of individual vehicles and thus may generate a curve that shows higher instantaneous flow rates. Short integration intervals may be required when the maximum peak flow on a roadway is needed.

Detector count accuracy is also critical in applications requiring instantaneous traffic flows. In computing flow in units of vehicles per hour, the values for the flow are quantized in steps of 60 divided by the integration interval in minutes. Thus,

Instantaneous Flow =

$$\frac{n}{t_i} \times \frac{60 \text{ min}}{\text{h}} = \frac{60}{t_i} n \quad \frac{\text{vehicles}}{\text{hour}} \qquad (10\text{-}1)$$

where

n = number of vehicles in the integration interval

and

t_i = integration interval in minutes.

For a 1-minute integration interval, each overcount or undercount of a vehicle equates to 60 vehicles per hour on the flow axis. Over a 5-minute integration interval, each vehicle represents 60/5 or 12 vehicles per hour in terms of flow. Hence, the shorter the integration interval, the greater the potential for variability in the computed traffic flow. However, on a percentage basis, the change in flow is the same as the change in vehicle counts. A detector that exhibits a consistent bias to either overcount or undercount could conceivably have its reported values adjusted by a correction factor in the software.

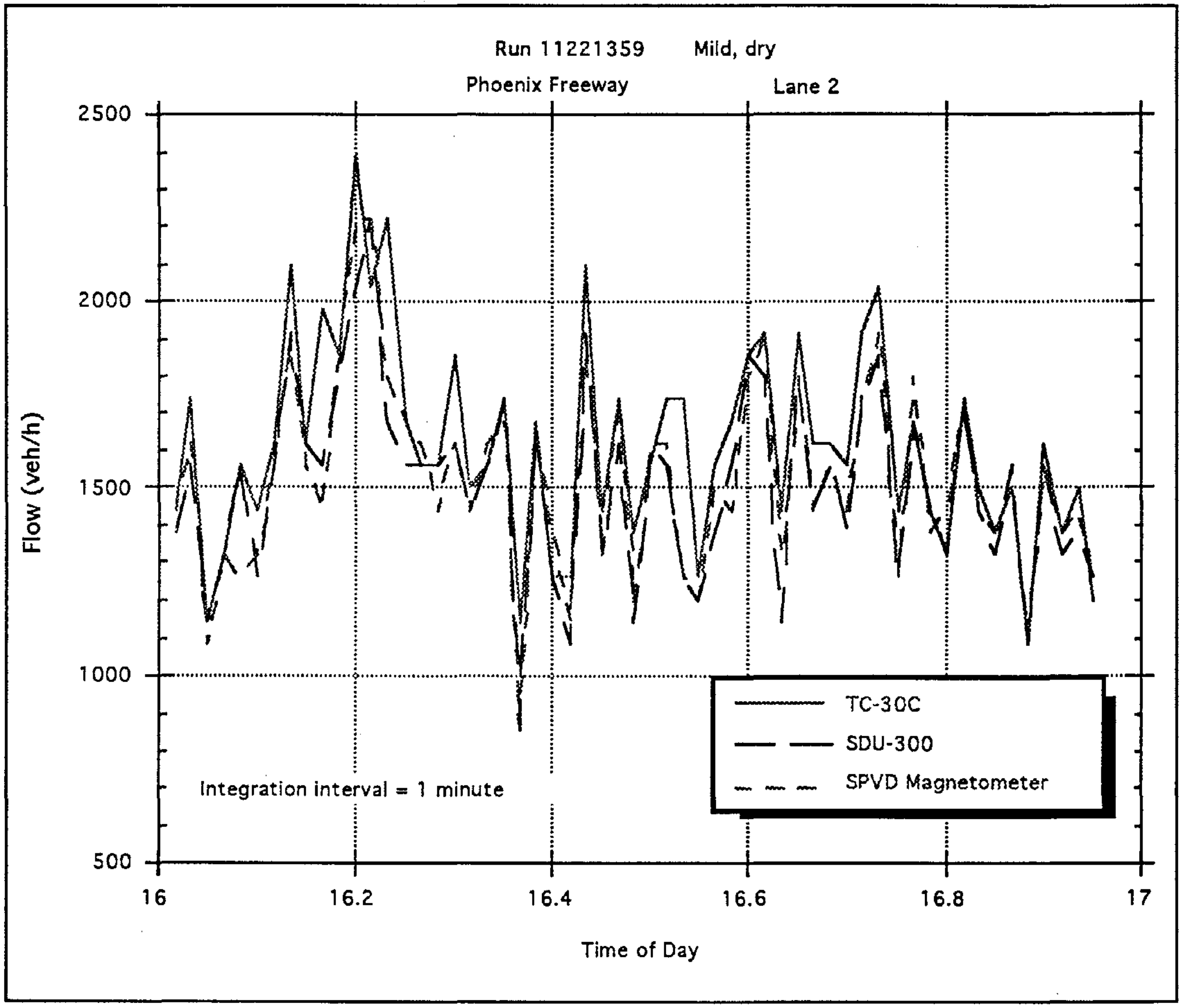


Figure 10-35. Vehicle Flow in Lane 2 Using Data From TC-30C, SDU-300, and SPVD Over 1-Hour Ground Truth Interval at Phoenix Site

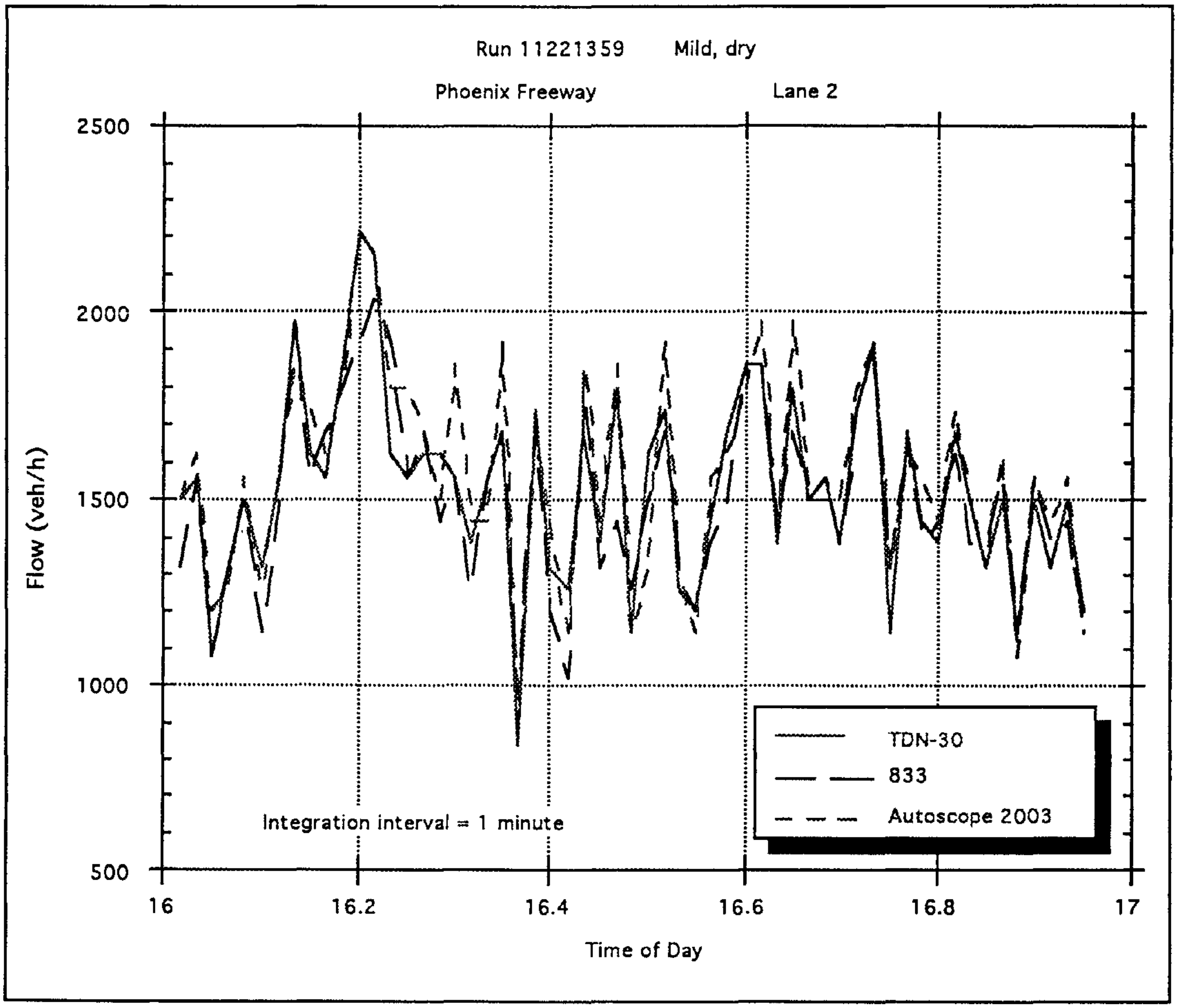


Figure 10-36. Vehicle Flow in Lane 2 Using Data From TDN-30, 833, and Autoscope 2003 Over 1-Hour Ground Truth Interval at Phoenix Site

Figure 10-37 shows flow versus time of day for three detectors located in lane 2 over the entire 3.5-hour run. The detectors represented are the TDN-30 microwave detector, SDU-300 ultrasonic detector, and the Autoscope 2003 video image processor. The flow was computed using a 5-minute data integration interval. If peak traffic flow information is required for a particular traffic management application, then a shorter integration interval that does not average the flow data as much should be used.

The three curves generally coincide except for a pronounced spike exhibited by the Autoscope from about 3:00 to 3:10 p.m. Upon examining the database file from which the plots were drawn, it was found that the counts recorded from Autoscope detection zone 3 (downstream detection zone) on the data logger suspended temporarily. The rising edge of a pulse was received by the data logger (corresponding to a vehicle entering the Autoscope detection zone), but the falling edge of the pulse was not received for up to 51 seconds.

In total, eight separate detections, with presence times between 5 and 51 seconds, were reported over a 26-minute interval between 2:45 and 3:11 p.m. Six occurred between 3:05 and 3:11. Seven of the eight detections occurred in lane 2 and one in lane 1. In each instance, the long presence values occurred for Autoscope zones 2 and 3 (the speed and downstream detection zones, respectively). Zone 1 (upstream detection zone) did not report long presence times. No presence times having the same duration were reported by the other detectors during this time period. Several vehicles were detected by other devices monitoring the same roadway segment during the times when Autoscope reported a single vehicle. The long presence values did not occur again during other time intervals in the run.

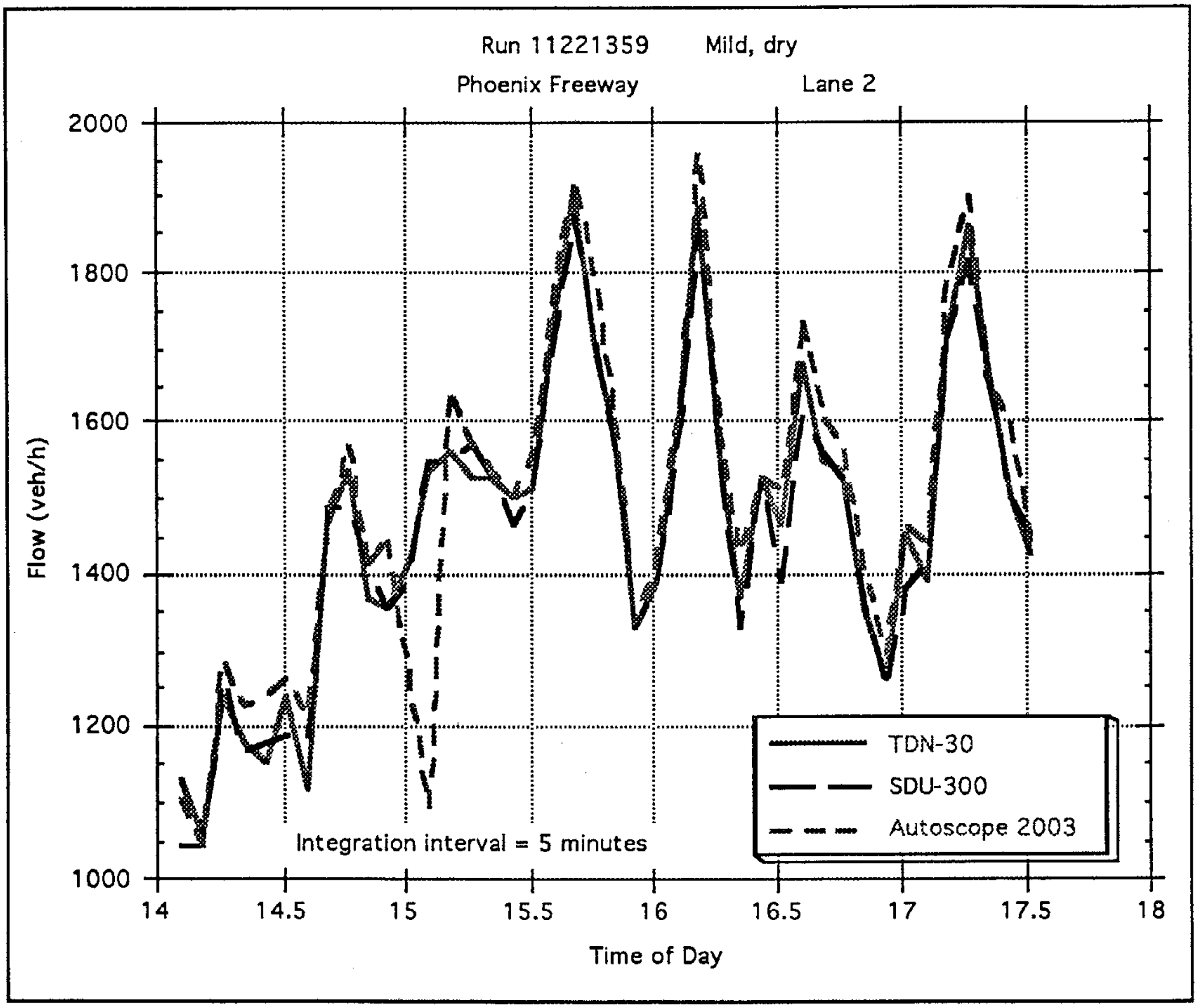


Figure 10-37. Vehicle Flow in Lane 2 for Run 11221359 at Phoenix Site

Figure 10-38 shows the data presented in Figure 10-37 fitted to a fifth-order polynomial. The discrete flow characteristics evident in Figure 10-37 are smoothed out by the curve fit. Fitting the data in this manner shows long-term traffic trends as opposed to the instantaneous flow.

Lane Occupancy vs. Time of Day

Figure 10-39 shows the lane occupancy for the same three devices represented in Figures 10-37 and 10-38 over the same approximate 3.5-hour period. Occupancy was computed as the sum of the vehicle presence times collected over a 5-minute integration interval divided by the integration interval itself. This yielded the percentage of time that the detector was in the active state over the 5-minute interval. Plots are shown for both the individual calculated results and the fifth-order polynomial fit. The anomaly discussed with respect to Autoscope in Figure 10-37, which was manifested as low traffic flow, is seen here as a long presence time between 3:00 and 3:10 p.m.

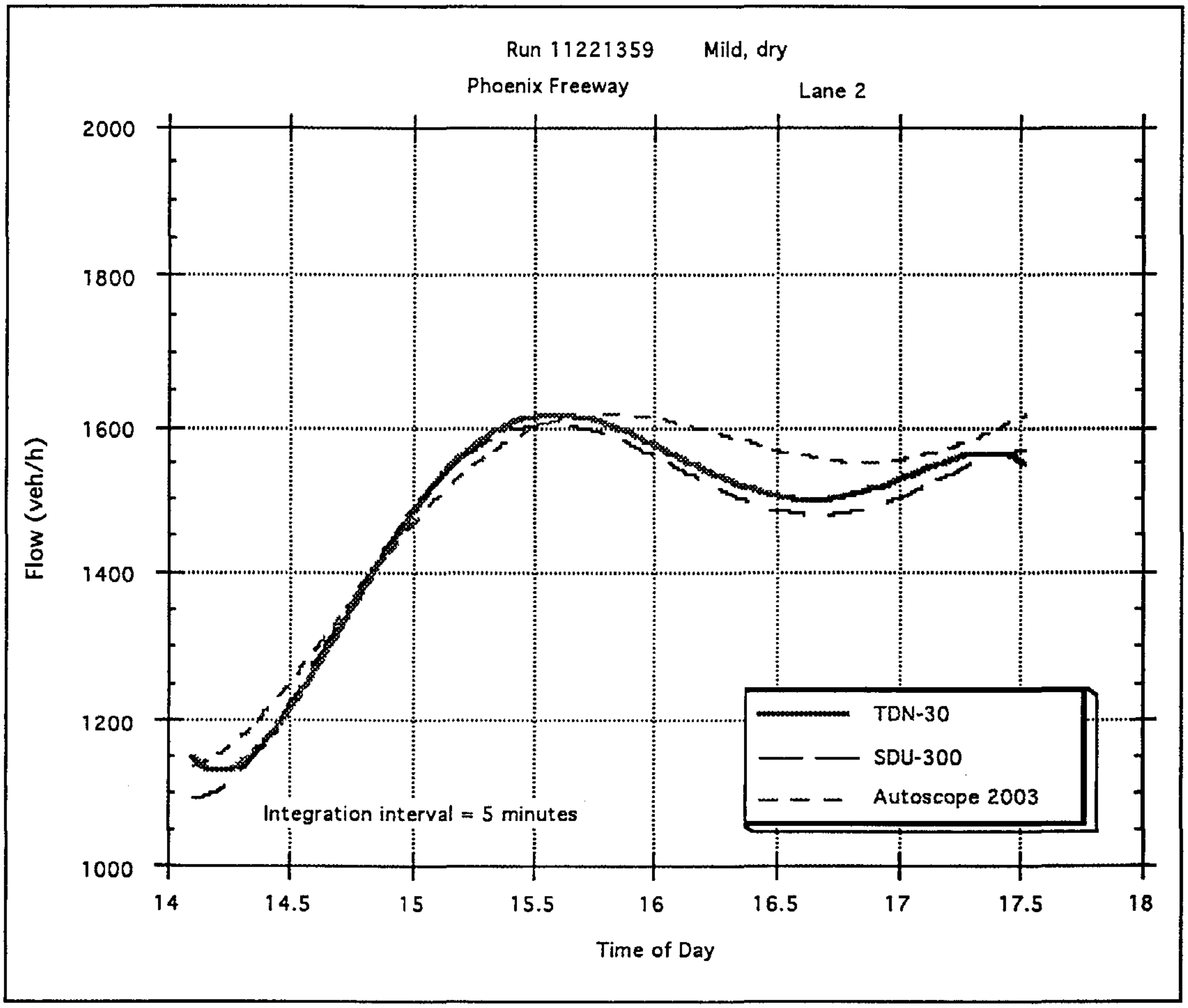


Figure 10-38. **Lane 2 Vehicle Flow for Run 11221359 at Phoenix Site Fitted to Fifth-Order Polynomial**

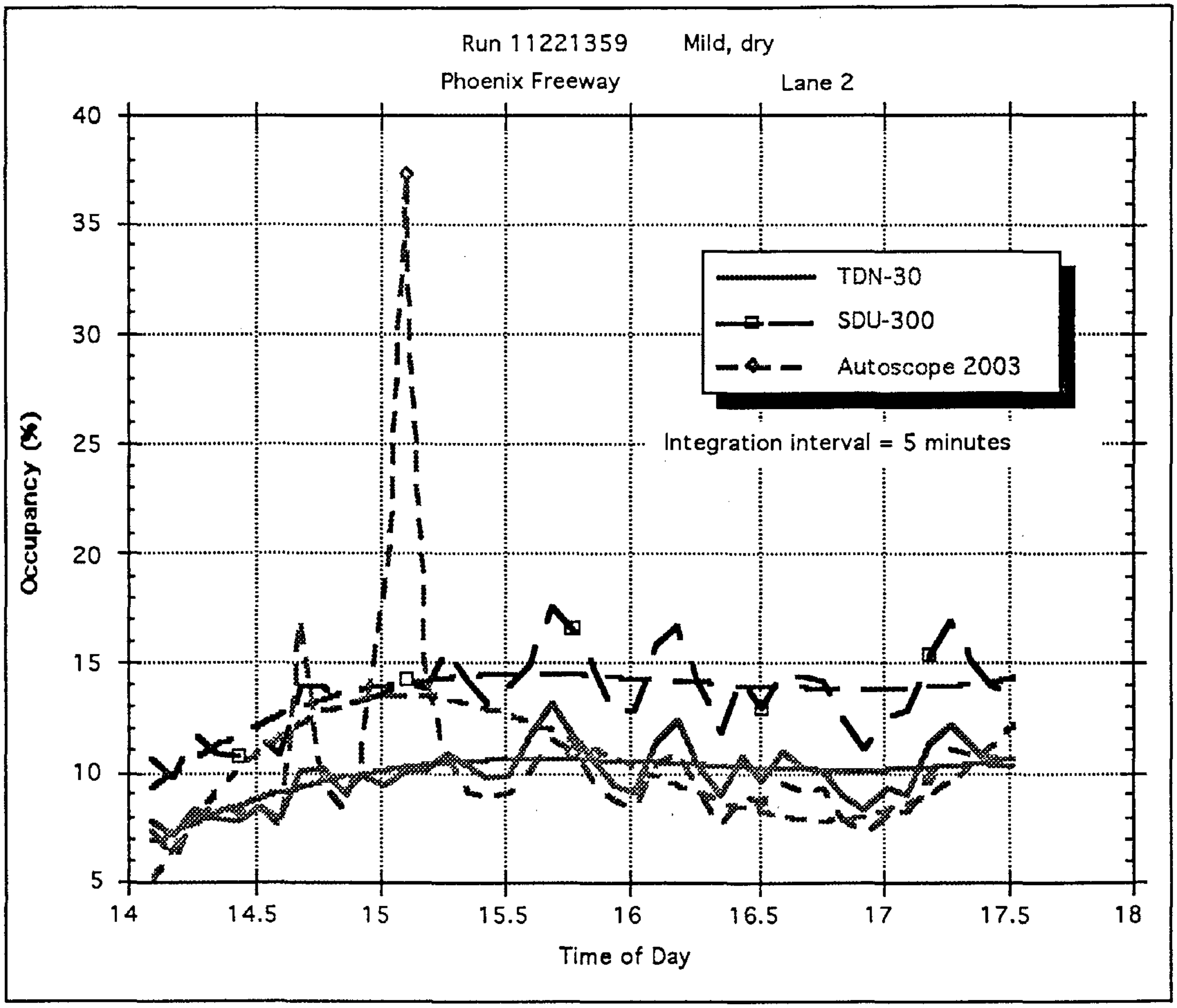


Figure 10-39. Lane 2 Occupancy for Run 11221359 at Phoenix Site Showing Curve Fit to Fifth-Order Polynomial and Unfitted Data

10.13 PHOENIX SUMMER 1994 FREEWAY DATA

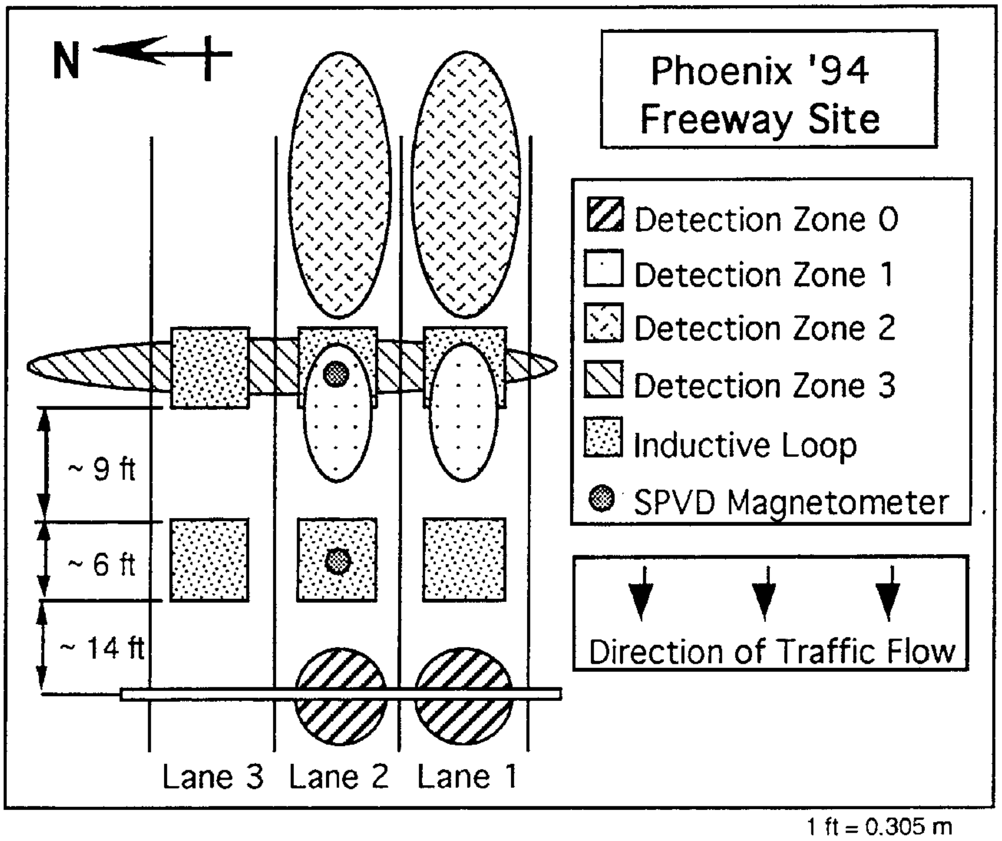
The Phoenix I-10 freeway site was revisited during the summer of 1994 in order to evaluate the performance of the detectors during the hot and dry desert weather. Since the AT&T acoustic array was not available during this period, only four detection zones were used.

The differences between the Autumn 1993 and Summer 1994 overhead detector configurations were as follows. The Eltec 833 passive infrared detector was pointed toward oncoming traffic in lane 2. The EVA 2000 video image processor monitored all three lanes of traffic and provided data through an RS-232 interface.

The detection zones and the detectors that they contained are shown in Figure 10-40.

10.13.1 Run 07281536

This run encompassed a variety of weather conditions over its approximate 4.5-hour duration. The temperature at the beginning of the session was greater than 100°F (37.8°C). High, gusty winds began blowing around 7:00 p.m., followed by thunderstorms. The video was ground truthed for a 1-hour



Zone	Lane 1		Lane 2		Lane 3	
	Symbol	**Model**	**Symbol**	**Model**	**Symbol**	**Model**
0	U3A U2A IL1A-2 IR1 IR2	MW Sensors TC-30C Sumitomo SDU-300 Inductive Loop Schwartz 780D1000 Eltec 842	U3B U2B IL1B-2 IR3 MG2A-2	MW Sensors TC-30C Sumitomo SDU-300 Inductive Loop Eltec 833 SPVD Magnetometer	IL1C-2	Inductive Loop
1	IL1A-1 M4B M2B M6A-3 U1	Inductive Loop Whelen TDN-30 MW Sensors TC-26 EIS RTMS (fwd-look) Sumitomo RDU-101	IL1B-1 M4A M1A MG2A-1	Inductive Loop Whelen TDN-30 MW Sensors TC-20 SPVD Magnetometer	IL1C-1	Inductive Loop
2	VP1C M6A-2	Autoscope 2003 VIP EIS RTMS (fwd-look)	VP1B M5A	Autoscope 2003 VIP Whelen TDW-10	VP1A	Autoscope 2003 VIP
3	M6A-5	EIS RTMS (side-look)	M6A-6	EIS RTMS (side-look)	M6A-7	EIS RTMS (side-look)

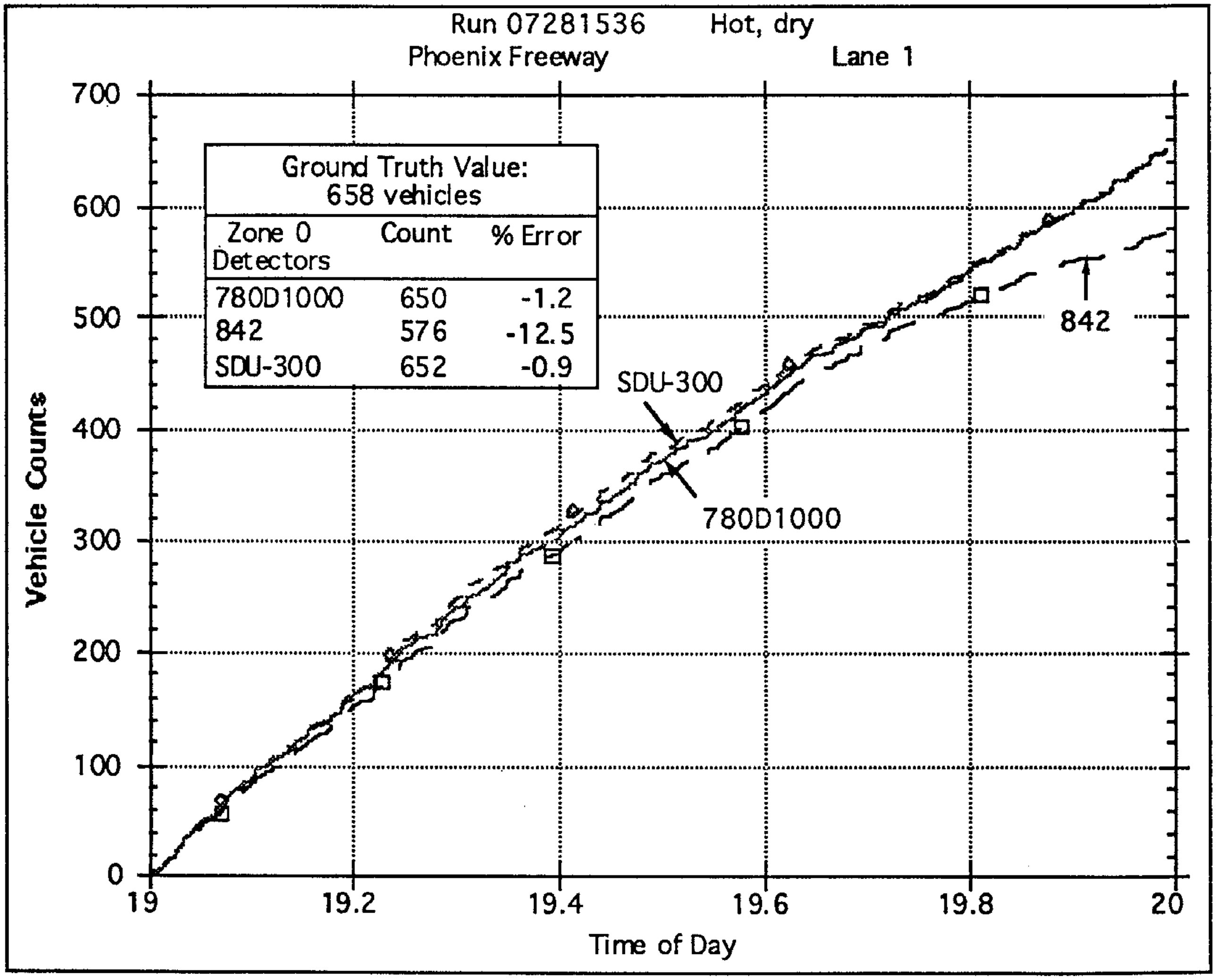
Figure 10-40. Detection Zones on I-10 in Phoenix, AZ During Summer 1994

period between 7:00 and 8:00 p.m. The following figures show the detector count accuracies referenced to these ground truth values.

Vehicle Counts vs. Time of Day

Figures 10-41 through 10-44 compare the accumulation of vehicle counts over time from several detectors with ground truth for lanes 1 and 2 of the westbound I-10 freeway. These plots group results from detectors occupying roughly coincident sensing areas. Figures 10-41 and 10-43 contain the counts for detector sensing areas in detection Zone 0 of lanes 1 and 2, respectively. Figures 10-42 and 10-44 give the lane 1 and 2 counts for detectors that have their sensing areas in detection Zones 1 and 2, respectively. The detection zones were defined in Figure 10-40.

The detectors represented in Figure 10-41 are the Schwartz laser radar, the Eltec 842 passive infrared detector, and the Sumitomo SDU-300 ultrasonic detector that view Zone 0 in lane 1. Both the laser radar and the ultrasonic detector agree with the ground truth value to within about 1 percent. The count from the 842 infrared unit falls off noticeably at around 7:45 p.m. The reason for this behavior has not been established.

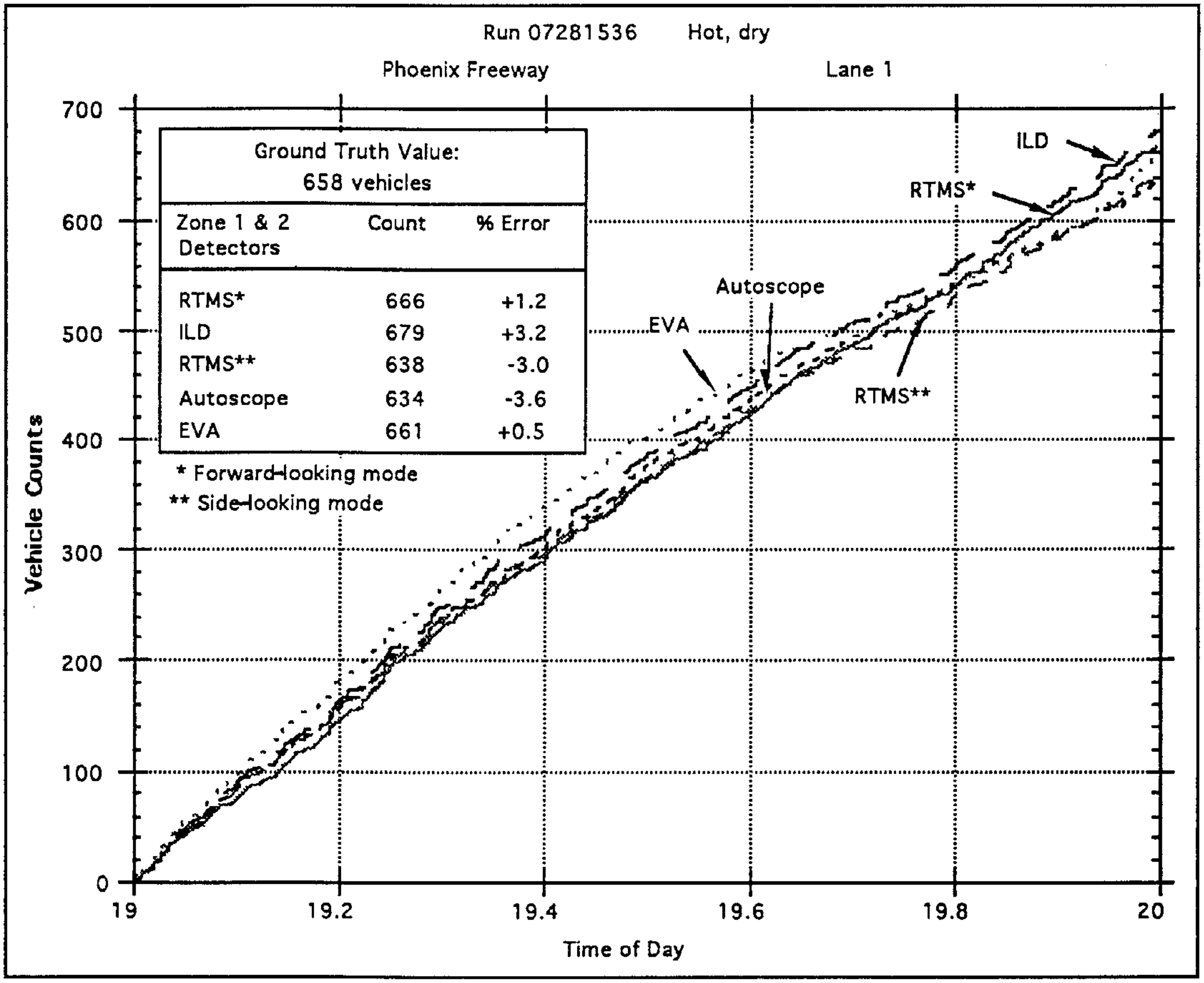


Ground Truth Value:
658 vehicles

Zone 0 Detectors	Count	% Error
780D1000	650	-1.2
842	576	-12.5
SDU-300	652	-0.9

Figure 10-41. Detection Zone 0 Vehicle Counts with Ground Truth in Lane 1 Versus Time of Day at Phoenix 1994 Site

Figure 10-42 shows the count relationships among five detectors monitoring Zones 1 and 2 of lane 1. Represented are two RTMS true-presence microwave radars (one forward looking and the other side looking), an inductive loop, and the Autoscope 2003 and EVA 2000 video image processors. The 0.5-percent error attributed to the EVA VIP overstates the accuracy of the device during this run in that it overcounts until approximately 7:40 p.m. (or slightly after 19.6 hours) and then undercounts until the end of the run segment. Its total count converges toward the recorded ground truth value at the end of the 1-hour ground truth interval. The dip occurring shortly after 7:40 p.m. perhaps indicates an anomaly in the detection algorithms when they transition from daytime to nighttime operation.



Ground Truth Value:
658 vehicles

Zone 1 & 2 Detectors	Count	% Error
RTMS*	666	+1.2
ILD	679	+3.2
RTMS**	638	-3.0
Autoscope	634	-3.6
EVA	661	+0.5

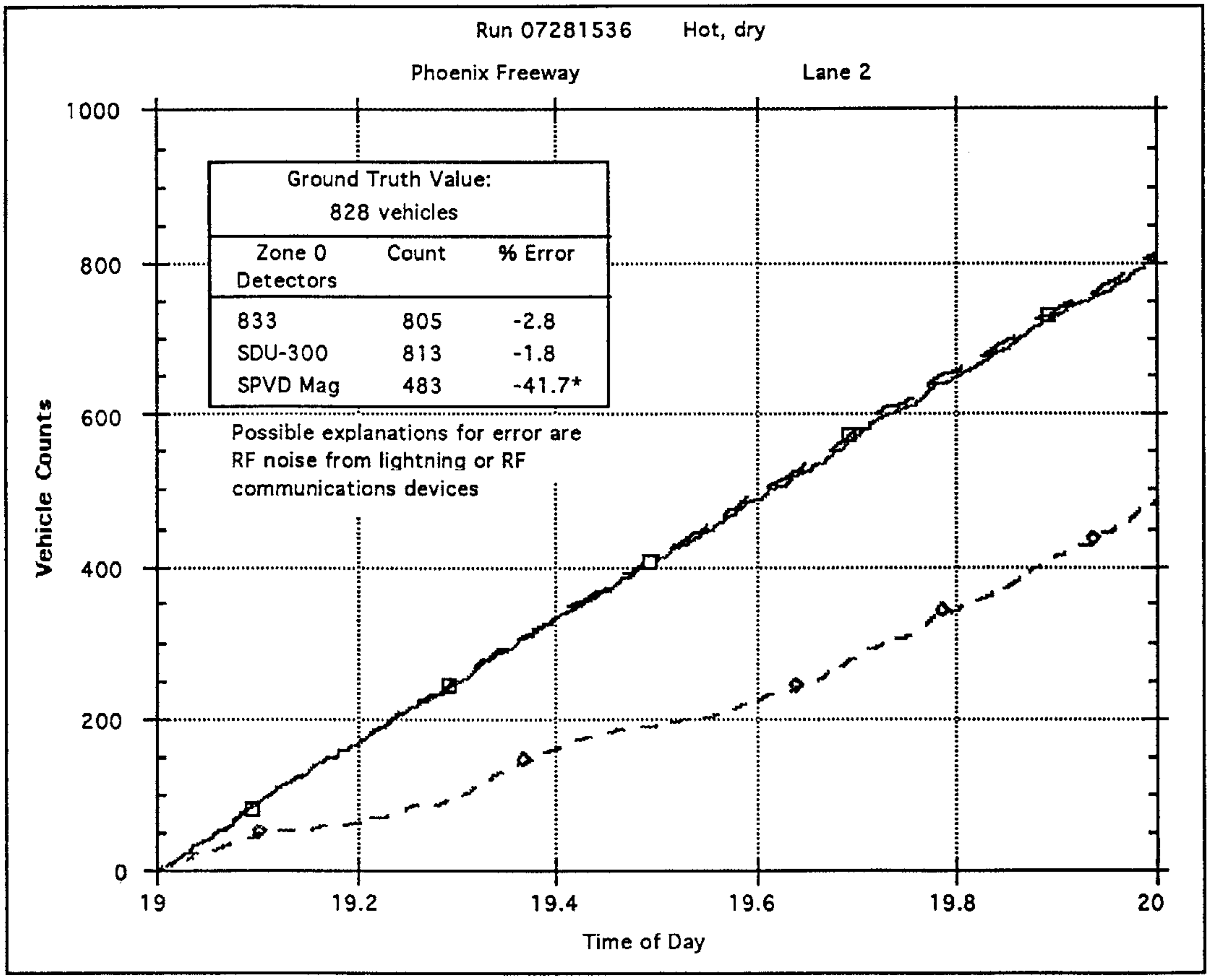
* Forward-looking mode
** Side-looking mode

Figure 10-42. Detection Zones 1 and 2 Vehicle Counts with Ground Truth in Lane 1 Versus Time of Day at Phoenix 1994 Site

For optimum operation, EVA recommends that the camera mounting height be at least 33 feet (10.1 m) above the road surface. During our tests, the camera was 26-1/4 feet (8.0 m) above the road. Although camera mounting height affects speed measurement accuracy more than vehicle count, the less than optimum mounting height may have contributed to the behavior observed in the EVA count output.

Figure 10-43 gives vehicle counts for three detectors monitoring detection Zone 0 in lane

2. Represented in this graph are the Eltec 833 passive infrared detector, the Sumitomo SDU-300 ultrasonic detector, and the SPVD magnetometer. The count from the magnetometer was consistently low by 40 to 50 percent throughout the 1-hour period. An explanation for this anomaly could not be positively ascertained. It is thought that electromagnetic interference played a role in its degraded performance. The interference could have come from the lightning that accompanied the thunderstorm, or perhaps from radio transmissions in the area (the SPVD receiver does not operate in protected frequency bands). In any event, the less than optimum result seen here was transient in nature and better performance from the SPVD was observed in subsequent runs without any modification to the hardware.

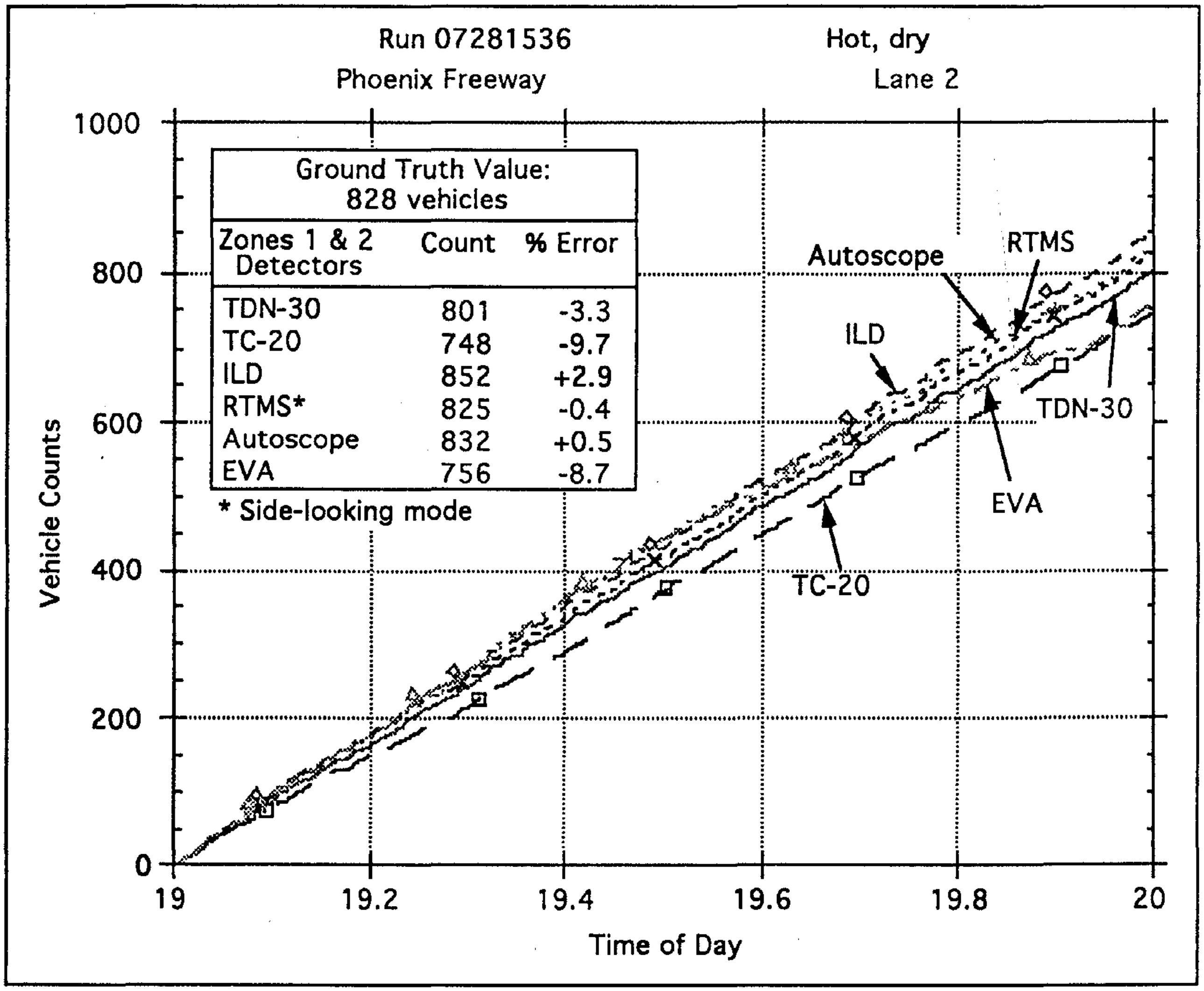


Ground Truth Value:
828 vehicles

Zone 0 Detectors	Count	% Error
833	805	-2.8
SDU-300	813	-1.8
SPVD Mag	483	-41.7*

Figure 10-43. Detection Zone 0 Vehicle Counts with Ground Truth in Lane 2 Versus Time of Day at Phoenix 1994 Site

Figure 10-44 contains the counts for six detectors monitoring Zones 1 and 2 of lane 2. As in lane 1, the count from the EVA VIP begins to dip around 7:40 p.m., indicating that the unit is undercounting at night. The inductive loops overcount by approximately 3 percent in both lanes. This may be due to double-counting of tractor-trailer rigs. This postulate can be checked in future analyses by overlaying the loop counts on the video imagery and correlating the displayed counts with vehicle type.



Zones 1 & 2 Detectors	Count	% Error
TDN-30	801	-3.3
TC-20	748	-9.7
ILD	852	+2.9
RTMS*	825	-0.4
Autoscope	832	+0.5
EVA	756	-8.7

* Side-looking mode

Figure 10-44. Detection Zones 1 and 2 Vehicle Counts with Ground Truth in Lane 2 Versus Time of Day at Phoenix 1994 Site

The vehicle counts from detection Zones 1 and 2 over the total run time are shown in Figures 10-45 and 10-46 for lanes 1 and 2, respectively. The purpose of these graphs is to examine the behavior of the EVA VIP over a longer time interval. Within the resolution of the scale, the EVA appears to overcount in lane 1 with respect to the RTMS in daylight and darkness, the overcount being 1.6 percent over the approximately 5-hour run duration. In lane 2, the EVA overcounts until approximately 8:30 p.m. and then undercounts for the rest of the run with respect to the RTMS. In this lane, the total undercount was 3.2 percent. If the run time had been shorter, the overcount in lane 1 attributed to the EVA would be greater, and the undercount in lane 2 would change to an overcount.

The RTMS was used as the basis for count comparison in this discussion because it appeared to be the most accurate vehicle count detector during the run as deduced from the ground truth results.

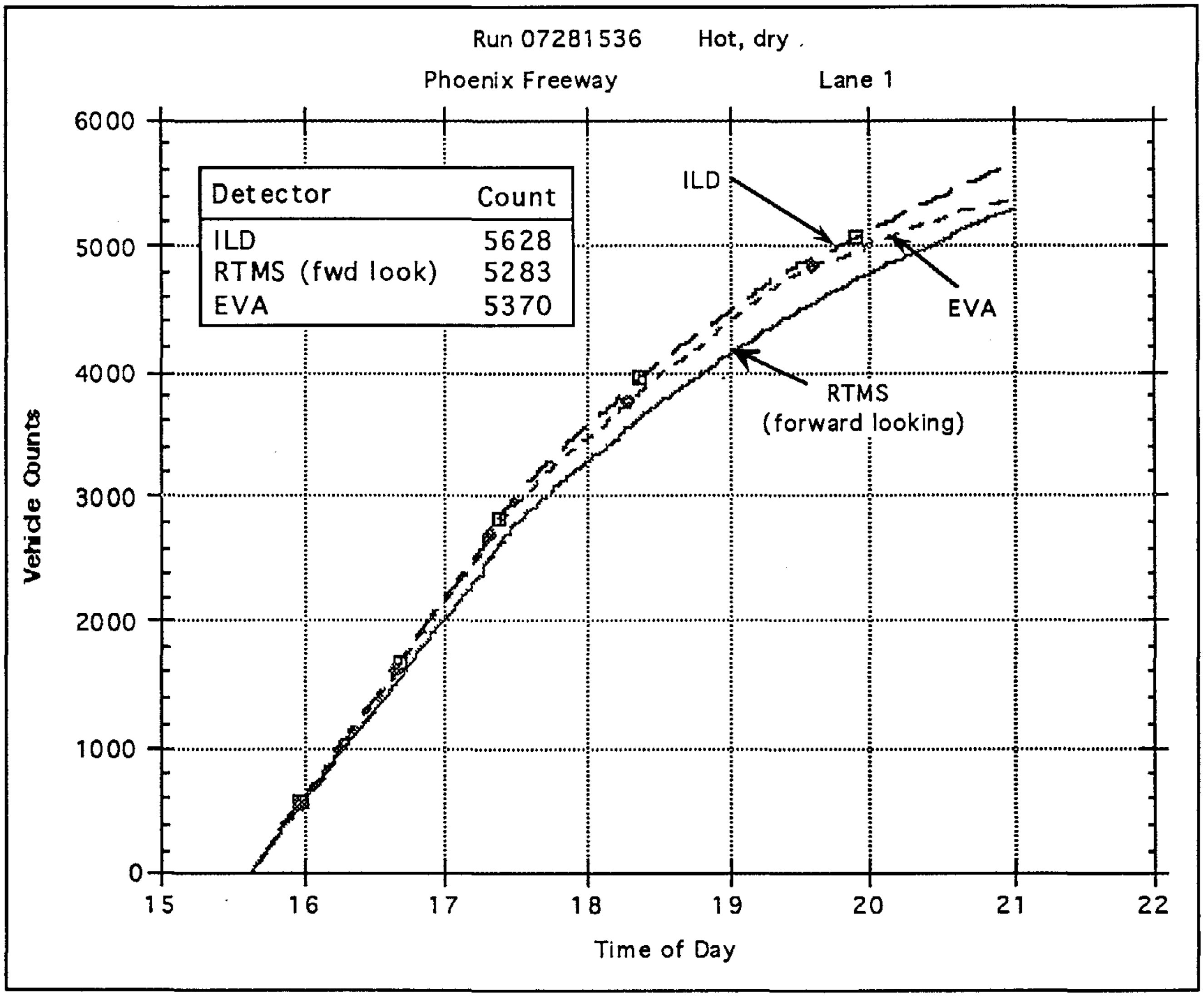


Figure 10-45. Vehicle Counts in Detection Zones 1 and 2 of Lane 1 for Entire Duration of Run 07281536 at Phoenix 1994 Site

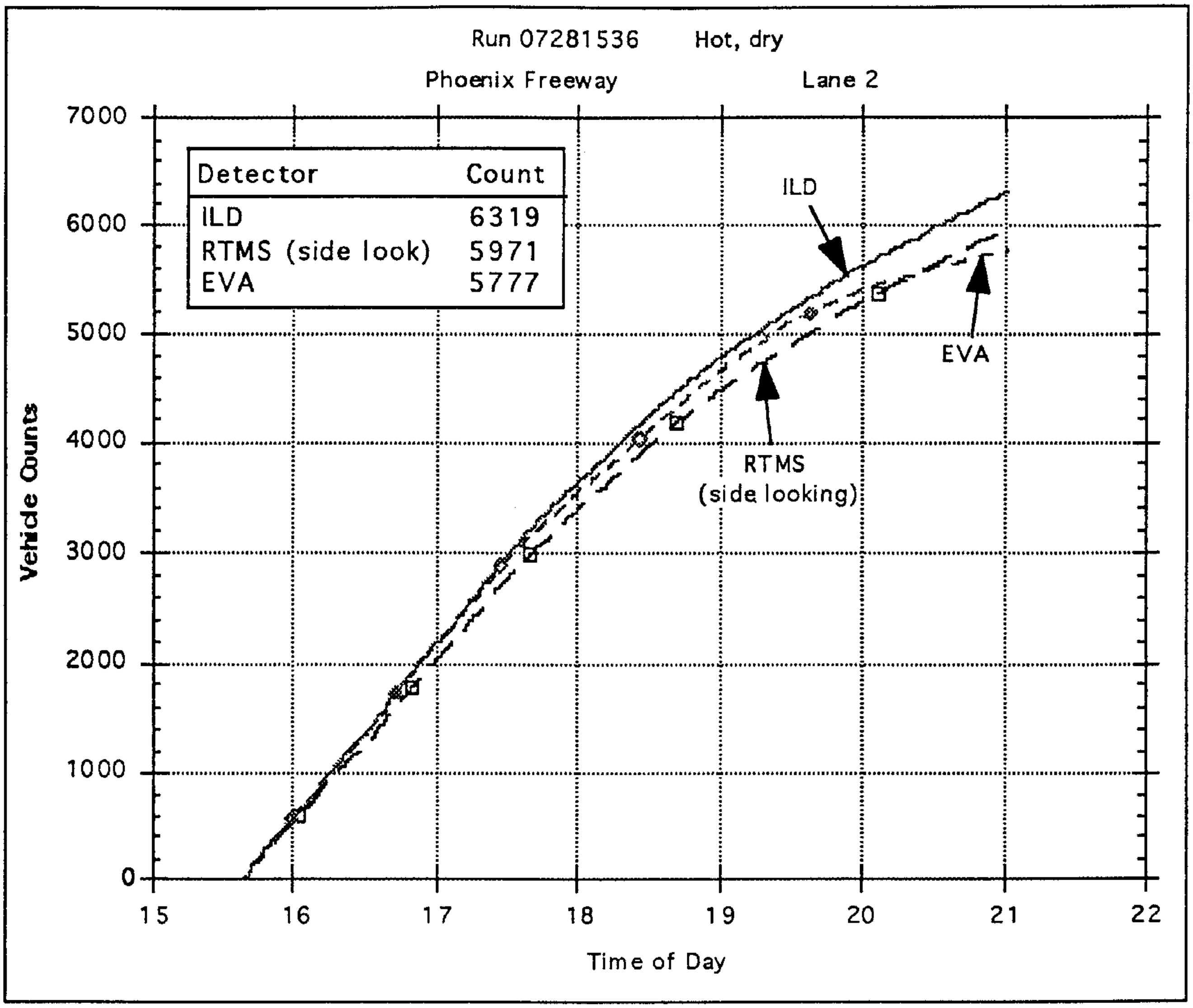


Figure 10-46. Vehicle Counts in Detection Zones 1 and 2 of Lane 2 for Entire Duration of Run 07281536 at Phoenix 1994 Site

10.13.2 Run 08041552

This run was characterized by intense dry heat (109°F [42.8°C] at the beginning of the run). The duration of the session was slightly more than 5 hours. Ground truth was obtained for a 1-hour period during the run, 5:00 to 6:00 p.m., by manually counting vehicles appearing in the recorded video imagery. The percentage errors listed in Table 10-9 are referenced to these ground truth values.

Vehicle Counts vs. Time of Day

Vehicle counts accumulated by the detectors over the 1-hour ground truth period were compared with the values recorded from the video imagery by a human observer. Nearly all of the detector count accuracies analyzed in this run were worse than those corresponding to the windy and stormy conditions evident in Run 07281536 as reported in Section 10.13.1. The inductive loops performed in a manner consistent with the results seen in earlier analyses of data from the Phoenix freeway site. Their tendency to overcount with respect to the observed ground truth data lends credence to the likelihood that the loops were double-counting tractor-trailer rigs. The side-looking RTMS measured detections to within a single count of the ground truth in lane 2, although the lane 1 results are inferior to those presented in 10.13.1. One notable change from Run 07281536 was the recovery of the SPVD magnetometer, which showed an undercount of 3.8 percent after the anomalous behavior exhibited during the run reported in 10.13.1.

Table 10-9. Vehicle Counts for Run 08041552 on Phoenix Freeway

Lane 1			Lane 2		
Detector	**Count**	**% Error**	**Detector**	**Count**	**% Error**
TDN-30	1201	-8.1	TDN-30	1331	-4.9
TC-30C	529	-59.5	TC-30C	138	-90.1
TC-26	1271	-2.8	TC-20	770	-45.0
780D1000	1267	-3.1	833	1324	-5.4
842	1162	-11.1	SDU-300	1333	-4.7
SDU-300	1233	-5.7	SPVD Mag	1346	-3.8
RTMS-X1 1 (fwd)	1170	-10.5	ILD	1447	+3.4
RTMS-X1 2 (fwd)	1271	-2.8	RTMS-X1 (side)	1400	+0.1
ILD	1341	+2.6	Autoscope 1	1336	-4.5
RTMS-X1 (side)	1184	-9.4	Autoscope 2	777	-44.5
Autoscope 1	1010	-22.7	Autoscope 3	1268	-9.4
Autoscope 2	479	-63.4	EVA	1378	-1.5
Autoscope 3	1218	-6.8			
EVA	1281	-2.0			
Ground Truth	1307		Ground Truth	1399	

10.14 TUCSON SURFACE-STREET DATA

The Tucson surface-street site was located at the southwest corner of Oracle Road and Auto Mall Drive. The detector layouts are shown in Figure 9-47. Four groups of detection zones in two lanes of traffic were present as illustrated in Figure 10-47. Zone 0 was dedicated to detectors oriented at or near nadir.

The detectors in Zone 1 were the lead square loops in each of the two instrumented lanes and the forward-looking RTMS-X1, Whelen TDN-30, and Eltec 842 in lane 2. The 842 was physically mounted over lane 3, but was side-looking into lane 2 per the manufacturer's suggestion. In lane 3 (curb lane) were the lead SPVD magnetometer, Sumitomo RDU-101, Whelen TDN-30, and Microwave Sensors TC-26.

Zone 2 corresponded to the area monitored by the side-looking RTMS-X1 true-presence microwave radar. An array of three-axis fluxgate magnetometers that were used to record analog vehicle signatures were buried in the roadway midway between the two pairs of square loops.

Detection Zone 3 contained the sensing area for the second square loop in each lane, as well as the second magnetometer and Autoscope 2003 VIP and Grumman passive imaging infrared VIP in lane 3. Beyond the square loops in lane 3 were a pair of 6-foot (1.8-m) diameter round loops. Two 3M microloop probes were placed in each of lanes 2 and 3, midway between the two round loops as shown in Figure 10-47. Other detectors in lane 2 of Zone 3 included the second range bin from the forward-looking RTMS-X1 and the Autoscope 2003 VIP.

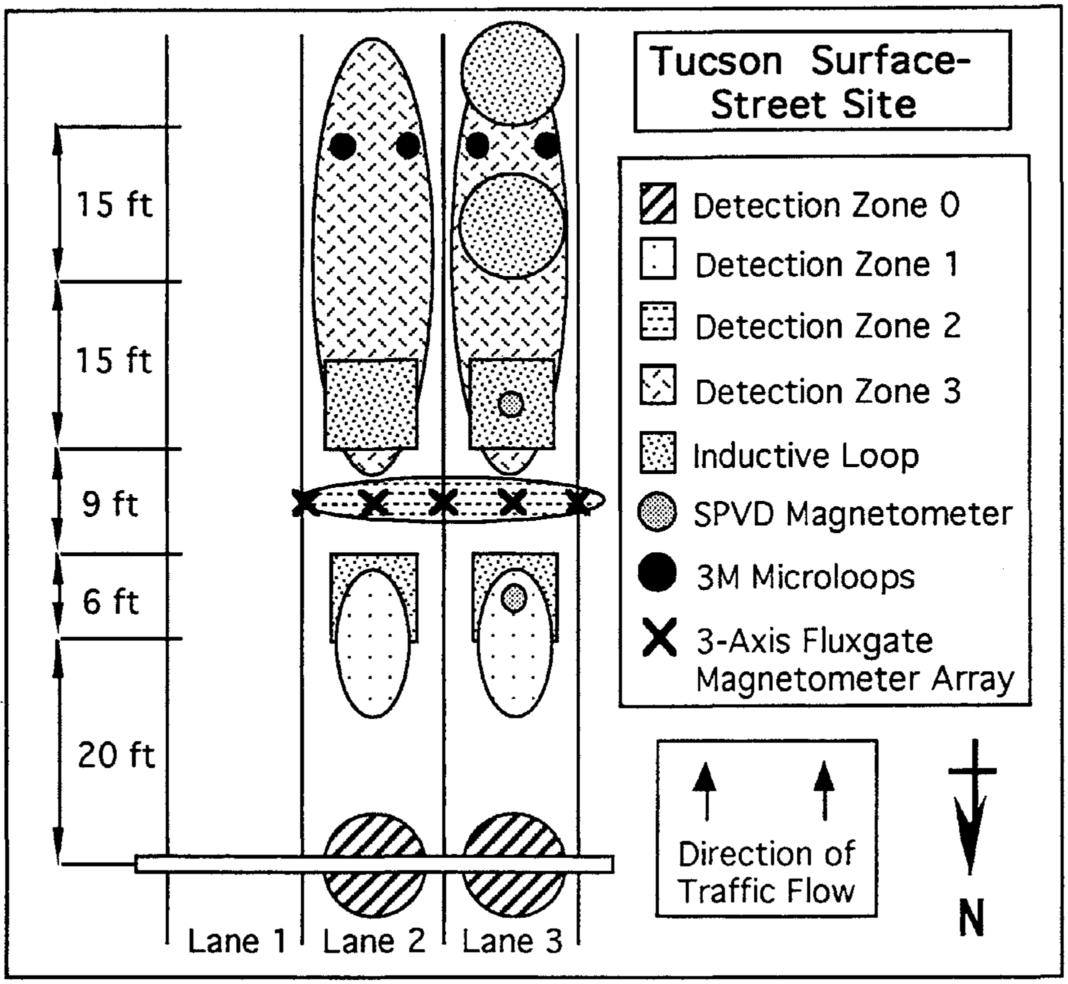
10.14.1 Run 03101008

This run was conducted with a special purpose in mind. It was hoped that the detectors would be tested in Minnesota under conditions that provided a significant amount of accumulated snow on the vehicles. Due to the absence of the desired weather conditions, it was decided to simulate these conditions in Tucson by attaching 1- and 2-inch (25.4- and 50.8-mm) sheets of styrofoam to the top of a probe vehicle and driving it repeatedly through one of the instrumented lanes that had been closed to normal traffic.

The styrofoam was applied in 1-, 2-, and 3-inch (25.4-, 50.8-, and 76.2-mm) thicknesses to determine its effect on vehicle detection. Of particular interest was the response of the microwave, ultrasonic, and infrared detectors to the styrofoam. It was postulated that the irregular surface of the layer may scatter or absorb a portion of the transmitted energy or modify the emitted energy, causing the detector to miss the vehicle. The results in Table 10-10 indicate otherwise. The TC-30C detected the styrofoam-covered probe vehicle in all of the passes, as did the other two overhead detectors examined, namely the 780D1000 laser radar and TDN-30 Doppler microwave detector. Detections were also tabulated for a pair of inductive loops that were not affected by the styrofoam addition to the top surface of the vehicle.

There were some other anomalies recorded during these drive-throughs. The second inductive loop failed to detect the probe vehicle on one occasion and double-counted the International S1600 bucket truck on another. The ultrasonic detector double-counted twice, once on a minivan and once on a police motorcycle. If this pattern held throughout the Tucson tests, one would expect the ultrasonic detector to produce vehicle counts that are consistently high with respect to the ground truth. To the contrary, the TC-30C tended to undercount slightly. It is possible that the ultrasonic detector picked up the presence of test personnel wandering through its detection zone after the passage of the target vehicle during the controlled drive-throughs. This cannot be ascertained from the video imagery as the TC-30C's detection zone is not within the field of view of the video camera.

The laser radar failed to detect three of the five passes made by tall bucket trucks, while having no problem with any other vehicles, including the motorcycle. The radar detector manufacturer did not attribute the missed truck detections to its large height. The reason for this anomaly is not known.



1 ft = 0.305 m

Zone	Lane 2		Lane 3	
	Symbol	**Model**	**Symbol**	**Model**
0	U2B	Sumitomo SDU-300	U2A	Sumitomo SDU-300
	U3B	MW Sensors TC-30C	U3A	MW Sensors TC-30C
	IR3	Eltec 833	IR1	Schwartz 780D1000
			A1	AT&T Acoustic Array
1	IL1A-1	Inductive Loop	IL1B-1	Inductive Loop
	M6A-2	EIS RTMS (fwd-look)	MG2A-1	SPVD Magnetometer
	M4A	Whelen TDN-30	U1	Sumitomo RDU-101
	IR2	Eltec 842	M4B	Whelen TDN-30
			M2B	MW Sensors TC-26
2	M6A-3	EIS RTMS (side-look)	M6A-2	EIS RTMS (side-look)
3	IL1A-2	Inductive Loop	IL1B-2	Inductive Loop
	M6A-3	EIS RTMS (fwd-look)	MG2A-2	SPVD Magnetometer
	IL1A-3	3M Microloop	IL1B-3	3M Microloop
	VIP1A	Autoscope 2003 VIP	IL1C-1	Inductive Loop (Round)
	M1A	MW Sensors TC-20	IL1C-2	Inductive Loop (Round)
	M5A	Whelen TDW-10	VIP1B	Autoscope 2003 VIP
			IIR-1	Grumman Imaging IR VIP

Figure 10-47. Detection Zones on Oracle Road Site in Tucson, AZ

Table 10-10. Vehicle Drive-Throughs in Lane 3 of Tucson Site

Event Number	Tape Index Number	Vehicle Type	Styrofoam Thickness	Vehicle Detected (Y/N)				
				ILD1	ILD2	IR1	M4B	U3A
1	1890	Int'l S1600 Truck	N/A	Y	Y	Y	Y	Y
2	2284	Int'l S1600 Truck	N/A	Y	Y(x2)	Y	Y	Y
3	2288	Chevrolet Corsica	N/A	Y	Y	Y	Y	Y
4	2422	Dodge Caravan	N/A	Y	Y	Y	Y	Y(x2)
5	2526	Int'l S1600 Truck	N/A	Y	Y	N	Y	Y
6	2788	Int'l S1600 Truck	N/A	Y	Y	N	Y	Y
7	3158	Kawasaki Motorcycle	N/A	Y	Y	Y	Y	Y(x2)
8	5731	Boyertown Truck	N/A	Y	Y	N	Y	Y
9	7062	Corsica w/ Styrofoam	2"	Y	Y	Y	Y	Y
10	7344	Corsica w/ Styrofoam	2"	Y	Y	Y	Y	Y
11	7428	Corsica w/ Styrofoam	2"	Y	N	Y	Y	Y
12	9287	Corsica w/ Styrofoam	3"	Y	Y	Y	Y	Y
13	9414	Corsica w/ Styrofoam	3"	Y	Y	Y	Y	Y
14	9642	Corsica w/ Styrofoam	3"	Y	Y	Y	Y	Y
15	10119	Corsica w/ Styrofoam	1"	Y	Y	Y	Y	Y
16	10181	Corsica w/ Styrofoam	1"	Y	Y	Y	Y	Y
17	10349	Corsica w/ Styrofoam	1"	Y	Y	Y	Y	Y
18	10847	Corsica w/o Styrofoam	0"	Y	Y	Y	Y	Y
19	10973	Corsica w/o Styrofoam	0"	Y	Y	Y	Y	Y

N/A = not applicable

1 in = 25.4 mm

10.14.2 Run 04121633

This run is representative of a typical evening rush hour. The session commenced at 4:33 p.m. and continued until approximately 9:15 p.m. This ensured that a light-to-dark transition occurred while the data collection was in process. The lighting change stresses the performance of the video image processors under daytime and nighttime conditions as well as the lighting transition period. The results shown in Figures 10-48 and 10-49 compare vehicle counts in the middle and curb lanes, respectively, for Doppler and true-presence microwave radars, ultrasonic detectors, video image processors, and magnetometers. Ground truthing indicated that the loop counts are accurate to approximately 1 percent as explained further under *Comparison of Video Image Processor Counts* at the end of this section.

Since the footprints of the various detectors are not necessarily coincident, vehicles moving from one lane to another may register counts on detectors in each of the two lanes. This problem can be particularly troublesome during the north-south red signal phase. During this time, the straight-through traffic on southbound Oracle Road is stopped north of the intersection, while right turns are made from Auto Mall Drive onto southbound Oracle. Left turns (from two lanes) are also made from the Tucson Mall onto southbound Oracle. These turning movements were seldom confined to a single lane, that is, vehicles tended to sweep out across multiple lanes of traffic on southbound Oracle Road during the completion of these turns. For example, a vehicle turning left from the Tucson Mall onto southbound Oracle may begin its turning movement by crossing over the middle lane (lane 2), thus tripping the detectors in that lane that have a steep incidence angle. The vehicle can then complete its turning movement by entering the curb lane (lane 3) and registering counts for the detectors having detection zones further down the curb lane. While none of these vehicle detections was actually "invalid," the result is that apparent errors are introduced when count accuracies are assessed, because it is difficult to manually locate and observe the detection zones that are activated in each lane by the vehicles during the ground truth process.

This problem can be treated in three different ways. First, the assumption can be made that these anomalies will cancel each other out, i.e., the errors incurred as the result of the left-turn movements will be negated by the errors introduced by the right-turn movements. Second, plots can be grouped by detectors having similar detection zone locations, i.e., detectors looking straight down or at a steep angle of inclination can be compared to one another, while those that detect traffic further down the lane can be compared against one another. The third approach is somewhat more involved. An attempt can be made to filter out the vehicle detections that result from turning movements, thus allowing only the vehicles that pass during the north-south green signal phase to be considered as valid detections. This does not completely eliminate the detection of turning vehicles (some vehicles will make right turns against their red), but the number will certainly be much less and the turns will be more likely to be confined to a single lane. This filtering process was performed for the graphs shown in Figures 10-46 through 10-49 using GP_COUNT.FOR (the name stands for green-phase count).

Vehicle Counts vs. Time of Day

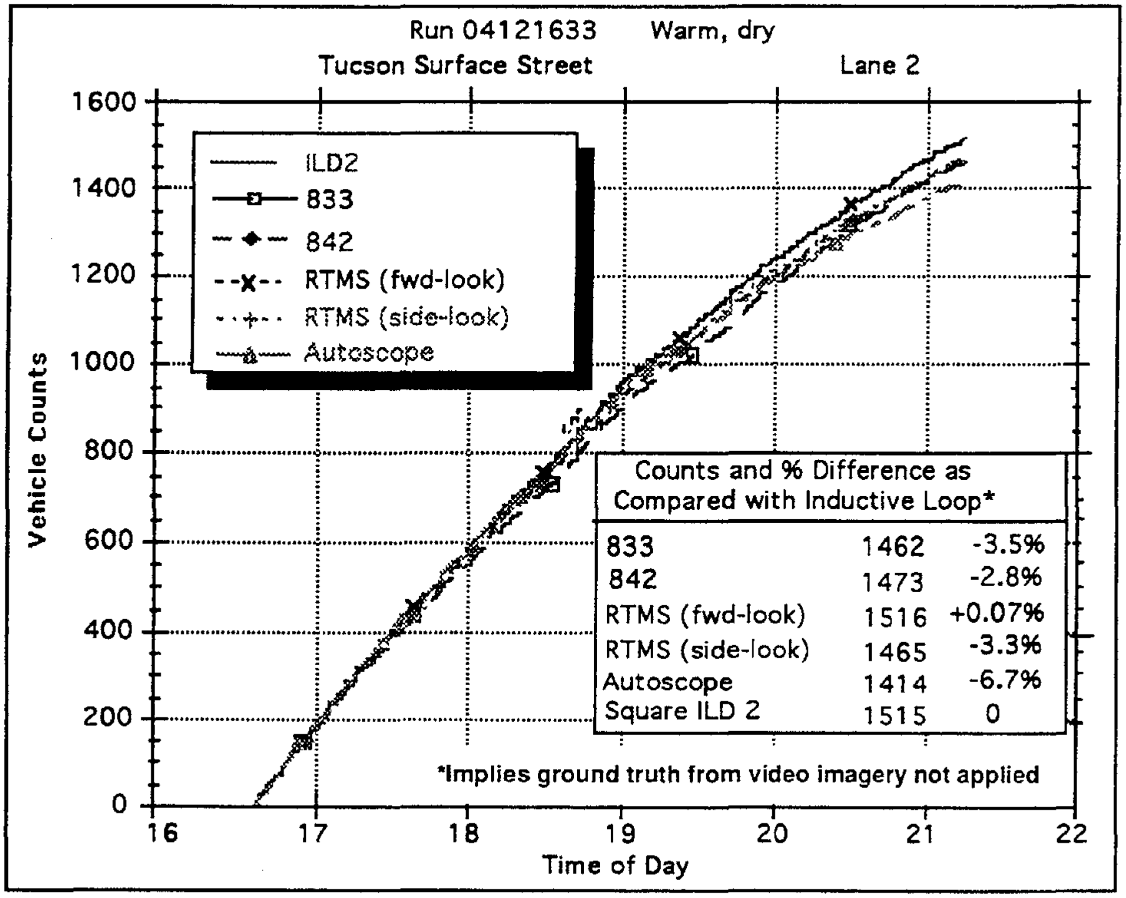
Figure 10-48 provides a comparison of vehicle counts for six different detectors (two passive infrared devices, two microwave presence radars, a video image processor, and an inductive loop) in the middle lane (lane 2) of traffic. Since the loops in Tucson appeared accurate to within approximately 0.5 percent (see *Comparison of Video Image Processor Counts* in the next section for the loop count error analysis), the count from the second square inductive loop in lane 2 was used as pseudo-ground truth, with which the counts from the other detectors were compared. This is illustrated by the percentage difference calculation in the plots. The forward-looking RTMS microwave radar was the most accurate, having a percentage difference of 0.07 percent as compared to the loop count, over the entire duration of this particular run. The Eltec passive infrared detectors had accuracies greater than 96 percent.

Figure 10-49 shows curb lane (lane 3) results from the same run. Here the count from the first square inductive loop was used as pseudo-ground truth, with which the counts from the other detectors were compared. (The counts from the two square loops in the lane were within 1 percent of each other.) The plot contains data from the 780D1000 laser radar, TDN-30 Doppler microwave detector, SDU-300 ultrasonic detector, SPVD magnetometer, Autoscope 2003 video image processor, and inductive loop. The Whelen TDN-30 performed best in this lane, with its count being within 0.8 percent of that measured by the loop. All detectors had count accuracies of 6 percent or better.

Comparison of Video Image Processor Counts

Three visible-spectrum and one infrared video image processors were fielded during the Tucson field tests. The visible spectrum VIPs were the Autoscope 2003, Traficon CCATS-VIP 2, and Sumitomo IDET-100. Each of these was configured to provide data from the middle through-lane and the curb lane (lanes 2 and 3, respectively). The Grumman infrared VIP was set up with detection zones in all three lanes, but they were located some 120 feet (36.6 m) downstream from the mast arm on which the overhead detectors were mounted. The Grumman VIP also had a fourth detection zone that coincided with the second round loop in lane 3.

It is difficult to compare the performance of the VIPs over time intervals on the order of tens of seconds or minutes due to the lack of standardization of their data output intervals as shown in Table 10-11. For example, the IDET-100 outputs vehicle detections and computed speeds on a per vehicle basis via a serial communications interface, while the CCATS-VIP 2 outputs results accumulated over 5-second integration intervals (also via an RS-232 interface). The serial interface

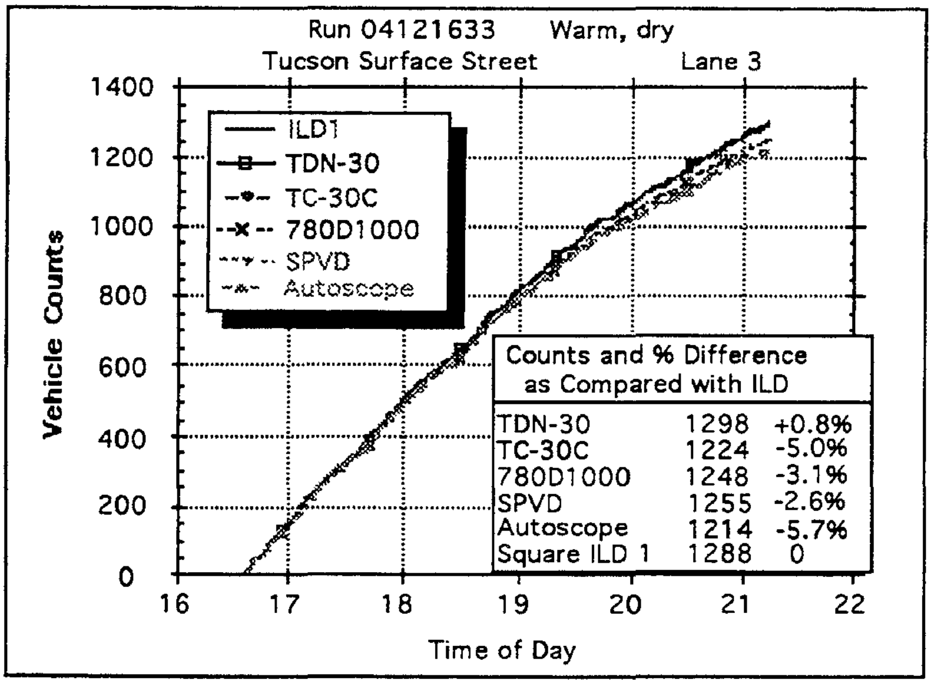


Counts and % Difference as Compared with Inductive Loop*

833	1462	-3.5%
842	1473	-2.8%
RTMS (fwd-look)	1516	+0.07%
RTMS (side-look)	1465	-3.3%
Autoscope	1414	-6.7%
Square ILD 2	1515	0

*Implies ground truth from video imagery not applied

Figure 10-48. Comparison of Vehicle Counts From Six Detectors on Lane 2 of Tucson Street Site



Counts and % Difference as Compared with ILD

TDN-30	1298	+0.8%
TC-30C	1224	-5.0%
780D1000	1248	-3.1%
SPVD	1255	-2.6%
Autoscope	1214	-5.7%
Square ILD 1	1288	0

Figure 10-49. Comparison of Vehicle Counts From Six Detectors on Lane 3 of Tucson Street Site

protocol for the Autoscope was not available for the field tests. Thus, the only data recorded from the Autoscope was from the outputs of the optically isolated transistors that corres-ponded to the passage of a vehicle. In order to compare the outputs from these VIPs, the data must be integrated (during post-processing) over an interval equal to the least common multiple of the collection intervals used by the devices in the comparison group.

Table 10-11. Data and Update Intervals in Detectors With RS-232 Interfaces

Detector	Update Interval	Count	Lane Occ.	Speed	Vehicle Type[b]
Whelen TDN-30 & TDW-10 Doppler Detectors	per vehicle	✓		✓	
EIS RTMS-X1 True-Presence Microwave Radar	10 seconds to 10 minutes[a]	✓	✓	✓	
Econolite Autoscope 2003 VIP[c]	10 s to 1 h	✓	✓	✓	✓
CRS Traffic Analysis System VIP	1 minute	✓	✓	✓	✓
Traficon CCATS-VIP 2	5 seconds	✓		✓	✓
Sumitomo IDET-100 VIP	per vehicle	✓		✓	✓
EVA 2000 VIP	per vehicle	✓	✓	✓	✓
Grumman Infrared VIP	1 second	✓		✓	

[a] User selectable in 10-s increments. Update interval set to minimum value of 10 s in field tests.

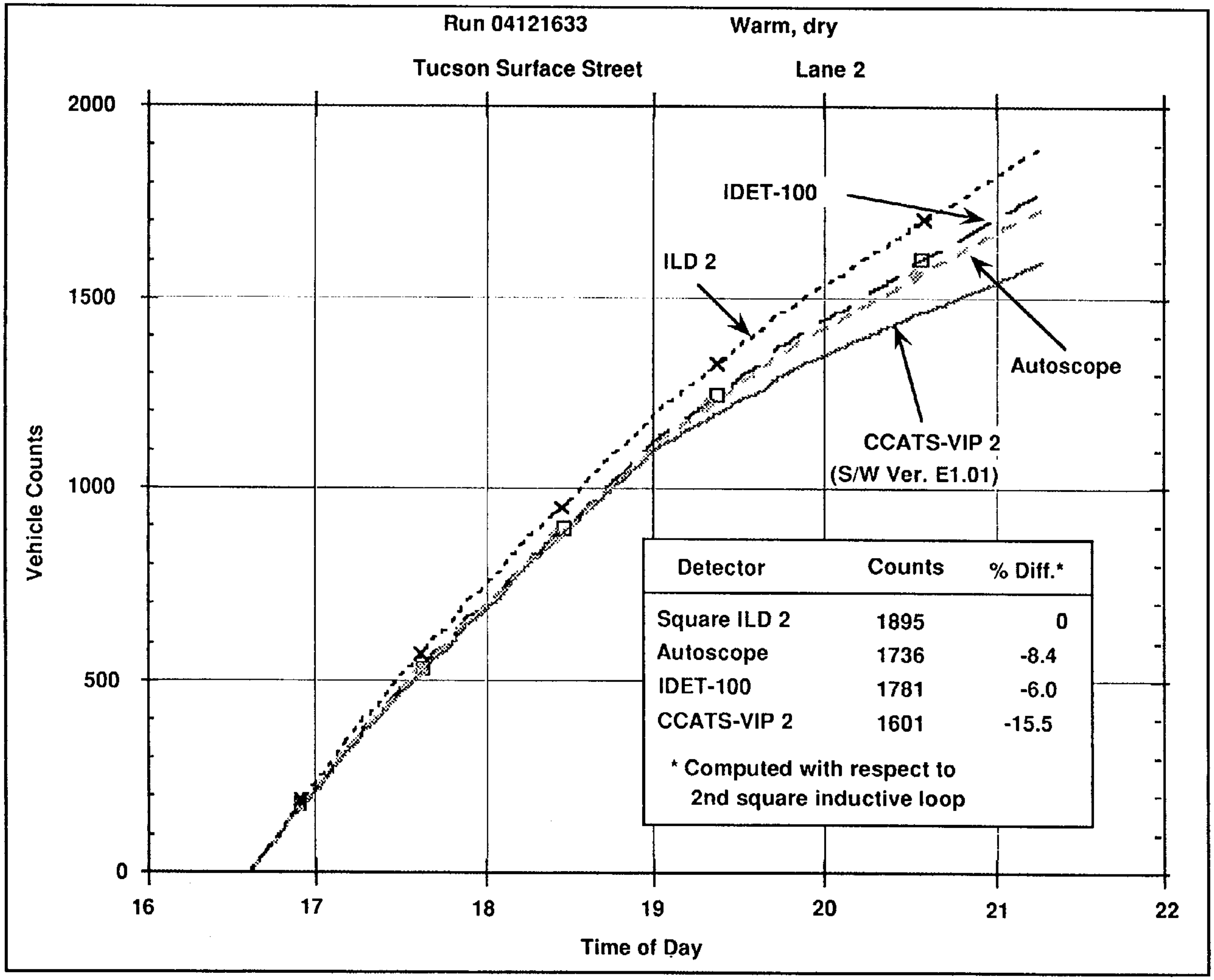
[b] Based on user-selected vehicle lengths.

[c] Autoscope serial data were not made available during the field tests.

Figures 10-50 and 10-51 show comparisons of the accumulated vehicle counts as output by the video image processors in lanes 2 and 3, respectively. The second square inductive loop in each lane was used as the count reference.

The count accuracy is difficult to analyze at this site due to the anomalies created by the tendency of vehicles to sweep out across multiple lanes when completing left or right turns onto southbound Oracle Road. A 1-hour time window was ground truthed for lanes 2 and 3 and compared to the counts reported by several detectors. The counts from the second inductive loop in each lane were approximately 2.5 percent higher than the observed ground truth. However, the decision to manually record a vehicle passage as a count was a judgment call on the part of the observer. Vehicles completing their turns may have passed through enough of a detector's sensing area to trigger a response, but may not have been recorded by the observer. The observer was deliberately conservative in his determination of what constituted a detection and fully expected the detector outputs to be somewhat higher.

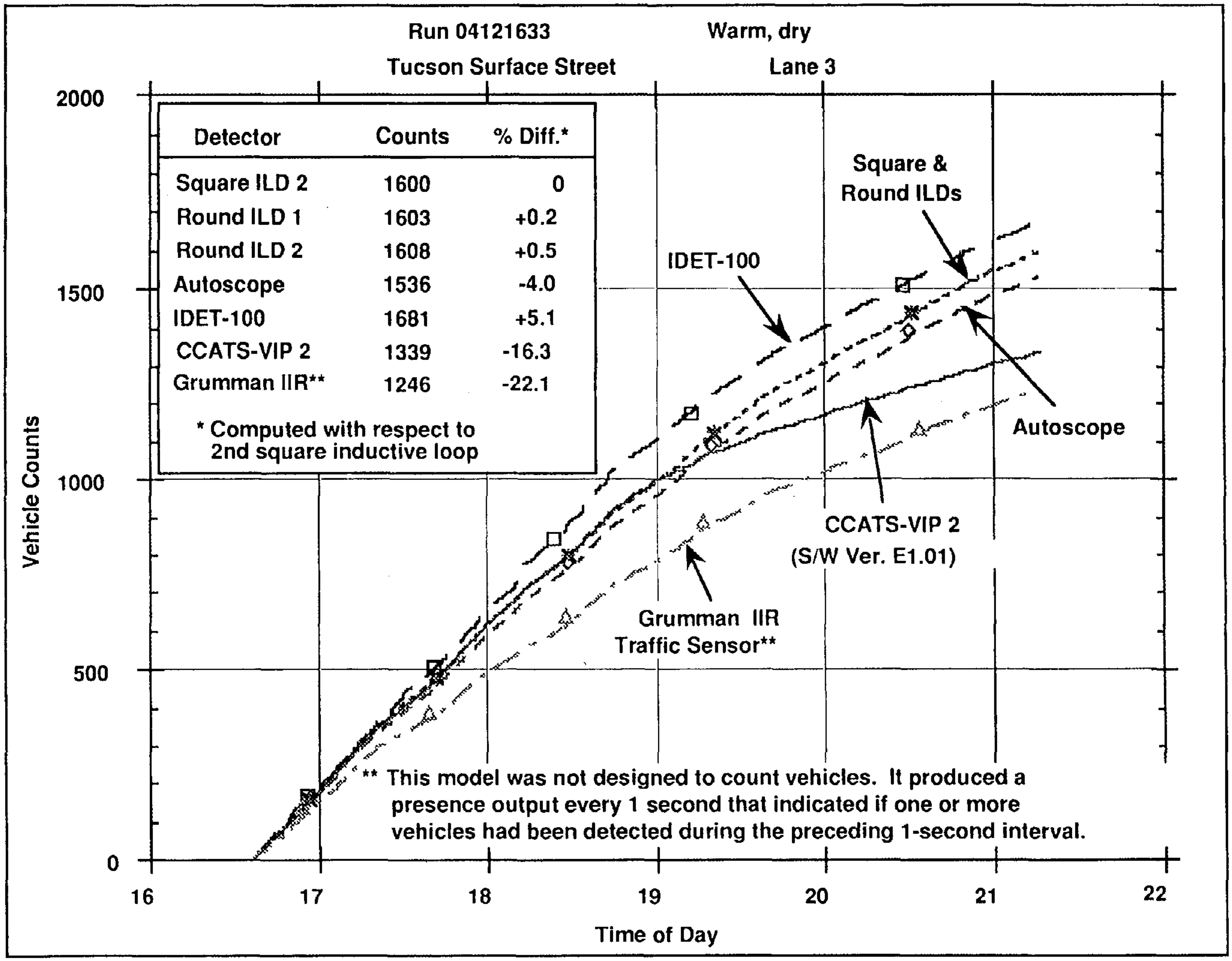
In the analyst's opinion, the second loop in each lane represents the vehicle count to within an error of no more than 1-percent of the actual number of vehicles traversing its detection zone. The 1-percent number is judged to be a better representation of the error, as compared to the 2.5-percent value, since some vehicles detected by the loop were purposely not counted by the analyst. This judgment is supported by the fact that counts are high by the same percentage in each lane with respect to the analyst's ground truth values. Also lending credence to the lower 1-percent count error for the loops is the close agreement among the counts given by the loops in lane 3 as seen in Figure 10-51. The second square inductive loop reported a total count of 1600 vehicles collected over nearly 5 hours. The first round loop located 15 feet (4.6 m) downroad from the second square loop reported 1603 vehicles, and the second round loop located another 15 feet (4.6 m) downroad reported 1608. The locations of



Detector	Counts	% Diff.*
Square ILD 2	1895	0
Autoscope	1736	-8.4
IDET-100	1781	-6.0
CCATS-VIP 2	1601	-15.5

* Computed with respect to 2nd square inductive loop

Figure 10-50. Comparison of Vehicle Counts in Lane 2 from VIPs in Run 04121633 at Tucson Site



Detector	Counts	% Diff.*
Square ILD 2	1600	0
Round ILD 1	1603	+0.2
Round ILD 2	1608	+0.5
Autoscope	1536	-4.0
IDET-100	1681	+5.1
CCATS-VIP 2	1339	-16.3
Grumman IIR**	1246	-22.1

* Computed with respect to 2nd square inductive loop

** This model was not designed to count vehicles. It produced a presence output every 1 second that indicated if one or more vehicles had been detected during the preceding 1-second interval.

Figure 10-51. Comparison of Vehicle Counts in Lane 3 from ILDs and VIPs in Run 04121633 at Tucson Site these three in-road detectors were well downstream and less susceptible to the maneuvering problems discussed previously. For these reasons, the counts represented in Figures 10-50 and 10-51 are compared with the outputs given by the second square inductive loop in lanes 2 and 3, respectively.

The vehicle counts from the CCATS-VIP 2 fall off from the others when darkness occurs. This is due to the particular algorithm in software version E1.01 supplied with the CCATS-VIP 2 that was tested. The algorithm was not able to distinguish all the dark-colored vehicles from the dark background. This phenomenon was observed in the field when viewing the television monitor that showed the traffic flow and the overlaid vehicle counts displayed by the VIP. The algorithm was written to prevent shadows from being recognized as vehicles. Traficon has since developed software version 2, which they claim increases the count between 9 and 20 percent, depending on the conditions of the run.

Zone 4 (overlapping the second round loop in lane 3 as shown in Figures 9-50 and 9-51) of the Grumman imaging infrared traffic sensor undercounted by 22 percent as compared to the second square loop. However, this particular model of the imaging infrared traffic sensor was not designed to count individual vehicles. It was designed to give a presence output every 1 second if one or more vehicles was within its detection zone in the preceding 1-second interval. Thus, if two or more vehicles passed through the detection zone in an interval, only one event would be registered by the sensor. From observation of the traffic flow, it appeared that multiple vehicles did pass through the sensor's detection zone during some of the 1-second intervals. Future analysis can verify the more than one vehicle per reporting interval hypothesis by overlaying the vehicle detections onto the video ground truth imagery and examining the correlation of reported and actual events. If the sensor consistently detects the first of two closely spaced vehicles but misses the second, this would indicate that the undercount is indeed due to the particular way the data are processed in the internal algorithms of the sensor. The crisp infrared imagery displayed on the television monitor appears to produce good thermal contrast between the vehicles and the background during day and night operation. This indicates that there is sufficient information in the image to recognize individual vehicles.

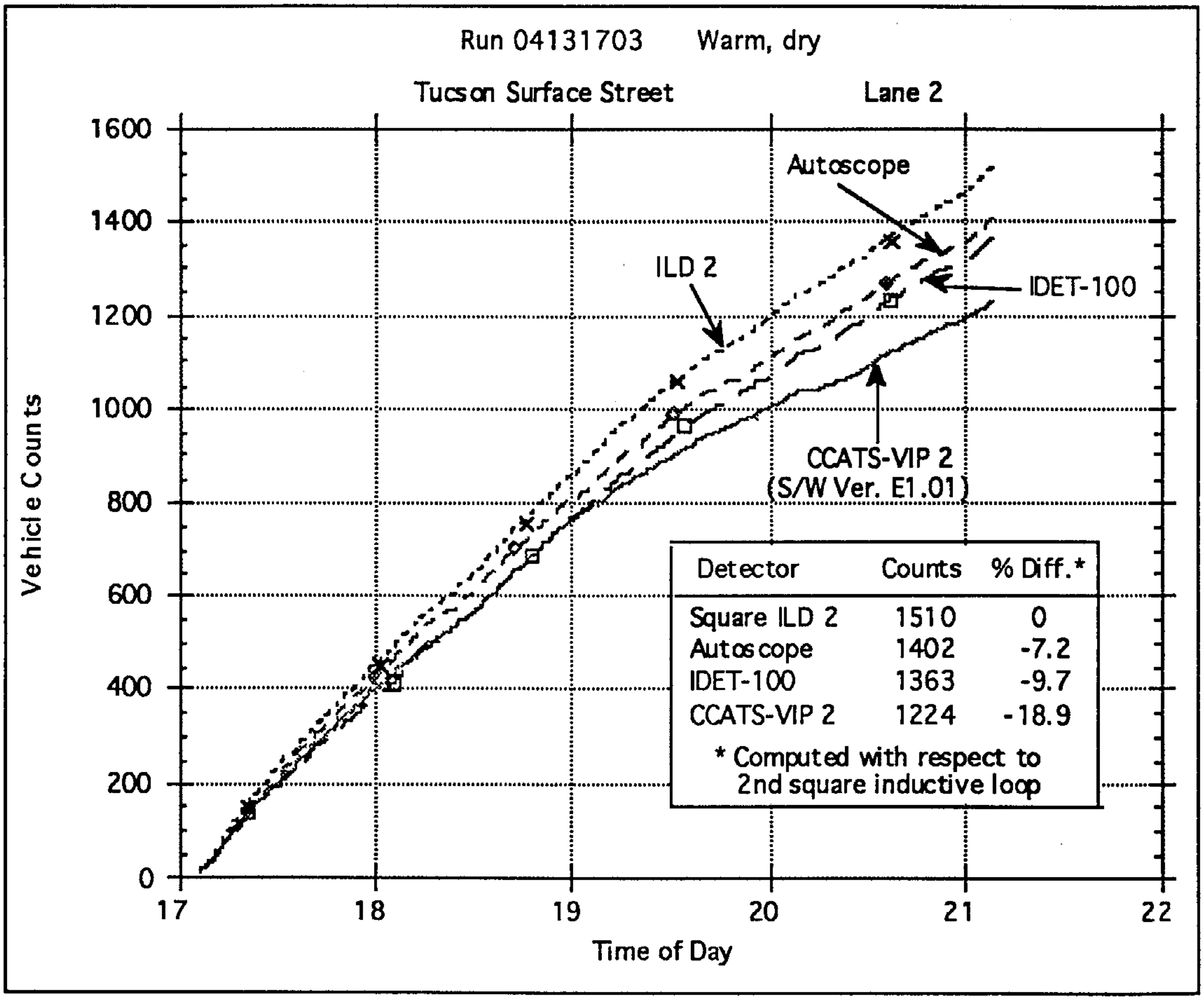
10.14.3 Run 04131703

This run occurred the evening following the run discussed in the previous section. It was selected for analysis to assess the repeatability of the trends observed in the performance of the video image processors in Run 04121633. Count accuracies were computed relative to the counts recorded from the second inductive loop in lanes 2 and 3 as before. The session began just after 5:00 p.m. and continued for approximately 4 hours.

Comparison of Video Image Processor Counts

The performance of the four video image processors (three visible band and one infrared) is consistent with results presented in Section 10.14.2. Figure 10-52 shows the cumulative vehicle counts for the three visible wavelength VIPs and the second inductive loop in lane 2. These VIPs undercounted, with respect to the loop, by approximately 7 to 10 percent until about 7:00 p.m. as compared with undercounts of 6 to 8 percent the night before. After 7 p.m., the percentage differences between the Autoscope and IDET-100, as compared to the inductive loop, remained fairly constant for the remainder of the run. However, the CCATS-VIP 2 began to miss more vehicle detections after 7:00 p.m. as nighttime darkness occurred. The CCATS reported 18.9 percent fewer counts than did the loop in this run and an undercount of 15.5 percent in the previous night's run.

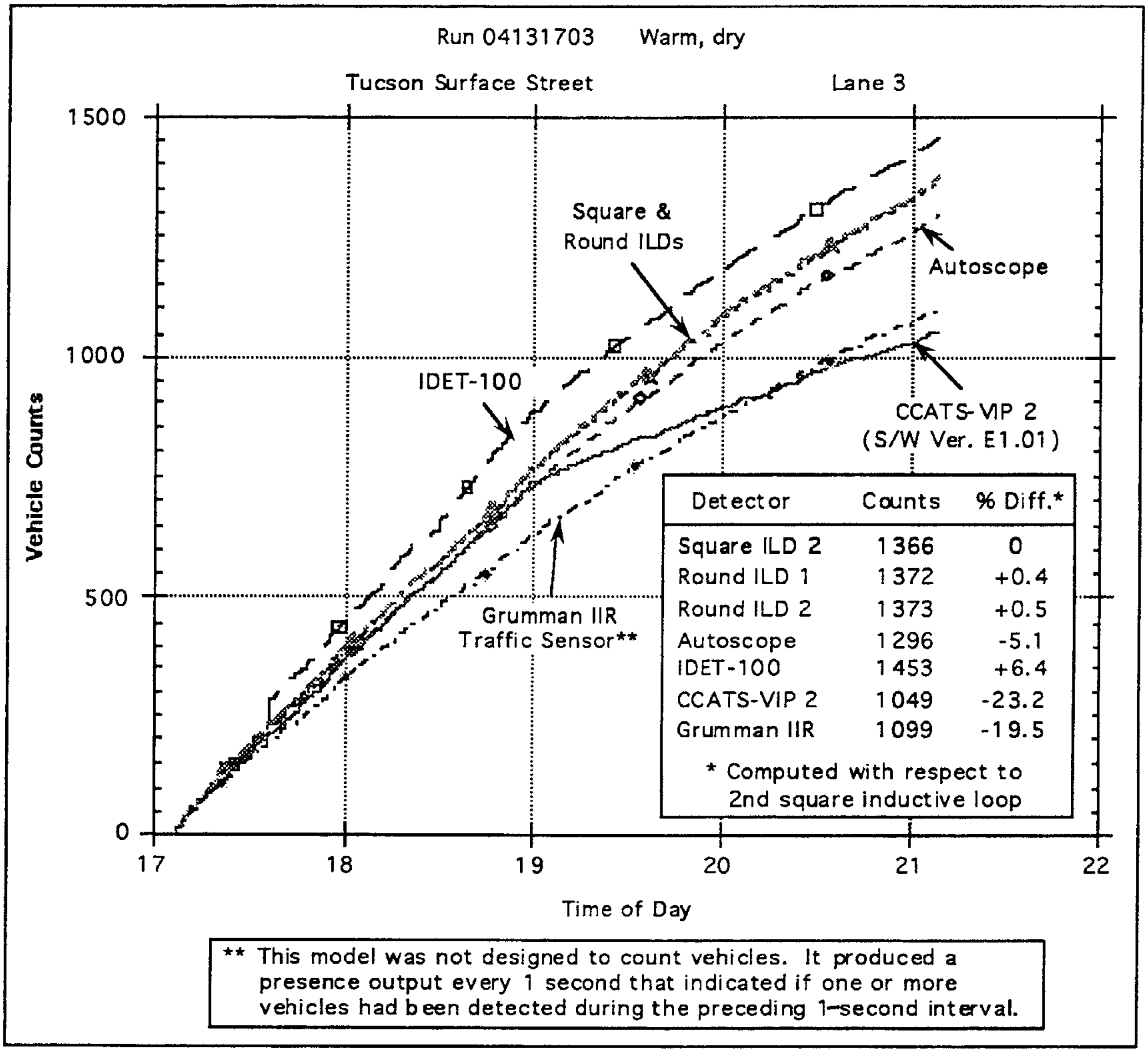
Figure 10-53 shows lane 3 count results from the visible spectrum VIPs represented in the lane 2 plot, as well as from the Grumman Traffic Sensor imaging infrared VIP and the two round inductive loops. The three loops (the second square loop and the two round loops) reported counts within 0.5 percent of each other. The Autoscope count was 5.1 percent below that reported by the second square loop. This result is consistent with the 4-percent undercount from the previous night's run. Similarly, the IDET-100 overcounted by 6.4 percent as compared to 5.1 percent the night before. Again, the counts from the CCATS decreased after 7:00 p.m. The unit reported 23.2 percent fewer counts than the loop, as compared to 16.3 percent from Run 04121633. The Grumman imaging infrared sensor undercounted by 19.5 percent, compared to 22.1 percent recorded in the previous night's run. As explained earlier, the Grumman algorithm evaluated in the field tests was not designed to count vehicles, but rather to give a presence output every 1 second if one or more vehicles were within its detection zone in the preceding 1-second interval.



Detector	Counts	% Diff.*
Square ILD 2	1510	0
Autoscope	1402	-7.2
IDET-100	1363	-9.7
CCATS-VIP 2	1224	-18.9

* Computed with respect to 2nd square inductive loop

Figure 10-52. Comparison of Vehicle Counts in Lane 2 from VIPs in Run 04131703 at Tucson Site



Detector	Counts	% Diff.*
Square ILD 2	1366	0
Round ILD 1	1372	+0.4
Round ILD 2	1373	+0.5
Autoscope	1296	-5.1
IDET-100	1453	+6.4
CCATS-VIP 2	1049	-23.2
Grumman IIR	1099	-19.5

* Computed with respect to 2nd square inductive loop

** This model was not designed to count vehicles. It produced a presence output every 1 second that indicated if one or more vehicles had been detected during the preceding 1-second interval.

Figure 10-53. Comparison of Vehicle Counts in Lane 3 from ILDs and VIPs in Run 04131703 at Tucson Site

11. TASK I

DETERMINE WHICH OF THE CURRENTLY AVAILABLE DETECTORS MEET THE IVHS SPECIFICATIONS OF TASK A

Accuracies for traffic parameters that support future applications of signalized intersection control, freeway incident detection and management, and freeway metering control were presented in Section 2. Not all of the parameters can be addressed based on the results of the *Detection Technology for IVHS* field tests. Among the information that can be evaluated at this time are data relating to vehicle counts, speed, and, to some extent, presence.

Several flow requirements are listed in the Traffic Parameter Specifications tables in Section 2. In the signalized intersection control, freeway incident detection and management, and freeway metering control applications, the allowable error for measuring traffic flow is ±2.5 percent at 500 vehicles per hour per lane. The data collection intervals vary by the period over which control of the traffic is exercised, namely, tactical, strategic, or historic.

For the postulated 20-second data collection interval for tactical control, an error of 0.07 in vehicle count for every 2.8 vehicles is implied at a flow of 500 vehicles per hour. Practically, this means that all vehicles must be detected during each 20-second interval. While no detector guaranteed 100-percent detection accuracy, some did perform with less than 1-percent error. Video image processors that use the detection zone approach to loop emulation can increase their detection accuracy by placing multiple zones in critical areas of the roadway.

For a 5-minute data collection interval typical of strategic control, the acceptable error is one vehicle count for every 41.7 vehicles at the specified flow rate. This requirement seems to be within the capability of currently available commercial technologies. As the data collection interval increases, as in the gathering of historic data, larger errors in count are acceptable (e.g., error of 3.1 in count for every 125 vehicles for a 15-minute interval and an error of 12.5 in count for every 500 vehicles during a 1-hour interval).

While inductive loops are probably the most consistently accurate detectors for vehicle counting applications currently available, several other candidates show a great deal of promise. Among them are video image processors, magnetometers, and microwave detectors. These technologies, as well as the ultrasonic, infrared, and acoustic devices, will continue to mature as they are deployed in support of new applications. Many of these technologies have only been applied to traffic management applications for a short time and will continue to improve as they gain acceptance and are used within the industry.

Unfortunately, many manufacturers cannot afford to develop their technology further without assurances, in the form of buy orders, from the traffic management community that a tangible market for their product exists.

The speed measurement requirement varies by application. Freeway metering control has the most relaxed accuracy of the applications that were studied, namely a mainline speed measurement accuracy of ±5 mi/h (±8.0 km/h) over a speed range of 0 to 80 mi/h (0 to 129 km/h). The data collection intervals for tactical, strategic, and historic collection periods are 20 seconds, 5 minutes, and 15 minutes or 1 hour, respectively. Signalized intersection control is postulated to have a future speed measurement requirement of ±2 mi/h (3.2 km/h) and a freeway incident detection requirement of ±1 mi/h (1.6 km/h).

Currently available Doppler microwave detectors are able to support the 5-mi/h (8.0-km/h) speed accuracy requirement on a per vehicle basis. The data collection interval can be under the control of the microprocessor that accumulates the data in the traffic controller or traffic management center. Doppler detectors, however, cannot detect stopped or slow (nominally below 3 to 5 mi/h [4.8 to 8.0 km/h]) traffic. The future and as yet in-development algorithms for signalized intersection control and freeway incident detection raise the speed measurement accuracy requirement further. The ±1-mi/h (1.6-km/h) accuracy is beyond the current state of the art of most detectors. If the importance of zero speed measurement during bumper-to-bumper traffic conditions is not critical to the execution of the traffic control algorithm, as when a lower speed threshold greater than 3 to 5 mi/h (4.8 to 8.0 km/h) is set, then the Doppler detectors will suffice. If speeds less than 3 to 5 mi/h are needed, improved video image processors and true-presence microwave radars or laser radars may have to be used.

Vehicle presence is an important parameter in signalized intersection control. Although it is difficult to compare the actual presence times from detector to detector because of differences in hold time and sensing area, it is intuitively possible to correlate vehicle presence with vehicle count. That is, as a vehicle is counted, it can be assumed that the presence of the vehicle is also detected, although no inference about the length of the presence time can be made. If the assumption about vehicle presence and vehicle count correlation is valid, then those detectors having the most accurate counts will also provide the most accurate presence in terms of identifying that a vehicle is within the sensing area of the detector.

12. CONCLUSIONS

One of the goals of the field tests and subsequent data reduction was to ascertain the relative performance of various detector technologies in different traffic and climatic conditions. These results are useful for assessing the applicability or suitability of particular types of technology to specific traffic management applications. The assessments were made with respect to only detector performance and not cost. Cost considerations must be traded off by the procuring organization. The cost-effectiveness of a particular detector or type of technology can only be judged when applied to a specific application and should include total life-cycle costs (i.e., take into account purchase price, installation, data interface preparation, and maintenance over an extended time period of 10 to 20 years) and the equivalent number of lower cost detectors (e.g., inductive loops) that it replaces.

Candidate overhead detector technologies have been identified for several traffic management applications and operational requirements as listed in Table 12-1. The technologies were selected based on the capabilities and types of outputs currently available from a particular technology and their suitability to the application. This list does not take into account the performance of these technologies during the field tests. The quality of the technology performance is discussed in Section 12.1.

Table 12-2 lists advantages and disadvantages associated with each technology. A more detailed matrix was presented in Appendix A of the Task A Report. For example, infrared detectors have an advantage over visible wavelength sensors in foggy conditions, but their effectiveness may still be limited by heavy rain or snow. Each technology has strengths and weaknesses imposed by the physics that governs its operation and the resolution of the detector. These may cause a specific technology to be wholly unsuitable or ideally suited for a particular application. The diversity of operating conditions and applications demonstrates the detector-specific selection that must be made for each installation. There is no generic "best detector." Selection of the appropriate traffic management system components is dependent upon not only the traffic management application, but on the operating conditions (including weather) and mounting requirements (e.g., in-road versus overhead, mast arm versus pole, upstream or downstream viewing of traffic).

12.1 ASSESSMENT OF BEST PERFORMING TECHNOLOGIES BY APPLICATION

Both quantitative and qualitative observations were made regarding how well a particular technology performed relative to others at the evaluation sites employed during the field tests. Judgments were made regarding which technologies exhibited the best performance with respect to supplying different traffic parameters. Table 12-3 provides a summary of the conclusions based on the results from the limited number of runs reduced so far and the general qualitative opinions gained from using these devices over an 18-month evaluation period.

12.1.1 Most Accurate Vehicle Count for Low Traffic Volume

Most of the detectors gave good results when used under light traffic conditions. It should be stressed that some detectors had an inherent advantage in the results displayed in Section 10 by virtue of their multiple outputs or detection zones. The most favorable of the outputs, when more than one zone was available, was shown in the graphs. For example, if loop #1 showed better agreement with the ground truth value than loop #2 (for the same lane), then the loop #1 results were presented. Likewise, if a single traffic detector had multiple detection zones, the most favorable of the outputs was used in the plotted results. This affords a greater opportunity for these devices to appear in a favorable light; whereas, a simple detector having a single relay output was represented solely on the basis of that single output.

Table 12-1. Overhead Detector Technology Applications to Traffic Management

Application	Assumptions	Overhead Technology
• Signalized intersection control	• Detect stopped vehicles • Weather not a major factor	• True-presence microwave radar • Passive infrared • Laser radar • Ultrasound • Video image processor
• Signalized intersection control	• Detect stopped vehicles • Inclement weather	• True-presence microwave radar • Ultrasound • Long-wavelength imaging infrared video processor
• Signalized intersection control	• Detection of stopped vehicles not required • Inclement weather	• True-presence microwave radar • Doppler microwave detector • Ultrasound • Long-wavelength imaging infrared video processor
• Real-time adaptive signal control (e.g., SCOOT)	• Desirable for detector footprint to emulate a 6-ft x 6-ft inductive loop • Side-mounting capability	• Video image processor • True-presence microwave radar • Passive infrared (with suitable aperture beamwidth)
• Vehicle counting (surface street or freeway)	• Detect and count vehicles traveling at speeds > 2-3 mi/h	• True-presence microwave radar • Doppler microwave detector • Passive infrared • Laser radar • Ultrasound • Video image processor
• Vehicle speed measurement	• Detect and count vehicles traveling at speeds > 2-3 mi/h	• True-presence microwave radar • Doppler microwave detector • Laser radar • Video image processor
• Vehicle classification	• By length	• Video image processor • Laser radar
• Vehicle classification	• By profile	• Laser radar

1 ft = 0.305 m
1 mi/h = 1.61 km/h

Table 12-2. Advantages and Disadvantages of Various Detection Technologies

Technology	Advantages	Disadvantages
Ultrasonic	• Compact size, ease of installation	• Performance may be degraded by variations in temperature and air turbulence
Microwave Doppler	• Good performance in inclement weather • Direct measurement of speed	• Cannot detect stopped or very slow-moving vehicles • Requires narrow-beam antenna to confine footprint to single lane in forward-looking mode
Microwave True Presence	• Good performance in inclement weather • Detects stopped vehicles • Can operate in side-looking mode to service multiple lanes	• Requires narrow-beam antenna to confine footprint to single lane in forward-looking mode
Passive Infrared	• Greater viewing distance in fog than with visible-wavelength sensors	• Performance potentially degraded by heavy rain or snow
Active Infrared	• Greater viewing distance in fog than with visible-wavelength sensors • Direct measurement of speed	• Performance degraded by obscurants in the atmosphere and weather
Visible VIP	• Provides visible imagery with potential for incident management • Single camera and processor can service multiple lanes • Rich array of traffic data available	• Large vehicles can mask trailing smaller vehicles • Shadows, reflections from wet pavement, and day/night transitions can result in missed or false detections
Infrared VIP	• Possibility of using same algorithms for day and night operation and avoiding day/night algorithm transition problems • Rich array of traffic data available	• May require cooled IR detector focal plane for high sensitivity; implies somewhat more power and less reliability
Acoustic	• Potential for identifying specific vehicle types by their acoustic signature	• Signal processing of energy received by the array is required to remove extraneous background sounds and to identify vehicles
Magnetometer	• Can detect small vehicles, including bicycles • Useful where loops cannot be installed	• Difficulty in discriminating longitudinal separation between closely spaced vehicles
Inductive Loop Detectors	• Standardization of loop amplifier electronics • Excellent counting accuracy • Mature, well understood technology	• Reliability and useful life are a strong function of installation procedures • Traffic interrupted for repair and installation • Decreases life of pavement • Susceptible to damage by heavy vehicles, road repair, and utilities

Table 12-3. Qualitative Assessment of Best Performing Technologies for Gathering Specific Data

Technology	Low-Volume Count	High-Volume Count	Low-Volume Speed	High-Volume Speed	**Best In Inclement Weather**
Ultrasonic	-	-	-	-	-
Microwave Doppler*	✓	✓	✓	✓	✓
Microwave True Presence	✓	✓			✓
Passive Infrared	-	-	-	-	-
Active Infrared	-	-	-	-	-
Visible VIP	✓	✓			-
Infrared VIP					
Acoustic Array	-	-			
SPVD Magnetometer	✓	-	-	-	✓
Inductive Loop	✓	✓	-	-	✓

✓ Indicates the best performing technologies.
- Indicates performance not among the best, but may still be adequate for the application. No entry indicates not enough data reduced to make a judgment.
* Does not detect stopped vehicles.

The ultrasonic and infrared detectors exhibit count accuracies that make them suitable for a variety of applications, but they were typically not among the most accurate. The SPVD magnetometer performed well in low-volume applications, as demonstrated by the zero-percent error over a 2-hour run during snowfall conditions for the Minnesota surface-street Run 03091019 (reference Figure 10-22).

Microwave radars were also well suited to low-volume conditions. The presence-type microwave radar consistently provided better vehicle count results in forward-looking operation than in side-looking orientation. Forward-looking count accuracies to within 1 percent were not uncommon; however, these accuracies were typically provided by only a single detection zone, due to the difficulty in confining the detector's elliptical beam footprint to a single lane of traffic. Because of this footprint geometry, only one detection zone tends to be optimally matched to the dimensions of the traffic lane, while the remainder of the zones tend to undercount (in the narrow parts of the beam where the detection zones are not as wide as the lane) or overcount (where the wide part of the beam tends to spill over into adjacent lanes of traffic).

Doppler-type microwave detectors fare well in low-to-moderate traffic volume conditions, where free-flowing traffic consistently provides a component of motion in the detector's viewing direction that is necessary for the operation of these units.

However, there can conceivably be traffic management applications where a knowledge of decreasing speeds can be used to infer that stopped vehicles are present even though the Doppler detector does not give an output indication. Again, care must be taken to ensure that the detector's beam footprint on the roadway is confined to the desired monitoring area.

Some video image processors exhibit counting characteristics similar to microwave detectors. The Autoscope 2003, for example, can be configured to have three separate detection zones per lane (two emulating a pair of inductive loops and a third configured as a speed trap). Data show that count results tend to be optimized for a given zone.

Inductive loops are among the most consistent performers, with count accuracies typically in the 99-percent range. Even so, problems with crosstalk and double- or triple-counting large trucks and tractor-trailer rigs have been seen when reviewing videotapes of the field tests.

12.1.2 Most Accurate Vehicle Count for High Traffic Volume

Many of the same observations made in the previous section apply here as well. However, counting vehicles at freeway speeds or during periods of heavy congestion presents additional difficulties. The electronic hold time of a detector begins to become an important factor when intervehicle gap times decrease. The hold time is the period over which a detector remains in the active state after the initial detection of a vehicle. Hold time is often adjustable by means of a potentiometer setting in the detector electronics or by software via a remote serial interface to the hardware.

For the field tests, the hold time of each device was always set to its minimum value. Increasing the hold time in heavy traffic conditions has a negative impact on count accuracy due to the detector's inability to determine when one vehicle departs the detection zone and another enters. With long hold times, a second vehicle enters the detection zone prior to the falling edge of the pulse created by the first vehicle. This can result in several closely spaced vehicles registering only a single count on a given detector. Such events are characterized by abnormally long presence times in the Paradox database file.

Although several detectors evaluated were designed with long hold times because of an initial traffic management requirement, devices of similar types can certainly be redesigned with shorter hold times as new applications arise.

12.1.3 Most Accurate Speed for Low Traffic Volume

Speed accuracy is a difficult parameter to assess due to the challenge of obtaining the true speeds against which to compare the detector speed outputs. Some detectors compute speeds based on average vehicle lengths. Such devices may yield acceptable accuracies over the long term, but not for applications that require periodic updates or vehicle-by-vehicle speeds. This requirement favors the implementation of detectors that make direct speed measurements, or pairs of detectors that can be used in a speed-trap configuration.

Speed traps are difficult to implement accurately due to the precision required in time-tagging the two pulse outputs that provide the time difference between passage of a vehicle over the two zones in the speed-trap. Further hindering the process is the probability that the two detectors have dissimilar sensing areas or detection zones. For instance, the fields associated with two inductive loops may not subtend the same sensing area due to differences in gain or sensitivity. They may have different response times or varying pulse widths. Although the two loops are similar, they do not necessarily share identical characteristics. These small differences are magnified greatly when monitoring the high speeds that occur in low-volume applications. In addition, the controller must have the programming capability to compute speeds from speed-trap timing pulses.

The simplest and most accurate way to measure speed is to use a detector that provides it directly, such as a Doppler microwave detector. Doppler devices require a component of motion in the direction of operation. Since free-flowing traffic is readily available in low-volume conditions, a Doppler device would seem a logical choice for such an application. Speed as measured by Doppler microwave detectors usually agreed within 1 to 2 mi/h (1.6 to 3.2 km/h) with readings from the speedometers of the probe vehicles. However, the imprecision associated with a human observer recording these values from an analog speedometer of unknown accuracy yields, at best, a reference value, not absolute truth.

Some detectors capable of providing speed outputs could not be evaluated with the single probe vehicle. These units output average speed data collected over some integration interval and, as such, do not give information on a per vehicle basis. Among these devices were several video image processors and the RTMS-X1 microwave true-presence radar. Thus, the selection of a preferred technology is application-dependent. If the requirement is for a unit that will supply average speed, occupancy, or some other statistically derived parameter, the choice should be one of the sophisticated detection systems employing enough processing capability to accurately compute the desired parameter(s). Conversely, if the data are required on a per vehicle basis, the choice narrows to devices that output the desired parameters in real time as they are acquired. Certainly the more sophisticated units, such as video image processors, multi-zone radars, and laser radars, have the ability to output data on a per vehicle basis as they must measure the characteristics of individual vehicles in order to produce their normal statistical outputs. However, the cost of these units will likely dictate that they be utilized only for applications that require statistical data or where their cost can be justified on an equivalent per detector basis or through life-cycle cost considerations.

12.1.4 Most Accurate Speed for High Traffic Volume

Many of the same points made in Section 12.1.3 apply here as well. The main difference in requirements between low- and high-volume applications stems from the change in vehicle speeds. Vehicles in low-volume conditions are likely to be free-flowing and unconstrained in their movements, while vehicles in high-volume conditions, where the roadway is at or near its designed capacity, will be restricted in their speed. When the traffic demand exceeds the capacity of the roadway, speeds will obviously decrease. If the speeds slow significantly and bumper-to-bumper traffic conditions ensue, then Doppler detectors will significantly degrade in their ability to accurately measure vehicle speeds. Perhaps this will not matter as the necessity for zero speed measurement may decrease once the traffic flow falls below some fixed threshold.

12.1.5 Best Performance in Inclement Weather

The detectors that seemed the most impervious to inclement weather conditions were the microwave detectors. No appreciable change in performance was noted during conditions such as rain, snow, wind, and extreme cold or heat. As mentioned earlier, one of the Doppler microwave units demonstrated degraded performance when an appreciable amount of rain leaked into the unit, but this was not a limitation of the technology. Likewise, the SPVD magnetometers suffered some rain-related damage, but the failure stemmed from a crack in the cylindrical case housing the electronics. The magnetometers performed well in the snow during the Minneapolis surface-street tests. The inductive loops, when properly installed, performed reliably through a broad spectrum of weather conditions.

The technologies with the greatest extreme weather limitations include the ultrasonic, infrared, acoustic, and video image processors. This is not due to any flaw in the design of these units, but rather to physical limitations caused by weather-related phenomena, such as gusty winds (greater than 56 mi/h [>25 m/s] in the case of the Doppler ultrasound detector) or the presence of atmospheric obscurants. However, even these devices are relatively unaffected by inclement weather conditions when operating at the short ranges typically associated with their normal usage.

12.1.6 Microscopic Single-Lane vs. Macroscopic Multiple-Lane Data

Several of the detectors were better suited for collecting data that characterized individual vehicles in multiple lanes, while others were better for gathering data from groups of vehicles in multiple lanes. The detectors best suited for acquiring microscopic (individual vehicle) data over multiple lanes were the true-presence microwave radar and the video image processors. Those useful for collecting macroscopic (groups of vehicles) data were the wide-beam Doppler microwave detectors, true-presence microwave radar, and the video image processors. Sufficient data have not been reduced to rank these detectors for these applications.

12.2 LESSONS LEARNED

Many of the qualitative results were gained from the familiarity that came with utilizing these detectors day in and day out in a number of different weather and traffic environments. The dynamic nature of the field tests and the interest displayed by the detector manufacturers to participate in them caused the number of devices under evaluation to grow steadily. This necessitated changes to both the data logger hardware and the software (both to record and post-process the data) so that the expanding number of detector outputs could be accommodated. Each new serial interface required that device-specific code be written to provide the proper RS-232 communication interface. In order to minimize this problem in future applications, a standardization of serial communication protocols would be most helpful.

The considerable amount of time necessary to examine the processed data and video imagery in detail dictated that only a portion of the runs were analyzed in depth for this report. Analyzed runs were selected to be representative of the broadest possible spectrum of weather and traffic conditions encountered. While this approach provided the analyst with a diverse set of data to evaluate, it did not allow for any detailed statistical analyses to be performed. Such analyses and conclusions should be a part of future efforts that explore more of the available database.

12.3 CONCLUDING REMARKS

The *Detection Technology for IVHS* field tests provided a substantial database of traffic detector performance information for a broad spectrum of weather and traffic conditions. Future data reduction will include analyses of additional runs to produce a larger set of results from which statistical conclusions may be drawn. Additional runs will be subject to ground truth. Vehicle-count ground truth will be analyzed over short intervals (such as a signal cycle period) in addition to the 1- to 2-hour intervals prevalent in previous analyses. This will better determine whether existing technologies are able to meet the traffic parameter update accuracy requirements specified for applications such as real-time signalized intersection control.

Additional ground truthing also is required for the Tucson surface-street site in order to minimize the effect of anomalies that occur when vehicles sweep out into multiple lanes as they complete their turning movements. This entails overlaying the signal green phase status on the video imagery and counting only those vehicles exiting the intersection during the green or yellow phase. This will eliminate most of the false counts associated with left or right turns and allow the count to properly reflect the vehicles that travel straight through the intersection with minimal lane changes.

The project wishes to express its gratitude to the many people who provided support in the acquisition and evaluation of the detectors. Engineers and technicians from the various detector manufacturers were consulted frequently and responded with timely and helpful technical advice. Some personally assisted with the installation of their systems. Their willingness to provide evaluation units and the spirit of cooperation with which they participated are greatly appreciated.

The assistance of the state, county, and municipal DOTs was invaluable. They supplied personnel, equipment, and use of their facilities, and patiently accommodated numerous requests for lane closures and adjustment of the detector viewing angles. The professionalism demonstrated by these agencies was a critical ingredient in the success of the field tests.

APPENDIX A.

TASK J: DETERMINE NEED AND FEASIBILITY OF ESTABLISHING PERMANENT VEHICLE DETECTOR TEST FACILITY

Detector manufacturers participating in the *Detection Technology for IVHS* program and the three universities selected as IVHS Research Centers of Excellence (CoE) were contacted to ascertain their opinions and ideas concerning the need and feasibility of establishing a permanent detector test and evaluation facility. In addition, the advisability of establishing and methods of funding an independent detector evaluation facility were also addressed under a separate contract issued by FHWA to New Mexico State University. The results of these efforts are summarized in this appendix.

A.1 CONCLUSIONS FROM THE DETECTION TECHNOLOGY FOR IVHS PROGRAM

Potential advantages of having a national detector evaluation facility include:

- Reduction of detector testing costs by eliminating repetitive tests by multiple traffic management agencies;
- Developing a set of standardized test procedures and test facilities that are accepted by traffic management and transportation agencies and detector manufacturers;
- Training agencies in the installation, calibration, and maintenance of detectors that exploit technologies not historically associated with traffic management; and
- Promoting the use of standard serial data interfaces between the detector and the traffic management system to minimize the need to write detector-specific software that is otherwise required to interpret the serial output.

The need for a detector test and evaluation facility should not be an issue. One is needed. However, there are other issues associated with the establishment of such a facility. These are: gaining acceptance of the results by local, county, and state traffic management and data collection agencies; location or locations of the facility; selection of the test facility management; types of tests to be performed; calibration and types of ground truth equipment; establishment of standard protocols for output data; and funding.

When the detector manufacturers were contacted as part of this task for their ideas about participation, types of tests, and funding for a detector evaluation facility, they were not enthusiastic as evidenced by the lack of replies to the letter, shown in Figure A-1, that was mailed. Another letter, contained in Figure A-2, expressing similar thoughts was sent to an ASTM committee that was considering a similar issue. This letter was one of the inputs that lead to the eventual award of the contract to New Mexico State University to independently evaluate the need and operation of a national test center for traffic monitoring devices. Now that the *Detection Technology for IVHS* project is complete, a greater interest in new detector technologies appears to have been generated and exhibited by the traffic management community. Hence there is more interest in the detector manufacturing community to have their products accepted and purchased. Based on the favorable experience with manufacturers making their products available for the detection technology program, they very likely will make their products available again for evaluation at a permanent facility when one is established.

A set of letters and telephone conversations were also exchanged with the IVHS Research CoEs, listed in Table A-1, about their capabilities and interest in hosting the detector evaluation facility. The substance of these letters is contained in Figure A-3. Naturally all CoEs were enthusiastic about

February 7, 1994

Name of Manufacturer's Contact Person
Manufacturer Company Name
Mail Stop
Street or P.O. Box
City, State, Zip

Dear (first name of contact person),

On behalf of Hughes Aircraft Company and the Federal Highway Administration, I want to thank you for your support of the Detection Technology for IVHS Program. Your prompt response to questions about detector operation and to repairing equipment have made the program successful. We are presently at the last planned test location in Tucson, although there may be an opportunity to return to Phoenix this summer for further hot weather evaluation of the detectors. In the meantime, Michael Kelley and I are reducing the data we have already obtained.

In addition to evaluating the detectors in three states, the program requires us to determine the need and feasibility of establishing a permanent vehicle detector test facility or facilities. The wording for this task as it appears in the contract is:

> The total life cycle cost of a vehicle detector is difficult to predict since vehicle detector hardware designs and installation techniques are continually improving. National vehicle detector test and evaluation facility/ies may be needed to provide up-to-date performance information on new vehicle detectors performance. Determine if national vehicle detector test and evaluation facility/ies are needed and develop a test plan for implementing such facilities. Determine if laboratory tests should be conducted at a single center with multiple field sites; determine the feasibility of testing environmental sensors for sensing roadway environmental conditions. Determine the feasibility of this facility/ies operating on a self-supporting basis. Document the results of this Task as an Appendix to the draft final report.

My initial approach for fulfilling these requirements is to contact the three IVHS Research Centers of Excellence designated by FHWA and obtain their thoughts, comments, and ideas about the need for implementing detector test and evaluation centers. These centers are Texas A&M, Virginia Polytechnic Institute, and the University of Michigan. At a minimum, I believe that the test and evaluation center should conduct temperature, humidity, and vibration tests in an environmental chamber to some accepted levels such as those established by NEMA. In addition, the center should expose the detectors to real traffic environments on both a freeway, where traffic parameters such as volume, speed, and density are important, and a surface street arterial where presence, queue length, and turning movements are important. Other parameters such as vehicle classification based on length or pattern recognition could also be verified if the detector provides this output. For that matter, the test center would have to be prepared to measure whatever type of detector output data were available in order to evaluate the detector's accuracy and ability to provide the specified data.

As FHWA pointed out, we need to determine the feasibility of the centers being self-supporting. To this end, I wish to inquire of you whether such a test and evaluation facility will be of value in verifying, to potential local, regional, and state transportation agencies, that your products satisfy the specifications that either you develop or an accepted professional organization such as NEMA or ASTM develops? If so, what would you be willing to pay such a facility for conducting the tests? Are there any seed monies or special test equipment that you could contribute to help set up the facility? What types of tests do you consider to be necessary to aid in selling your products? What are your comments about conducting extended, perhaps six-month, simultaneous outdoor evaluations of the product at locations with hot and cold weather environments?

Please send me your thoughts about the test and evaluation center, including funding options and types of tests you deem important. If you have any questions, please call me at (714) 732-7995 or fax me at (714) 732-2613.

Sincerely,

Lawrence A. Klein,
Principal Investigator

Figure A-1. Letter Sent to Detector Manufacturers

January 1993

Emerging technologies are being applied to traffic management in areas such as weigh-in-motion, automatic vehicle classification, congestion management, and incident detection. Products that incorporate newer technologies create a need for standardized methods to test and verify device performance and to compare their data with data collected by other products performing the same function. This need has been expressed by several organizations and agencies, including the Federal Highway Administration, state and city departments of transportation, equipment manufacturers, and standard-setting groups such as ASTM.

The types of products to be tested cover the spectrum of Intelligent Vehicle-Highway System applications. They include axle count and weight detectors; vehicle presence and speed detectors; imaging detectors installed on highways and surface streets; traveler information devices such as changeable message signs, in-vehicle displays, and video displays in areas where large numbers of people gather (e.g., shopping centers, amusement parks, office buildings, etc.); and communications media including roadside-to-vehicle radios, satellite transmission devices, and vehicle identification tags and other in-vehicle transmitters that send various types of information and data to roadside receivers.

In order to: (1) determine what facilities, tests, and resources are available, and (2) obtain user input as to the types of testing that are desired, ASTM is conducting a survey of state and city departments of transportation. We ask that the information indicated below be provided, along with any other pertinent comments you choose to make.

I. Test facilities available or planned. These can include outdoor ranges, indoor environmental chambers, instrumented highway segments, state-run or national laboratories located within your jurisdictional area (please list specific facilities you would use in these laboratories), university assets, private industry assets, etc. Specify which of these facilities are available for outside use.

List the technologies that your facilities can evaluate. For example, axle weight detectors can be based on bending plates, piezoelectric devices, and rubber tube technologies. The response, in this case, should identify which of the technologies can be tested and what facilities and equipment are used, available, or proposed for the tests. As another example, consider vehicle count and presence detectors. These can employ inductive loops, magnetics, microwave or laser radar, passive infrared, ultrasound, acoustic arrays, and video image processors to gather data. Once again, the response should specify which of these technologies can be accommodated in the available or planned test facilities. Communications media are still another type of device. These include leased or dedicated line communications, spread spectrum radio, highway advisory radio, satellite terminals, microwave and laser links, etc. The types of communications devices that can be tested should be noted.

II. Personnel conducting the tests. Are they state employees, university employees, contractors, consultants, etc.

III. Current tests performed and procedures used. Include devices currently tested. If possible, estimate the cost for each test.

IV. Calibration or accreditation procedures used to ensure accurate test data are obtained. Include items such as how often the test equipment is calibrated and the calibration techniques that are used. If satellite test facilities are used, how frequently are they visited to ensure that the standard and approved test methods are being followed?

V. Types of products you use or products requiring test data before a purchase decision can be made. List types of test data required and associated measurement accuracy (if known).

Figure A-2. Draft of Letter Mailed in Response to a Request From ASTM Committee 17.52

January 25, 1994

Contact Person
IVHS Research Center of Excellence
University Name
Street or P.O. Box
City, State, Zip

Dear (name of contact person),

To follow up on our telephone conversation of last week, I will describe the task that I am required to perform under my present contract with FHWA to determine the need and feasibility of establishing a permanent vehicle detector test facility or facilities. The task in the contract reads as follows:

> The total life cycle cost of a vehicle detector is difficult to predict since vehicle detector hardware designs and installation techniques are continually improving. National vehicle detector test and evaluation facility/ies may be needed to provide up-to-date performance information on new vehicle detectors performance. Determine if national vehicle detector test and evaluation facility/ies are needed and develop a test plan for implementing such facilities. Determine if laboratory tests should be conducted at a single center with multiple field sites; determine the feasibility of testing environmental sensors for sensing roadway environmental conditions. Determine the feasibility of this facility/ies operating on a self-supporting basis. Document the results of this Task as an Appendix to the draft final report.

My initial thoughts are to contact the three IVHS Research Centers of Excellence designated by FHWA and obtain their thoughts, comments, and ideas about the need for implementing detector test and evaluation centers. At a minimum, I believe that such a center should conduct temperature, humidity, and vibration tests in an environmental chamber to some accepted levels such as those established by NEMA. In addition, the center should expose the detectors to real traffic environments on both a freeway, where traffic parameters such as volume, speed, and density are important, and a surface street arterial where presence, queue length, and turning movements are important. Other parameters such as vehicle classification based on length or pattern recognition could also be verified if the detector provides this output. For that matter, the test center would have to be prepared to measure whatever type of detector output data were available in order to evaluate the detector's accuracy and ability to provide the specified data.

As FHWA pointed out, we need to determine the feasibility of the centers being self-supporting. To this end, I will write to the detector manufacturers who are participating in the Detection Technology for IVHS Program and solicit their thoughts about the center and how much they might be willing to pay to have one of their detectors tested and evaluated at the center.

Please send me your thoughts about the test and evaluation center, including funding options and types of tests you deem important. Include a description of your Research Centers of Excellence facilities that could be used to support this activity. Would there be a need for multiple test centers to evaluate the detectors under all of the anticipated real-world traffic conditions? Should the test center provide some pre-established certification for operation in one or more applications or should the center simply verify that the detector meets the manufacturer's specifications?

I would appreciate your comments and any other inputs about any of the issues encompassed by the above task. If you have any questions, please call me at (714) 732-7995 or fax me at (714) 732-2613.

Sincerely,

Lawrence A. Klein,
Principal Investigator

enc.

Figure A-3. Substance of Letters Sent to IVHS Research Centers of Excellence

managing such a facility. The responses from the Center for Transportation Research at Virginia Tech and the Texas Transportation Institute at Texas A&M are shown as Figures A-4 and A-5, respectively. The semi-governmental agencies, such as the Jet Propulsion Laboratory and the Department of Energy laboratories, also want to be the facility manager. They all appear to have pockets of excellence, but it is difficult to say if any one presently has all the expertise required to run the series of tests that most likely will be required. Fortunately, the knowledge to execute any group of detector evaluation tests and procedures that is deemed necessary can be easily acquired, and after some learning period, the tests will most likely be performed flawlessly by any of these institutions.

Table A-1. IVHS Research Centers of Excellence

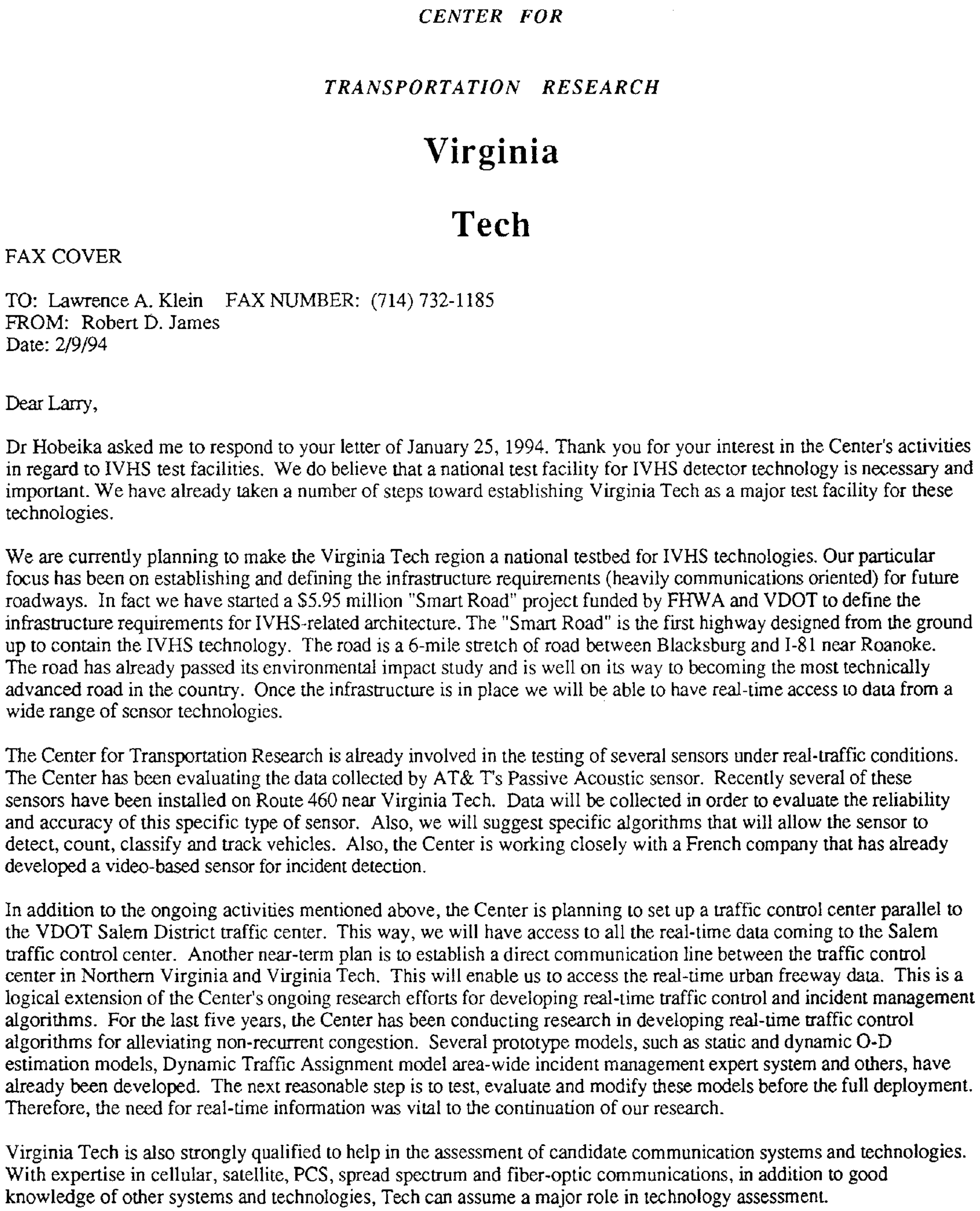
Dr. Tony Hobeika	Dr. Thomas Urbanik, II	Dr. Steven Underwood
Director, Center for Transportation Research	Division Head-Transportation Systems	University of Michigan
Virginia Tech	Texas Transportation Institute	IVHS Program
106 Faculty Street	The Texas A&M University System	4110 EECS Building
Blacksburg, VA 24061	College Station, TX 77843-3135	Ann Arbor, MI 48109-2122

Perhaps a way to begin the process of selecting the test facility manager is to convene a working group composed of members of the CoEs and other universities with active transportation research programs, the DoE laboratories, NASA laboratories, private industry with ongoing FHWA programs, and traffic management agencies. The group would initially be chaired by an employee of FHWA. The chair could remain in the hands of FHWA or be passed onto another public or private sector employee whose employer will not run the detector evaluation facility. Suggestions from the participants will be solicited for the types of tests (field or laboratory) to be performed, test locations (cold and hot weather sites, rain and fog sites, etc.), length of the tests, distribution of results, and other issues that are generated.

A.2 NEW MEXICO STATE UNIVERSITY INVESTIGATION

Most of the issues described above have been addressed by New Mexico State University in the execution of their contract with FHWA to investigate the feasibility of establishing a national center to test monitoring devices used by state highway agencies to gather traffic data. Under the leadership of Dr. Rudi Schoenmackers of the Southwest Technology Development Institute at New Mexico State, representatives from 10 state highway and transportation agencies, the American Association of State Highway and Transportation Officials (AASHTO), Iowa State University, New Mexico State University, FHWA, and the Alliance for Transportation Research initially participated in a 2-day working session that:

- Determined the types and uses of traffic monitoring devices to be tested;
- Investigated the need for standard test procedures;
- Recognized need to specify laboratory and field test environments;
- Recognized need to develop a process to disseminate test results;
- Determined extent of manufacturer participation;
- Addressed representation of state highway agencies and national associations in the management of the test facility;
- Explored relationship of a national testing program for traffic monitoring devices to other existing national testing programs and



CENTER FOR

TRANSPORTATION RESEARCH

Virginia

Tech

FAX COVER

TO: Lawrence A. Klein FAX NUMBER: (714) 732-1185
FROM: Robert D. James
Date: 2/9/94

Dear Larry,

Dr Hobeika asked me to respond to your letter of January 25, 1994. Thank you for your interest in the Center's activities in regard to IVHS test facilities. We do believe that a national test facility for IVHS detector technology is necessary and important. We have already taken a number of steps toward establishing Virginia Tech as a major test facility for these technologies.

We are currently planning to make the Virginia Tech region a national testbed for IVHS technologies. Our particular focus has been on establishing and defining the infrastructure requirements (heavily communications oriented) for future roadways. In fact we have started a $5.95 million "Smart Road" project funded by FHWA and VDOT to define the infrastructure requirements for IVHS-related architecture. The "Smart Road" is the first highway designed from the ground up to contain the IVHS technology. The road is a 6-mile stretch of road between Blacksburg and I-81 near Roanoke. The road has already passed its environmental impact study and is well on its way to becoming the most technically advanced road in the country. Once the infrastructure is in place we will be able to have real-time access to data from a wide range of sensor technologies.

The Center for Transportation Research is already involved in the testing of several sensors under real-traffic conditions. The Center has been evaluating the data collected by AT& T's Passive Acoustic sensor. Recently several of these sensors have been installed on Route 460 near Virginia Tech. Data will be collected in order to evaluate the reliability and accuracy of this specific type of sensor. Also, we will suggest specific algorithms that will allow the sensor to detect, count, classify and track vehicles. Also, the Center is working closely with a French company that has already developed a video-based sensor for incident detection.

In addition to the ongoing activities mentioned above, the Center is planning to set up a traffic control center parallel to the VDOT Salem District traffic center. This way, we will have access to all the real-time data coming to the Salem traffic control center. Another near-term plan is to establish a direct communication line between the traffic control center in Northern Virginia and Virginia Tech. This will enable us to access the real-time urban freeway data. This is a logical extension of the Center's ongoing research efforts for developing real-time traffic control and incident management algorithms. For the last five years, the Center has been conducting research in developing real-time traffic control algorithms for alleviating non-recurrent congestion. Several prototype models, such as static and dynamic O-D estimation models, Dynamic Traffic Assignment model area-wide incident management expert system and others, have already been developed. The next reasonable step is to test, evaluate and modify these models before the full deployment. Therefore, the need for real-time information was vital to the continuation of our research.

Virginia Tech is also strongly qualified to help in the assessment of candidate communication systems and technologies. With expertise in cellular, satellite, PCS, spread spectrum and fiber-optic communications, in addition to good knowledge of other systems and technologies, Tech can assume a major role in technology assessment.

Figure A-4. Reply from the Center of Transportation Research at Virginia Tech Concerning National Detector Test and Evaluation Facilities

The communication groups at Virginia Tech are part of the Center for Wireless Telecommunications, a technology development center of the Virginia Center for Innovative Technology, and the Fiber and Electro-Optics Research Center (FEORC), a leading center for fiber-optics research in the nation.

The Fiber and Electro-Optics Research Center of Virginia Tech, one of the University partners of IVHS Research Center of Excellence, is heavily involved in developing fiber sensors. They are extremely experienced in evaluating the effects of temperature variation, humidity and contaminant build-up on the orientation of sensors. They perform the environmental studies at Virginia Tech using a Thermetron environmental testing chamber. With this chamber it will be possible to cycle any sensor through the expected operating temperature and humidity ranges to determine the sensitivity of the sensor to adverse environmental conditions. The FEORC group is also experienced in evaluating the effects of contaminants, such as petroleum products, on the integrity of the sensor components.

FEORC is involved in developing and testing fiber-optic sensors for different purposes. They have already developed and tested under real-traffic conditions a fiber-optic sensor to measure the velocity and quantity of vehicles in motion on a roadway. They have also developed a parking lot sensor. They have conducted extensive tests at Virginia Tech's commuter lot.

The Mobile Portable Radio Group (MPRG) at Virginia Tech is nationally renown for its extensive database and lab testing capabilities They have conducted many studies for all the major telecommunication companies. They have also been very active in IVHS communication issues. Their satellite and cellular research is well known in the IVHS arena.

The AT&T Passive Acoustic detector project is a great example of how industry and state can work together to fund the testing of these sensors. This project has been funded by AT&T with matching funding from Virginia's Center for Innovative Technology. VDOT has provided significant technical and financial assistance for the installation of the sensors on the roadway. We see the Federal Government contributing to the initial setup for the national testbed and industry in combination with various Federal, State and local agencies involved in paying for the testing of individual sensors. Industry benefits by having their sensor evaluated based upon national standards and having access to an independent team of experts for system development. Also, with the use of graduate students the cost for data collection and analysis can be kept very low. Government agencies benefit by having candidate technologies tested under real-world conditions and performance based upon a national standard. This makes for a win-win situation!

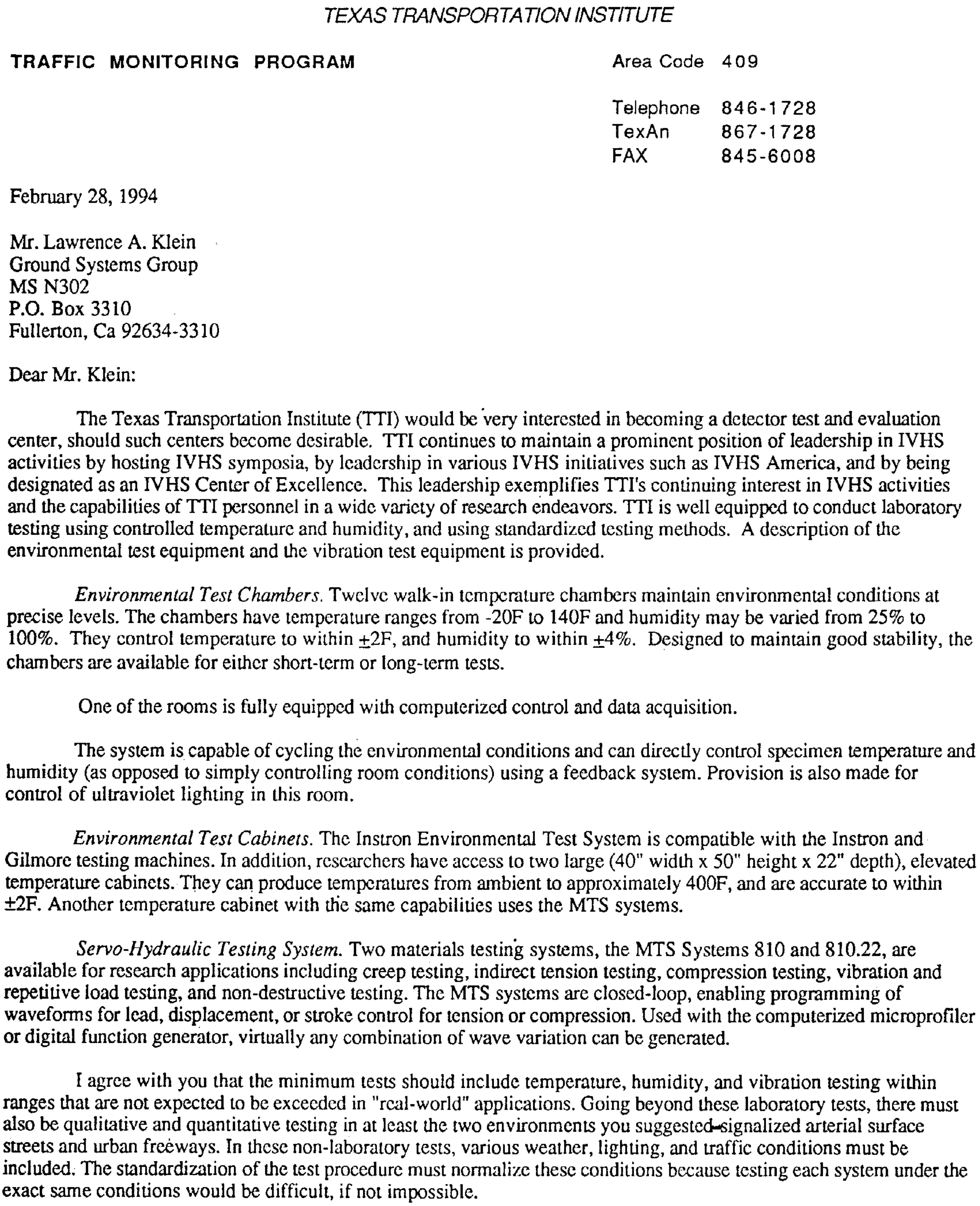
In summary, our vision is to start a national test lab for advanced IVHS technologies around Virginia Tech, first on Route 460 and I-81, then on the "Smart Road." This unique setting will give us the opportunity of testing different sensors under real-traffic conditions. Moreover, the road expertise of the various Virginia Tech centers involved in IVHS Research Centers of Excellence and the availability of high-tech labs at the Virginia Tech campus will give us the capability of testing and evaluating different types of sensors, ranging from more conventional embedded types of sensors to the cellular and satellite types of sensors.

I will send you some materials on the various facilities at the University. If there is anything else you need please let me know and I will be happy to help. I look forward to working with you in future efforts along these lines. If there are any programs you would like to work together on, please let me know. I can be reached at (703) 231-7740 or FAXed at (703) 231-5214. Thank you for your interest.

Sincerely,

Robert D. James

Figure A-4. Reply from the Center of Transportation Research at Virginia Tech Concerning National Detector Test and Evaluation Facilities (continued)



TEXAS TRANSPORTATION INSTITUTE

TRAFFIC MONITORING PROGRAM

Area Code 409

Telephone 846-1728
TexAn 867-1728
FAX 845-6008

February 28, 1994

Mr. Lawrence A. Klein
Ground Systems Group
MS N302
P.O. Box 3310
Fullerton, Ca 92634-3310

Dear Mr. Klein:

The Texas Transportation Institute (TTI) would be very interested in becoming a detector test and evaluation center, should such centers become desirable. TTI continues to maintain a prominent position of leadership in IVHS activities by hosting IVHS symposia, by leadership in various IVHS initiatives such as IVHS America, and by being designated as an IVHS Center of Excellence. This leadership exemplifies TTI's continuing interest in IVHS activities and the capabilities of TTI personnel in a wide variety of research endeavors. TTI is well equipped to conduct laboratory testing using controlled temperature and humidity, and using standardized testing methods. A description of the environmental test equipment and the vibration test equipment is provided.

Environmental Test Chambers. Twelve walk-in temperature chambers maintain environmental conditions at precise levels. The chambers have temperature ranges from -20F to 140F and humidity may be varied from 25% to 100%. They control temperature to within ±2F, and humidity to within ±4%. Designed to maintain good stability, the chambers are available for either short-term or long-term tests.

One of the rooms is fully equipped with computerized control and data acquisition.

The system is capable of cycling the environmental conditions and can directly control specimen temperature and humidity (as opposed to simply controlling room conditions) using a feedback system. Provision is also made for control of ultraviolet lighting in this room.

Environmental Test Cabinets. The Instron Environmental Test System is compatible with the Instron and Gilmore testing machines. In addition, researchers have access to two large (40" width x 50" height x 22" depth), elevated temperature cabinets. They can produce temperatures from ambient to approximately 400F, and are accurate to within ±2F. Another temperature cabinet with the same capabilities uses the MTS systems.

Servo-Hydraulic Testing System. Two materials testing systems, the MTS Systems 810 and 810.22, are available for research applications including creep testing, indirect tension testing, compression testing, vibration and repetitive load testing, and non-destructive testing. The MTS systems are closed-loop, enabling programming of waveforms for lead, displacement, or stroke control for tension or compression. Used with the computerized microprofiler or digital function generator, virtually any combination of wave variation can be generated.

I agree with you that the minimum tests should include temperature, humidity, and vibration testing within ranges that are not expected to be exceeded in "real-world" applications. Going beyond these laboratory tests, there must also be qualitative and quantitative testing in at least the two environments you suggested-signalized arterial surface streets and urban freeways. In these non-laboratory tests, various weather, lighting, and traffic conditions must be included. The standardization of the test procedure must normalize these conditions because testing each system under the exact same conditions would be difficult, if not impossible.

Figure A-5. Reply from the Texas Transportation Institute at Texas A&M Concerning National Detector Test and Evaluation Facilities

Based on TTI's test equipment, its several satellite offices in large urban areas, and its very capable and diverse research staff, there should be no need to establish multiple test facilities unless weather conditions in Texas are not suitable for all outdoor tests. If the testing of a new device is to occur within a reasonable time frame, it is anticipated that some tests must be done indoors. Temperature and humidity testing must be done under laboratory conditions because ambient conditions at certain times of the year at any one location would not represent the extremes needed to test a new product. It is assumed that longevity testing will not be included.

If new equipment is to be tested under hot and cold extremes outdoors, Texas would provide adequate high temperatures and other weather conditions such as fog and rain. Another state should be selected with other extremes, including low temperatures. Testing would need to occur in the varied weather extremes of summer in Texas and winter in the northern state selected. Periods of inclement weather, to include poor visibility, would be used to fully evaluate the test systems. TTI has satellite facilities in Houston, Dallas, and San Antonio in close proximity to both signalized arterials and urban freeways where systems could be deployed for a prescribed test period.

One of the fundamental issues to be addressed by the FHWA is the manner in which such centers will be funded, and furthermore, whether they can be self-sufficient. Your contacts with detector manufacturers will provide insight into their willingness to participate in funding all or part of the expense involved in testing their products. The manufacturer's perspective must consider the benefits to them in having a facility that can conduct qualitative testing in an unbiased manner. The primary question for them is, *Why should the manufacturers want to pay to have a device tested ?* Possible answers to this question include the following:

1. A law has been passed requiring manufacturers to pay for testing.
2. Manufacturers hope to reduce potential litigation due to product failure.
3. Customers will not buy the device unless it has undergone rigorous testing.
4. Manufacturers hope to gain a competitive advantage by having their detection system thoroughly tested.

Adherence to electrical and other codes for safety falls within the realm of Item 1. Manufacturers of vehicle detection devices routinely submit their equipment for testing by Underwriters Laboratories. This program also addresses Item 2.

Item 3 is prevalent in many devices and products evaluated under the National Type Testing program of the National Institute of Standards and Technology (NIST). In this program, standards and test procedures are developed or adopted from some other source, such as the American Society for Testing and Materials (ASTM) or the American National Standards Institute (ANSI). NIST then approves testing agencies to whom manufacturers submit sample equipment for evaluation and pay a fee for the service.

If the device passes the relevant tests in the National Type Testing program, it is certified as having done so. Customers then will purchase the device if it otherwise meets their needs based on cost, quality, service, and so forth. The device does not have to undergo rigorous testing by every purchaser.

Item 4 would be important to a manufacturer that has a device that is clearly superior to the competition and wants to make that fact known. For example, if a manufacturer has based a product on new technology that is not yet incorporated into its competitor's products, it might want an independent laboratory to compare the two and publish the results.

If I can be of further assistance to you in your current research effort, or if you want to discuss TTI's interest in the detector test and evaluation center, please do not hesitate to give me a call.

Sincerely,

Dan Middleton, P.E.
Assistant Research Engineer

cc: Tom Urbanik

Figure A-5. Reply from the Texas Transportation Institute at Texas A&M Concerning National Detector Test and Evaluation Facilities (continued)

centers such as the Highway Innovative Technology Evaluation Center; and

- Identified sources of income from states, counties, other municipal agencies, and manufacturers as sponsors of the test center; testing fees from manufacturers; and startup funds.
- Developed three budgets based on:
    - ❑ No memberships in the test center by sponsor states or manufacturers in the first year of operation;
    - ❑ Greater reduction in membership growth, staffing, and testing than in the first budget;
    - ❑ No memberships in the test center by sponsor states or manufacturers in the first year, reduced membership growth, and staffing reduced to two professionals.

The group recommended that the testing program initially evaluate volume counters, vehicle classifiers, speed monitors, and weigh-in-motion equipment. The types of traffic devices evaluated in the Detection Technology program were not specifically included in the New Mexico State program. However, they can certainly be added as devices to be tested if the proper personnel and test equipment are made available.

In the Fall of 1994 a report was issued that identified:

- A mission statement for a national test center;
- Types of testing to be included (pre-qualification, quality control, and verification);
- A test flow procedure;
- Identification of typical concerns that transportation agencies and detector manufacturers may have;
- Funding options that include income from full memberships, associate memberships, and testing fees; and
- Management structure for the test facility.

Their future plans include finalizing a business plan after review by the states and detector manufacturers, preparing a report on test procedures, and obtaining startup funds and memberships.

A.3 RECOMMENDATIONS

- Continue to explore where the detection technology evaluation facilities should be located;
- Establish a process to select a facility manager and center management procedures that include inputs from the IVHS Research Centers of Excellence;
- Review the facility funding options developed under the New Mexico State University contract for realism;
- Obtain firm commitments from traffic management agencies to use the results of the detection technology evaluation facility as this will induce detector manufacturers to support the facility with equipment and testing fees.

APPENDIX B. DETECTOR MANUFACTURERS AND CONTACT PEOPLE

AT&T
1919 South Eads Street, Suite 300
Arlington, VA 22202-2886
(703) 271-7319; Fax (703) 271-7676
Attention: Greg Pieper
or Joe Lee at (919) 279-7744

Computer Recognition Systems
639 Massachusetts Avenue
Cambridge, MA 02139
(617) 491-7665
Fax (617) 491-7753
Attention: Sal D'Agostino

Condition Monitoring Systems
2412 East First Street
Long Beach, CA 90803
(310) 438-4875
Attention: Kay Dermer or Bob Nasburg

Detector Systems
661 Distel Drive
Los Altos, CA 94022
(415) 948-6243
Fax (415) 949-1651
Attention: John Kluga
or Gary Mayder at (800) 828-7775

Econolite/Autoscope
3360 East La Palma Avenue
Anaheim, CA 92806-2856
(714) 630-3700
Fax (714) 630-6349
Attention: Gary Duncan

Electronic Integrated Systems, Inc.
150 Bridgeland Avenue
North York, Ontario, Canada M6A 1Z5
(416) 785-9248
Fax (416) 785-9332
Attention: Dan Manor

Eltec Instruments, Inc.
P.O. Box 9610
Daytona Beach, FL 32120
(800) 874-7780 or (904) 252-0411
Fax (904) 258-3791
Attention: David Cima (Technical)
Douglas Armstrong (Sales and Mktg)

Eva, Inc.
300 Montgomery Street
Suite 633
San Francisco, CA 94104
(415) 433-7653; Fax (415) 433-7654
Attention: Ignacio Lopez or Renato Martinez

Golden River Traffic Ltd.
Churchill Road, Bicester
Oxfordshire, OX6 7XT England
011 44 869 240400
Fax 011 44 869 246858
Attention: Michael Dalgleish

Image Sensing Systems
1600 University Avenue West
Suite 500
St. Paul, MN 55104-3825
(612) 642-9904
Attention: Craig Anderson

Intelligent Vision Systems, Inc.
6575 West Loop South
Suite 498
Bellaire, TX 77401
(713) 662-0004
Fax (713) 662-3147
Attention: Paul Mayeaux

Max Kutter, Inc.
16150 Lindbergh Street
Van Nuys, CA 91406
(818) 994-0953
Fax (818) 994-2780
Attention: Ralph Ferguson

Microsense Inc.
4800 Bethania Station Road
Winston-Salem, North Carolina 27105-1201
(919) 744-5333
Fax (919) 744-5054
Attention: Ann Hayes

Microwave Sensors
7885 Jackson Road
Ann Arbor, MI 48103
(800) 521-0418
Fax (313) 426-5950
Attention: Don Johnston or Bob Hunter

Midian Electronics, Inc.
2302 East 22nd Street
Tucson, AZ 85713
(602) 884-7981
Fax (602) 884-0422
Attention: Chuck Soulliard or Bud Ward

Northrop-Grumman Corporation
1111 Stewart Avenue
Bethpage, NY 11714-3580
Attention: Joseph Franachio, M.S. 0835
(516) 346-2769 or 575-3294
Fax (516) 346-3670

Schwartz Electro-Optics, Inc.
3404 North Orange Blossom Trail
Orlando, FL 32804
(407) 298-1802
Fax (407) 297-1794
Attention: Robert Gustavson or Bob Hoffman

Sumitomo Electric U.S.A., Inc.
3235 Kifer Road
Suite 150
Santa Clara, CA 95051
(408) 737-8517
Fax (408) 737-0134
Attention: Takehiko Barada

Traficon N.V:
Bissegemsestraat 45
B-8501 Kortrijk, Belgium
+ 32 56 37 22 00
Fax + 32 56 37 21 96
Attention: Jo Versavel

3M Center
Building 225-4N-14
St. Paul, MN 55144-1000
(612) 733-4056
Fax (612) 736-2298
Attention: George Palm
or Earl Hoekman at (612) 733-6416

Timemark, Inc.
P.O. Box 12947
Salem, OR 97309
(800) 755-5882 or (503) 363-2012
Fax (503) 363-1716
Attention: Dan Gossack

Whelen Engineering Company
Route 145, Winthrop Road
Chester, CT 06412-0684
(203) 526-9504
Fax (203) 526-4078
Attention: Tom Fredericks

APPENDIX C. DATA LOGGER

C.1 FUNCTION OF DATA LOGGER

The data logger system, shown in Figure C-1, simultaneously time tags and records data output by the detectors under test. It also includes software and hardware that permit later data analysis and the overlay of selected detector output data on imagery previously recorded on video tape.(1) Typical recorded detector data are vehicle count, presence, speed, lane occupancy, and classification, depending on the specific detector. Some detectors output both discrete and serial (RS-232) traffic parameter data, while others output only discrete data using Form C relay closures or optically isolated outputs.

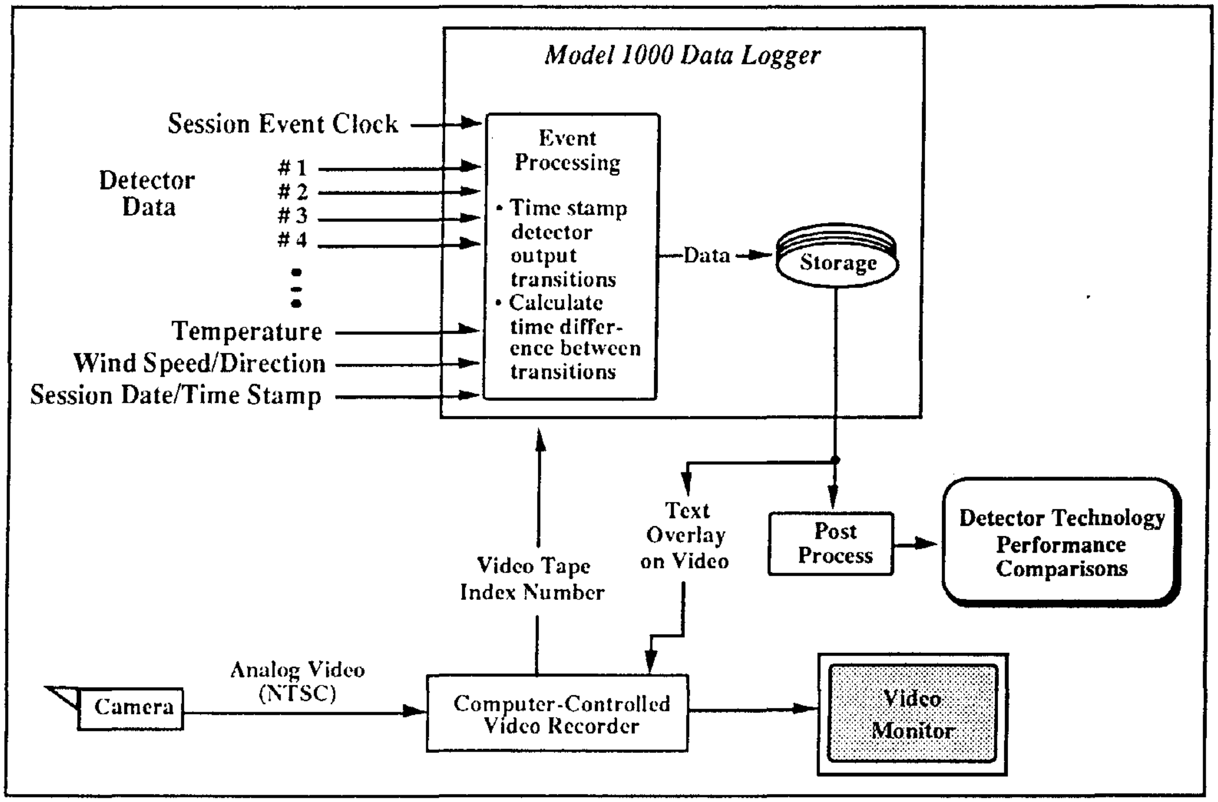


Figure C-1. Data Logger Recording and Analysis System

The application-specific Phase II software, represented by the Post Process box, converts the raw data into comma-delineated fields that can then be transformed into a database format using almost any commercial database software. Paradox database software was used in this project to extract similar output data from several detectors for display as a function of time or another variable, and as inputs to analysis programs that calculated their mean values and standard deviations. Mathcad, KaleidaGraph, and custom FORTRAN programs were used to analyze and generate plots of the data. Selected detector outputs or analysis results can also be superimposed onto the video tape that was recorded during the data collection process. Superimposed information includes detector technology type, associated traffic parameters (e.g., count and speed), and mean and standard deviation of the traffic data parameter. The visual presentation facilitates a qualitative comparison of the performance of the different detector technologies.

C.2 TYPES OF DETECTOR OUTPUTS SUPPORTED

Up to 16 serial detector outputs, 40 optically isolated outputs, 16 Form C relay closure outputs, and 8 analog outputs that include environmental data (e.g., temperature, wind speed, wind direction) and analog detector outputs, such as Doppler frequency, can be recorded. The first 16 optically isolated outputs are monitored by the main logger chassis shown in Figure C-2 and the remaining 24 by an auxiliary opto chassis. The auxiliary opto chassis is connected to the main logger by power and data cables as shown in Figure C-3. The lower portion of the figure describes how to verify that an opto module on the data logger is functioning properly.

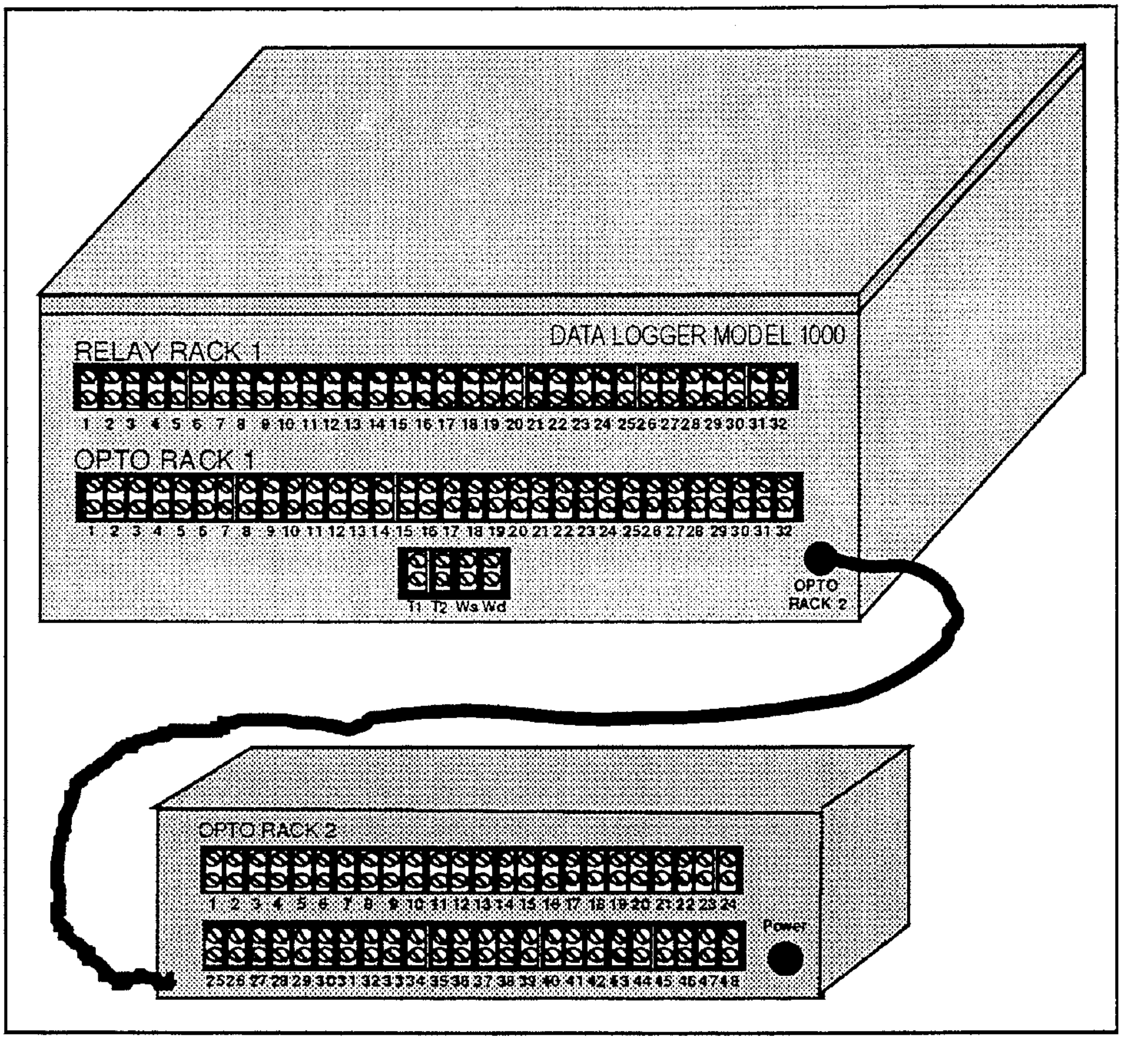


Figure C-2. Data Logger Main and Auxiliary Chassis

C.3 MAJOR DATA LOGGER ASSEMBLIES

The data logger consists of five major assemblies, namely a main processing unit (MPU), removable storage unit (RSU), intelligent serial interface system (ISIS), discrete interface system (DIS), and video control system (VCS).

C.3.1 Main Processing Unit

The main processing unit consists of a personal computer (PC) containing an Intel 80386 40-MHz processor in an advanced technology (AT) architecture, 8 megabytes (MB) of random access memory (RAM), 80

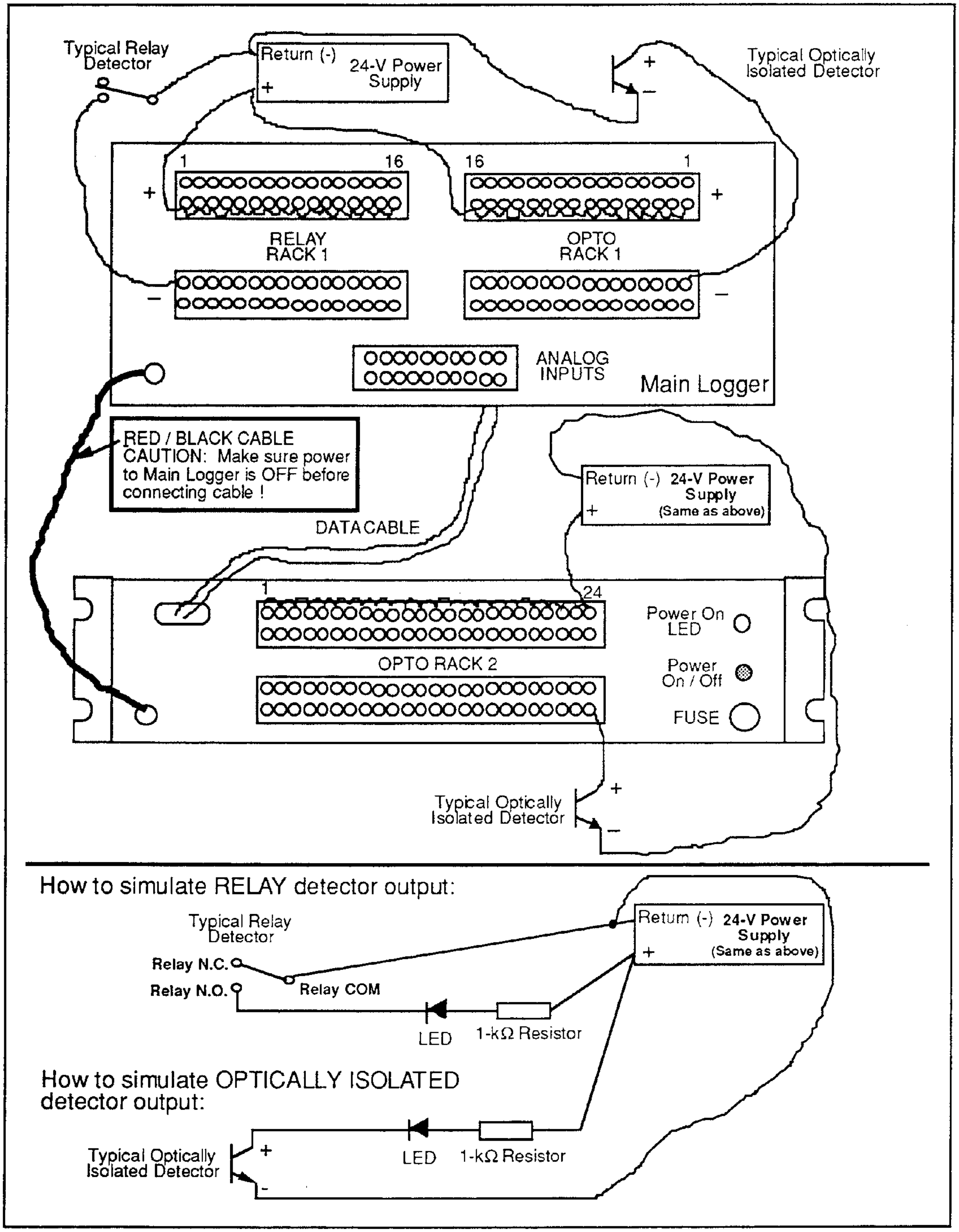


Figure C-3. Connection of Auxiliary Data Logger Opto Chassis to Main Data Logger Along with Test Connections for Verifying Proper Opto Operation

MB of hard-disk storage, video graphics adapter, two serial ports, and one parallel port. The MPU stores and executes the operating system, application-specific software, and user interface. The RSU, ISIS, DIS, and VCS are connected to the MPU either through the internal bus or via the external serial and parallel connectors.

C.3.2 Removable Storage Unit

The removable storage unit consists of an external hard drive that stores data on 88-MB cartridges, an internal high-density 5.25-inch (1.2-MB) floppy disk drive, and an internal high-density 3.5-inch (1.44-MB) floppy disk drive. The external drive is connected to the MPU through the parallel connector, while the floppy drives are connected internally through the bus.

C.3.3 Intelligent Serial Interface System

The intelligent serial interface system uses a 16-channel Digiboard to transfer serial outputs from the detector outputs to the 88-MB cartridges and to communicate with other components in the data logger. Specific Digiboard ports communicate with video image processors, computer-controlled video cassette recorders (VCRs), non-imaging detectors, and the DIS. The ISIS is connected to the MPU through the internal bus.

C.3.4 Discrete Interface Subsystem

The discrete interface subsystem is based on an Opto 22 industrial process controller. It uses a digital brain board to communicate from the local controller to the digital input modules that accept the 40 optically isolated outputs and 16 Form C relay closure outputs. An analog brain board executes communications from the local controller to the analog input modules that accept up to eight analog detector or environmental sensor outputs. The DIS is connected to the MPU through the internal bus.

C.3.5 Video Control System

The video control system consists of up to three VCRs and the distribution amplifiers, video switcher, and video monitor required for recording, distributing, switching, and displaying the video signals, respectively. Connections to the VCS are through the ISIS.

C.4 DATA ANALYSIS SOFTWARE

The data recording and analysis flow is shown in Figure C-4. MS-DOS is used as the operating system and Windows 3.1 as the graphical user interface. The Phase II software hosted on the PC performs three functions:

(1) Displays specific screens for each of the detectors under test so that the detector input connections to the data logger are easily recorded,

(2) Contains detector data conversion software that transforms the recorded raw data record into a comma-delimited, database-compatible record, and

(3) Supports the overlaying of selected detector data onto the video tape.

Paradox allows the data to be segregated by detector technology, time of run, weather, data type, or any combination of criteria desired. Paradox can also perform some data analysis, such as vehicle speed calculation using vehicle detection times recorded by two appropriately positioned optically isolated detectors (or from one detector having two optically isolated outputs available). Mathcad analyzes the selected data and summarizes the data in the form of tables, graphs, and statistical measures.

C.5 DATA RECORDING

The analog outputs from the detectors that are connected to the analog input modules are polled at 10-millisecond intervals. Exceptions are the wind speed and temperature sensors that are sampled at 10-second intervals because of their more slowly varying data. The time of an event captured by a detector using relay outputs is recorded when the relay output returns to its deactivated state. The time between relay activation and deactivation is also recorded as the pulse width. Relay output levels, such as

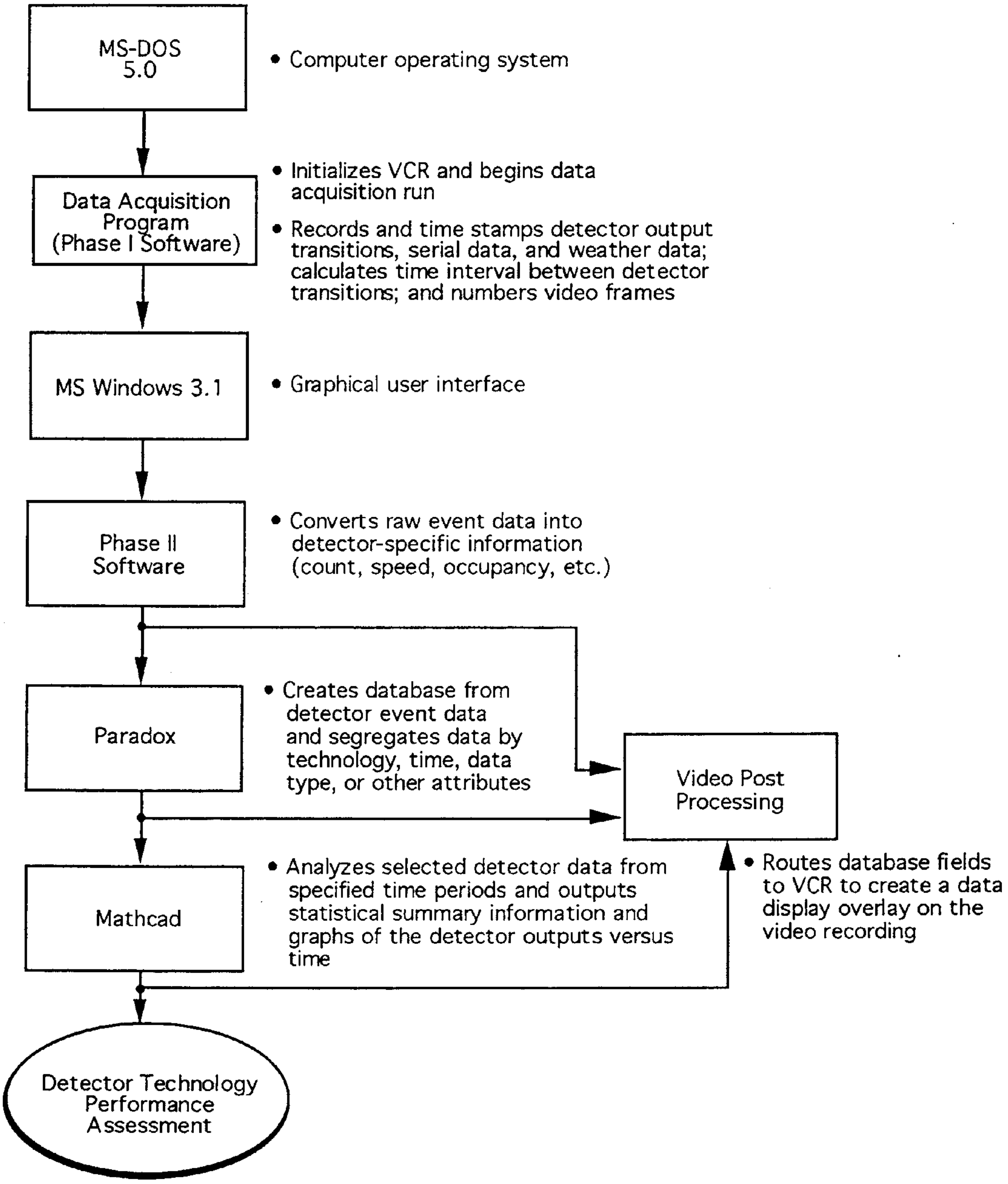
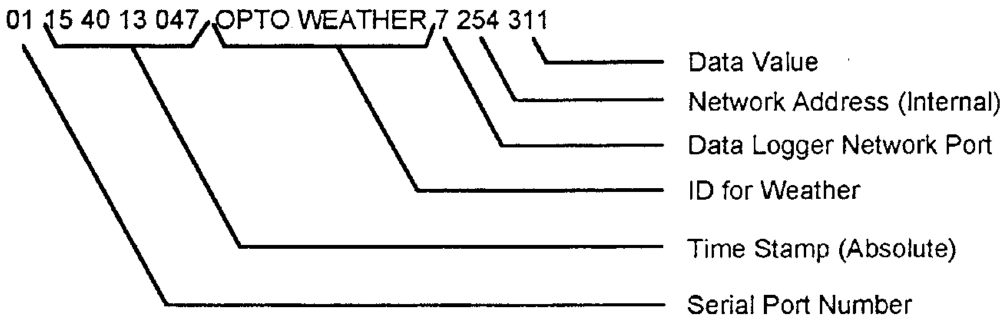


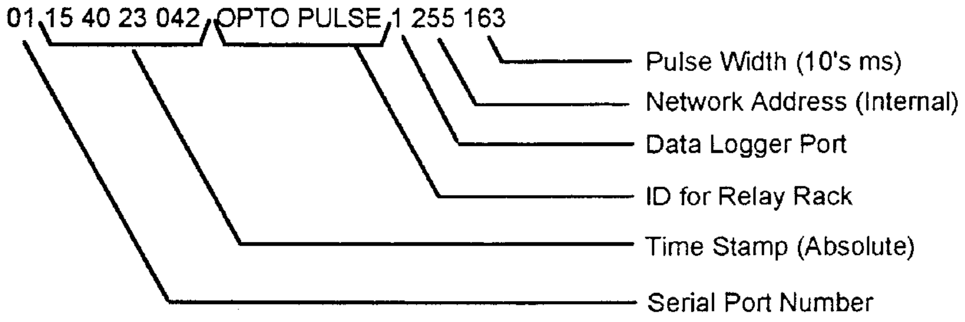
Figure C-4. Data Recording and Analysis Flow

those from Form C relays, are measured with 10-millisecond resolution. The recording of optically isolated detector outputs is event driven. When an event such as vehicle passage occurs, the time at which the level of the appropriate optically isolated output changes is recorded relative to the number of 250-microsecond intervals that have elapsed since the data logger was turned on. RS-232 serial data are recorded as events occur.

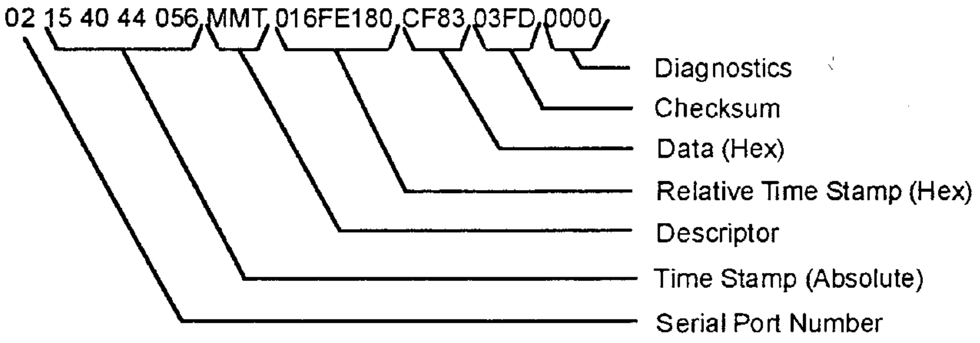
Records containing the serial input port number, absolute time stamp (generated by the PC), detector identification, data address, and data value are stored on the 88-MB cartridge in ASCII format to facilitate readability, portability, and post analysis. Records from the optically isolated detector outputs contain two additional pieces of information, a relative time stamp that contains the number of 250-microsecond intervals that have elapsed since the data logger was turned on and a checksum. The weather sensors, analog detector outputs, and Form C relays use serial port 01 to input data that are recorded by the data logger. The weather data format is shown in Figure C-5a and the relay data format in Figure C-5b. Optically isolated detector outputs are recorded on serial port 02 in the format shown in Figure C-5c. The video frame numbers are synchronized with the absolute time stamp using serial port 05, as shown in Figure C-5d. Detectors with RS-232 serial outputs use ports 06 through 20. An example of a serial detector data record is shown in Figure C-5e.



a. Weather Sensor Data Format

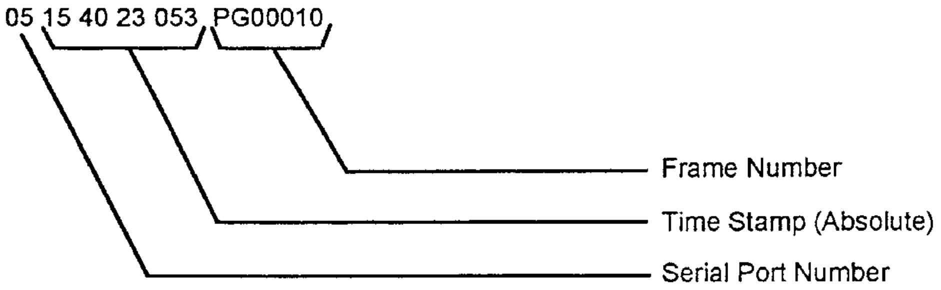


b. Relay Input Data Format

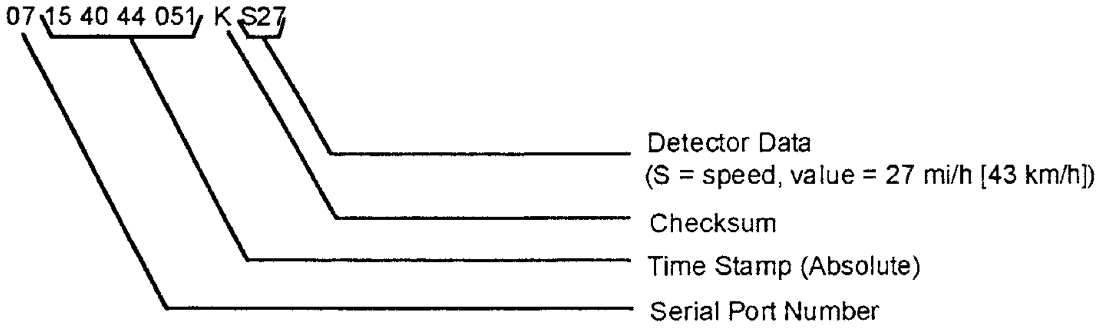


c. Optically Isolated Input Data Format

Figure C-5. Detector Input Data Formats as Recorded by Data Logger



d. Video Frame Data Format



e. RS-232 Serial Input Data Format

Figure C-5. Detector Input Data Formats as Recorded by Data Logger (continued)

REFERENCES

1. Klein, Lawrence A., MacCalden, Jr., M. Scot, and Mills, Milton, "Detection Technology for IVHS," Presented at IVHS AMERICA Third Annual Meeting, April 1993, Washington, D.C.

APPENDIX D.

CONCEPTUAL DESIGN OF AN FMCW MICROWAVE RADAR THAT RESOLVES MULTIPLE VEHICLES IN ITS FIELD OF VIEW

D.1 FMCW WAVEFORM PARAMETERS

The triangular FMCW (frequency-modulated continuous wave) waveform shown in Figure D-1 illustrates the vehicle range and speed information contained in the received signal. The range information is contained in the instantaneous frequency difference Δf between the backscattered signal received at the radar (corresponding to the frequency transmitted at time t_1) and the radar's present transmitted frequency (corresponding to the frequency at time t_2). In the absence of Doppler frequencies, the frequency difference is the same for the upsweeps and downsweeps of the waveform and is proportional to the time delay T between transmission of a segment of the waveform and the reception of the backscattered signal from that same segment.

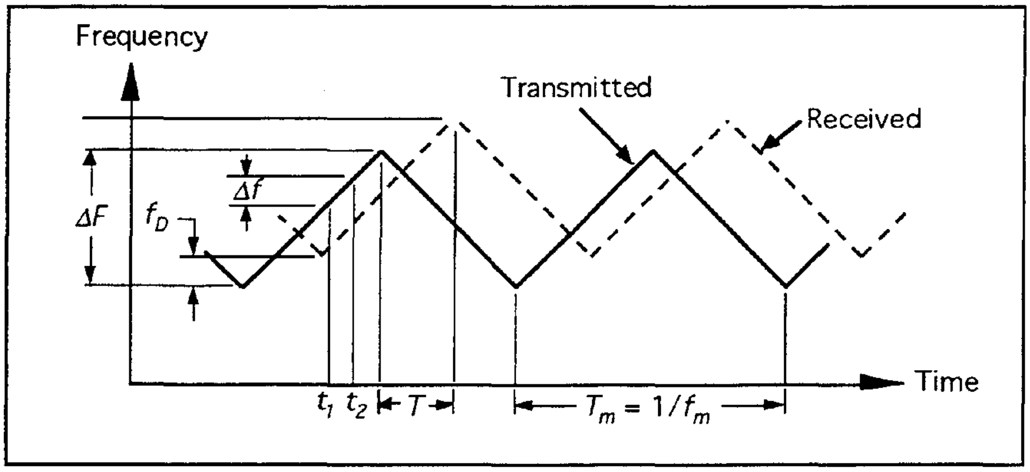


Figure D-1. Two-Segment FMCW Waveform and Defining Parameters

Thus,

$$\Delta f = \frac{2\,\Delta F\,T}{T_m} \tag{D-1}$$

where

ΔF = radio frequency (RF) modulation bandwidth equal to the difference between the highest f_H and lowest f_L frequencies in the transmitted wave and

T_m = modulation period.

The range R is calculated from the waveform parameters as

$$R = \frac{c\Delta f}{4\Delta F f_m} \tag{D-2}$$

where c is the speed of light and f_m is the RF modulation rate equal to $1/T_m$. Equations D-1 and D-2 can be derived from one another by using the relation

$$R = c\ T/2 \tag{D-3}$$

A Doppler-shifted target modifies the received waveform by producing two difference frequencies as shown in the figure, one for the upsweep δf_u and one for the downsweep δf_d. The frequencies δ_u and δf_d contain both the Doppler shift frequency and the frequency shift caused by target range.

When the Doppler shift is smaller than the range shift, δf_u represents the difference between the range and Doppler frequencies, and δf_d represents the sum of the two frequencies. Assuming the slopes of the two sweeps are additive inverses (equal magnitudes, different signs) leads to the calculation of the Doppler shift frequency component f_D and range shift frequency component Δf as

$$f_D = (\delta f_d - \delta f_u)/2 \qquad (D-4)$$

$$\Delta f = (\delta f_d + \delta f_u)/2 \qquad (D-5)$$

D.2 RESOLVING MULTIPLE VEHICLES IN THE FOOTPRINT

If two or more vehicles are present in the radar antenna footprint, then each produces a backscatter signal at the radar with each signal having a unique instantaneous frequency difference. The composite signal is the sum of the backscattered signals. A spectrum analysis of the upsweep and downsweep frequency differences gives the individual vehicles in different frequency bins, assuming they are resolvable in range and Doppler frequency. An example of such spectra is given in Figure D-2.(1)

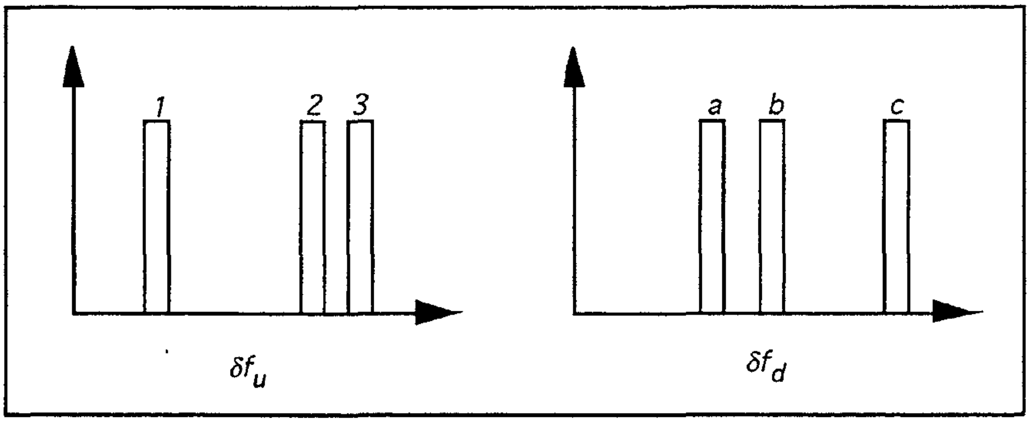


Figure D-2. Spectra Corresponding to Upsweep and Downsweep Frequencies

As shown, the spectra do not contain information that links an upsweep difference frequency (*1, 2, 3*) to a downsweep difference frequency (*a, b, c*). Therefore, vehicles detected by a waveform of the type shown in Figure D-1 produce scrambled return signals. To unscramble the information, an unmodulated third waveform segment is added. The Doppler shifts of the multiple vehicles are obtained from a spectrum analysis of the returns produced by the unmodulated continuous wave segment. Then through trial-and-error pairing of the upsweep and downsweep difference frequencies, pairings are found that produce the same Doppler shifts as the unmodulated waveform segment.

The following example illustrates this concept. Suppose that the radar illumination waveform is as shown in Figure D-3. Each sweep segment is 167 µs in duration. This corresponds to a Doppler resolution of 6000 Hz, more than three times that produced by a vehicle traveling at 96.6 km/h (60 mi/h) illuminated by a radar operating at a center frequency of 10.525 GHz. The RF bandwidth is 45 MHz to lie within the Federal Communications Commission (FCC) limit of 50 MHz.

Suppose the spectrum analysis of the upsweep shows three echoes at 70.433 kHz, 88.276 kHz, and 106.12 kHz; the downsweep three echoes at 73.567 kHz, 91.724 kHz, and 109.88 kHz; and the unmodulated segment three echoes at 1567 Hz, 1724 Hz, and 1880 Hz. The task is to find the range and speed of the three vehicles.

It is known from the unmodulated waveform segment that three Doppler shifts are present: 1567 Hz, 1724 Hz, and 1880 Hz. Assume the upsweep frequency of 70.433 kHz is paired with the downsweep frequency of 91.724 kHz. From equation D-4, the Doppler shift of this pairing is 10.645 kHz. This does not match one of the known Doppler shifts and, therefore, this pairing must be incorrect. Next, we pair the 70.433-kHz upsweep with the 73.567-kHz downsweep. This gives a Doppler shift of 1567 Hz, which is one of the known Doppler frequencies. This pairing could, therefore, be correct. As a check, pairing the 88.276-kHz upsweep with the 91.724-kHz downsweep gives a Doppler of 1724 Hz that is, again, one of the known Doppler frequencies. The final pairing of the 106.12-kHz upsweep with the 109.88-kHz downsweep gives the last Doppler frequency.

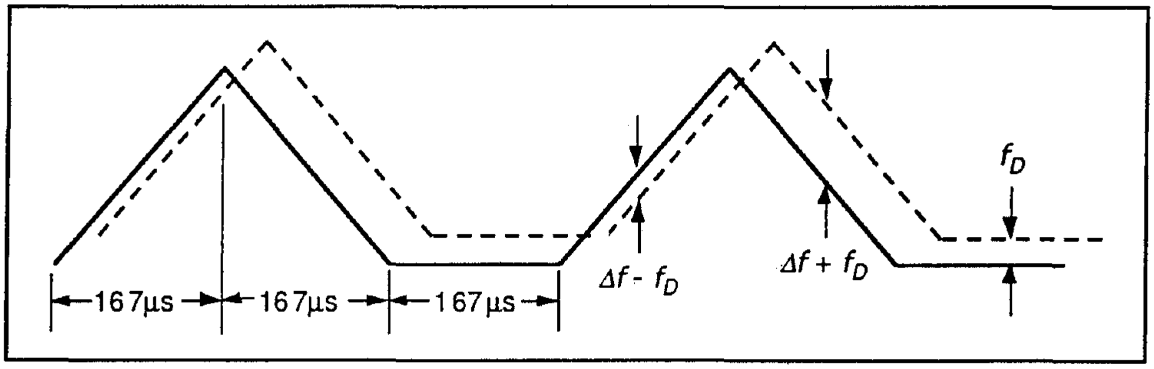


Figure D-3. Three-Segment Linear FM Waveform

The range to the vehicles can be calculated from the paired upsweep and downsweep frequencies using equations D-5 and D-2. Thus, the range to the vehicle with the 1567-Hz Doppler shift is 40 m, to the vehicle with the 1724-Hz Doppler is 50 m, and to the vehicle with the 1880-Hz Doppler is 60 m.

The radial velocity v_R of the vehicles is found by converting the Doppler frequency to velocity using

$$v_R = \frac{cf_D}{2f} \qquad (D\text{-}6)$$

where f is the transmitted frequency of 10.525 GHz. Applying this equation gives speeds of 22.3 m/s (50 mi/h), 24.6 m/s (55 mi/h), and 26.8 m/s (60 mi/h) for the three vehicles, respectively.

REFERENCES

1. Edde, Byron, *Radar: Principles, Technology, Applications*, PTR Prentice Hall, Englewood Cliffs, NJ, 1993.

APPENDIX E.

PIPE TREE INSTALLATION AND INTERSECTION PLAN-VIEW DRAWINGS FOR MINNEAPOLIS SITES

This appendix contains portions of the drawings made for attaching the pipe trees to the overpass at I-4 and Penn Avenue and the sign bridge at Olson Highway and Lyndale Avenue North. Plan-view drawings of the two sites are also provided.

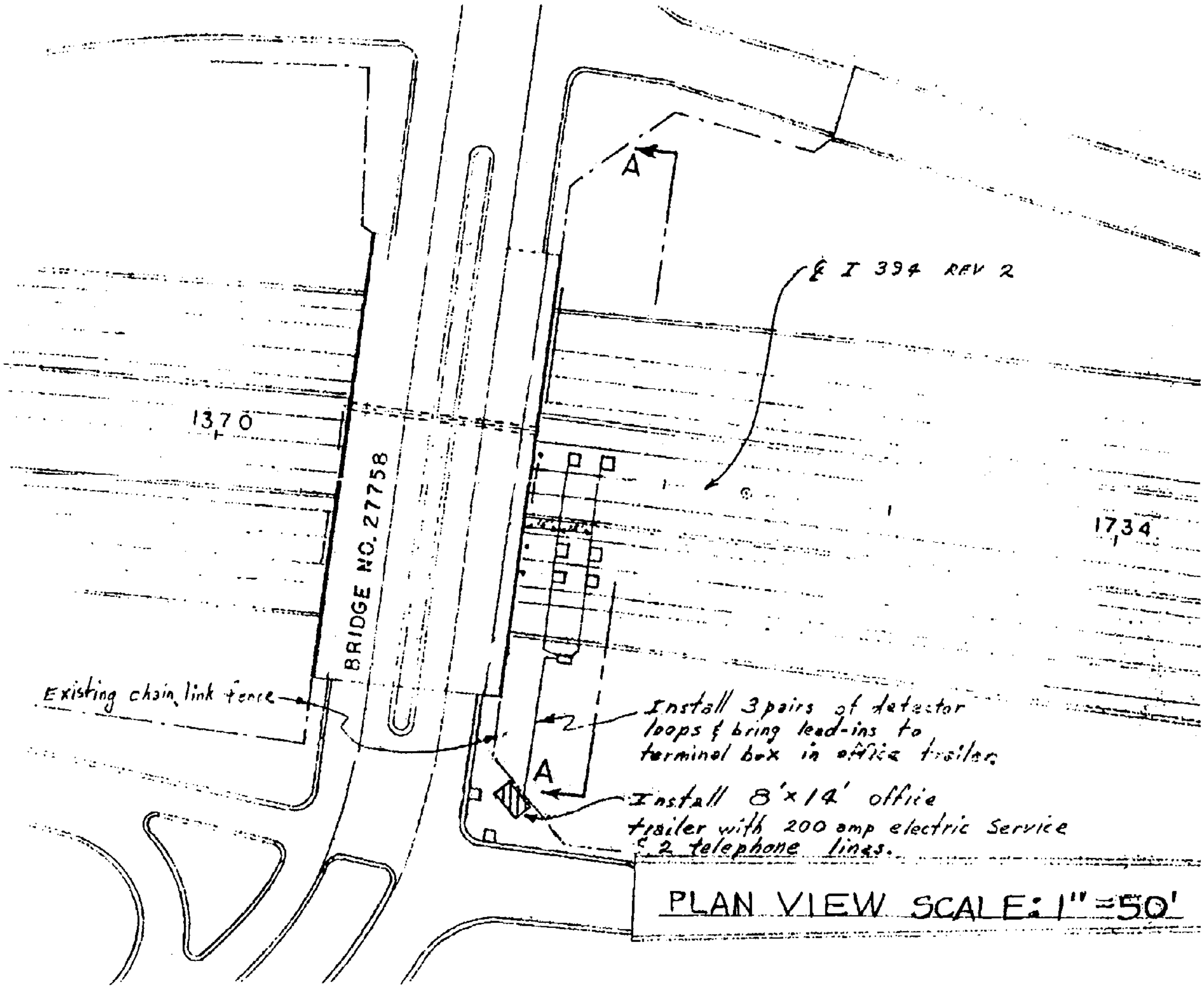
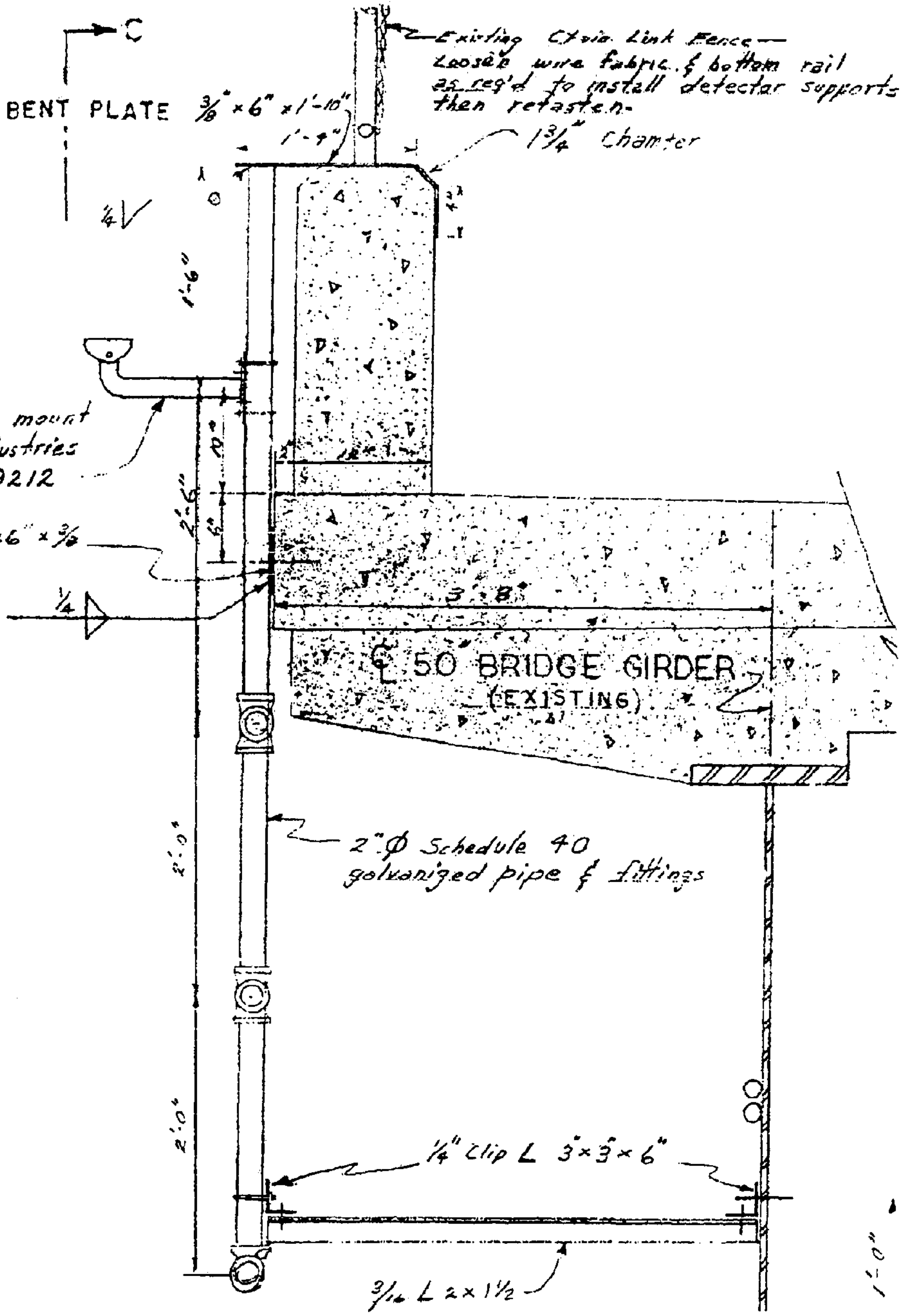
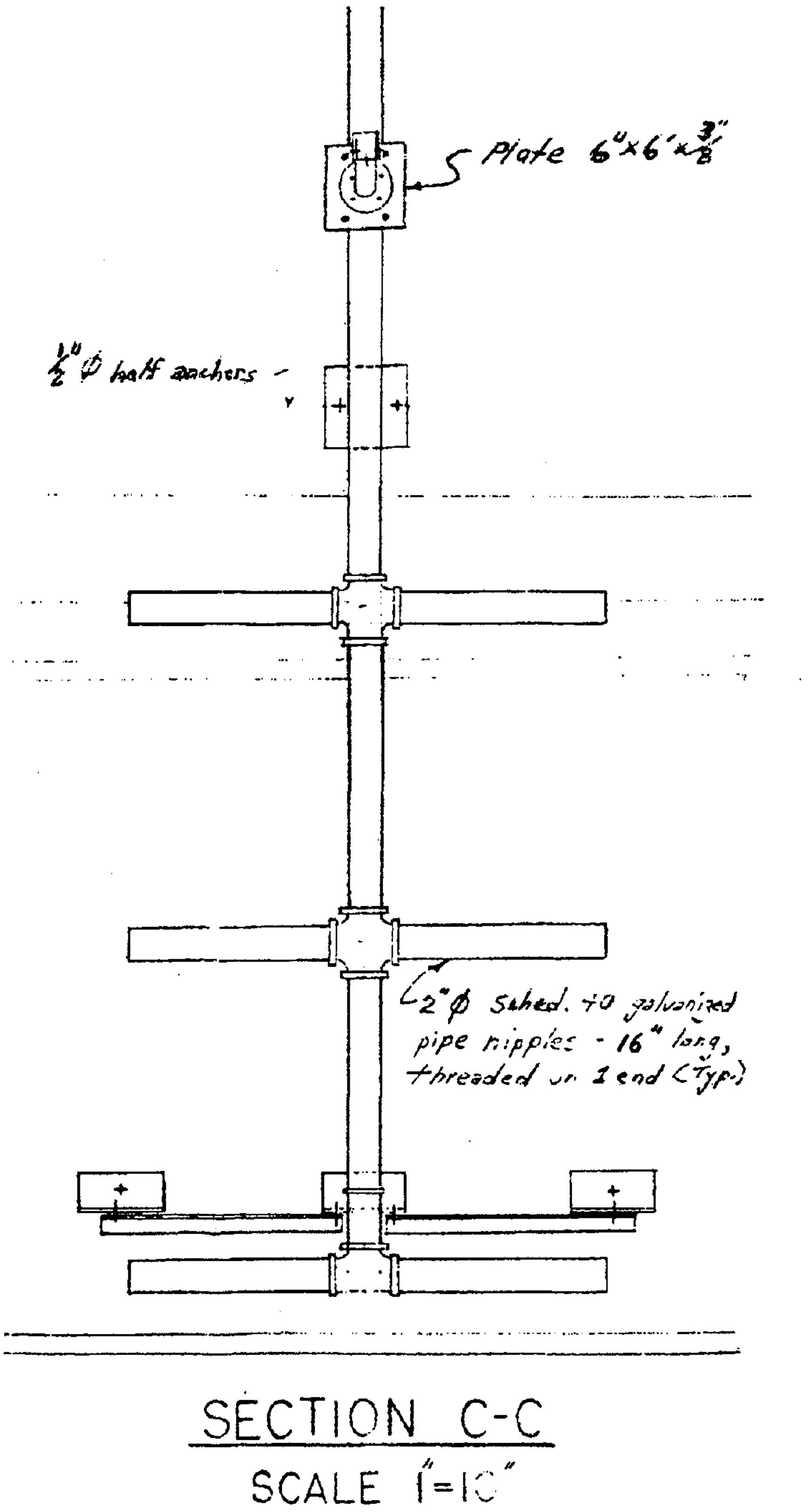


Figure E-1. Plan View of I-394 and Penn Avenue Site



1 in = 25.4 mm
1 ft = 0.305 m

Figure E-2. Mounting of Pipe Trees to Penn Avenue Bridge Girder



1 in = 25.4 mm
1 ft = 0.305 m

Figure E-3. Pipe Tree Detail

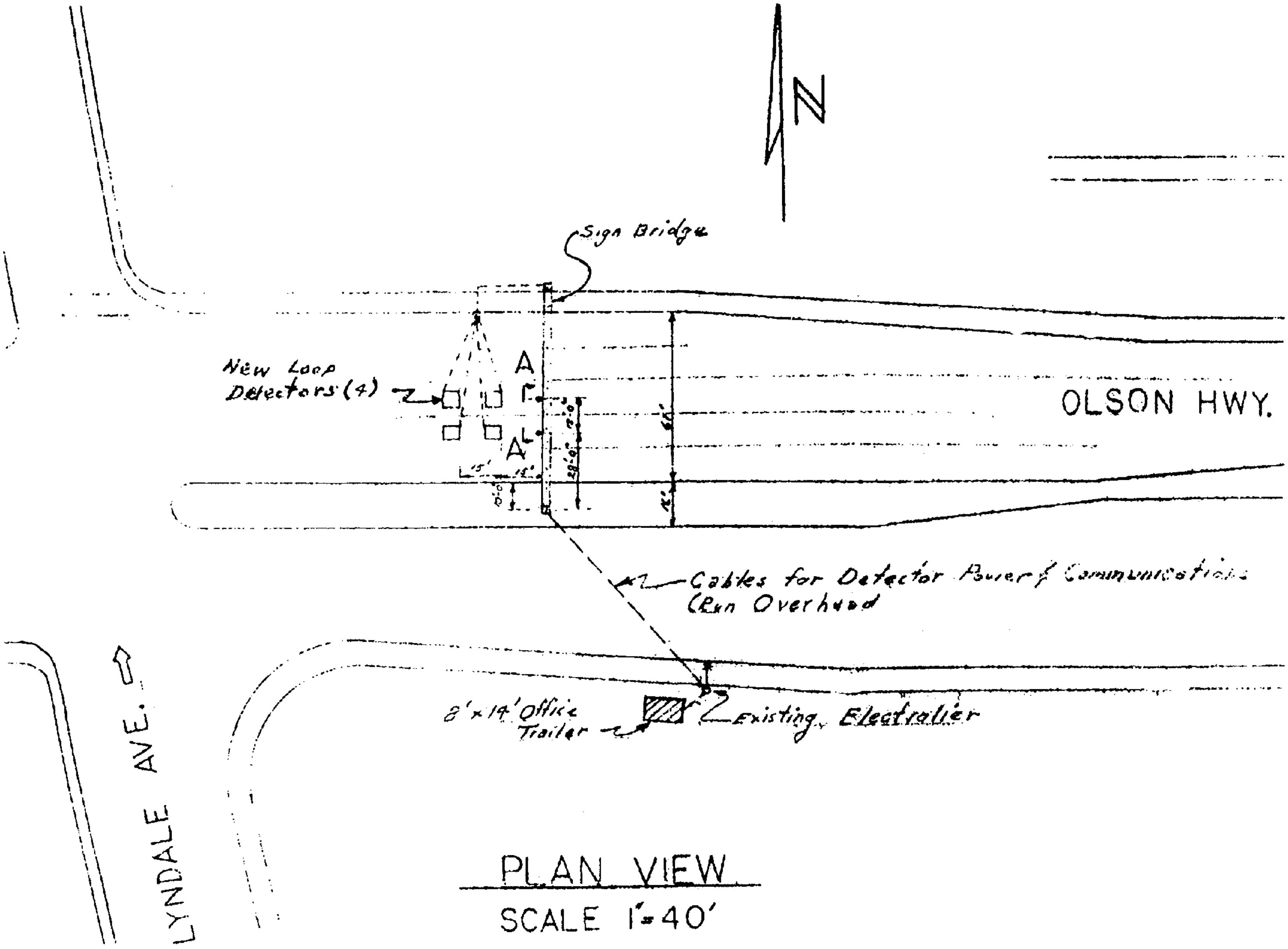


Figure E-4. Plan View of Olson Highway and Lyndale Avenue North Site

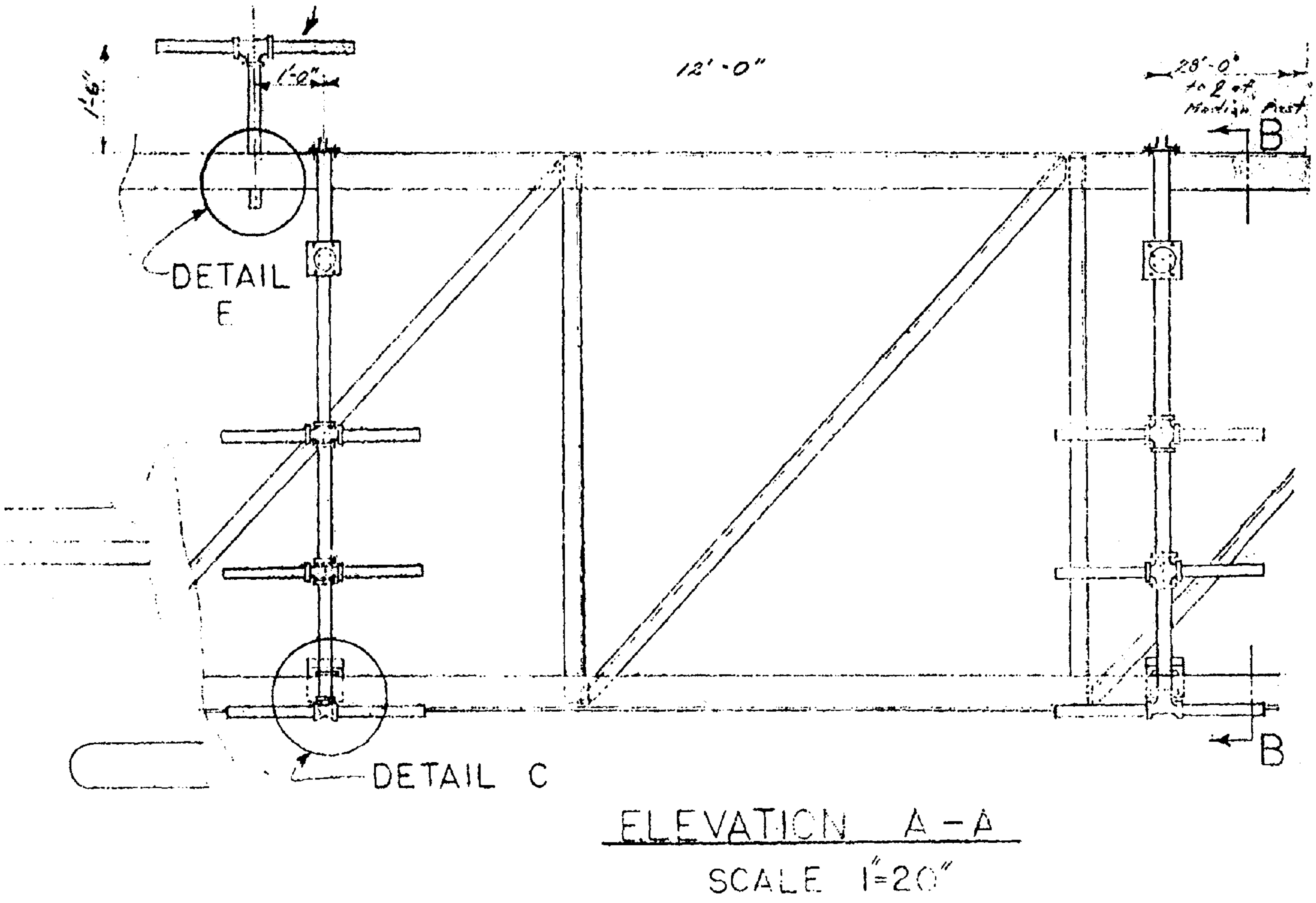


Figure E-5. Sign Bridge Structure Over Olson Highway Showing Attachment of Pipe Trees

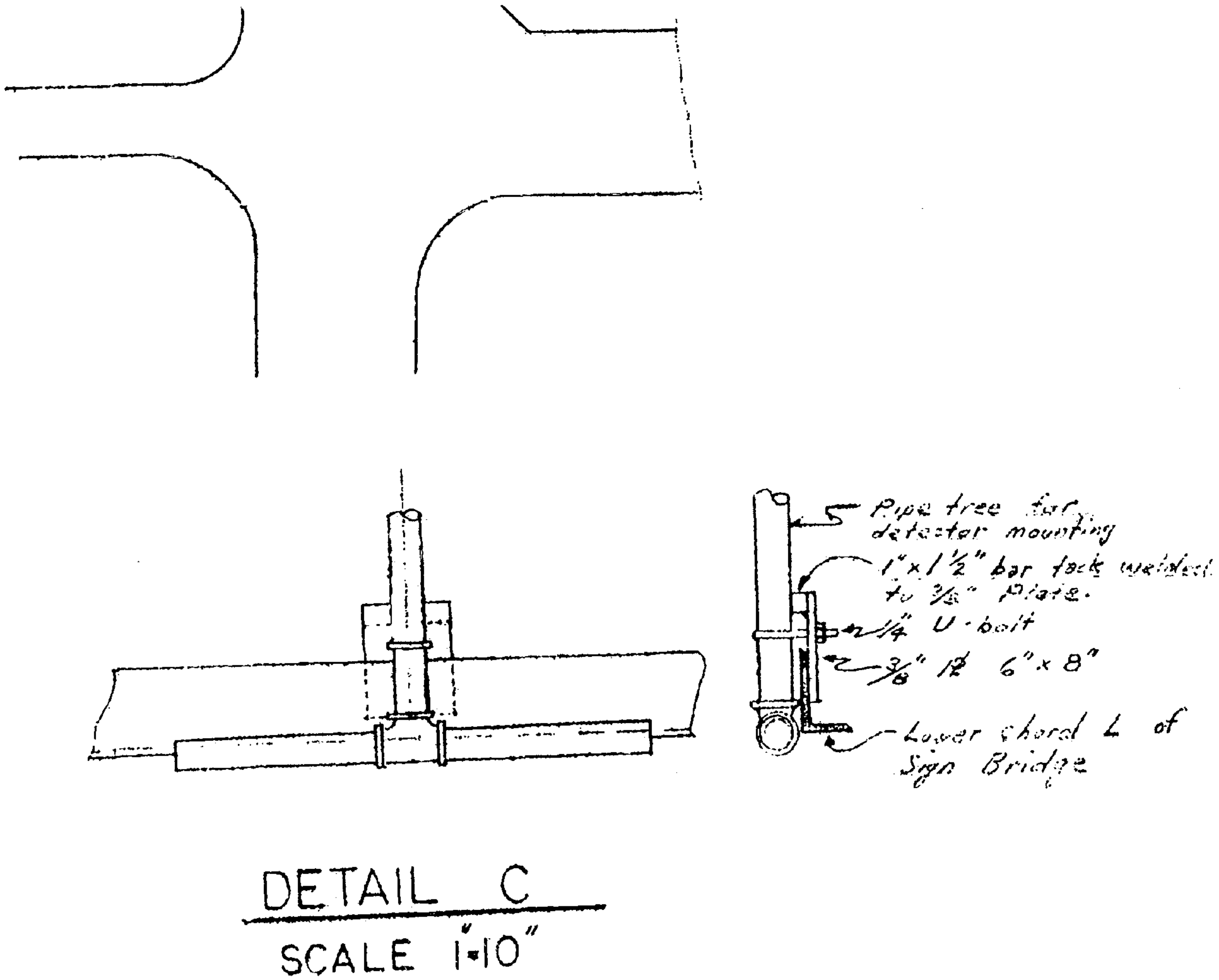


Figure E-6. Attachment of Pipe Trees to Lower Horizontal Bar of Sign Bridge

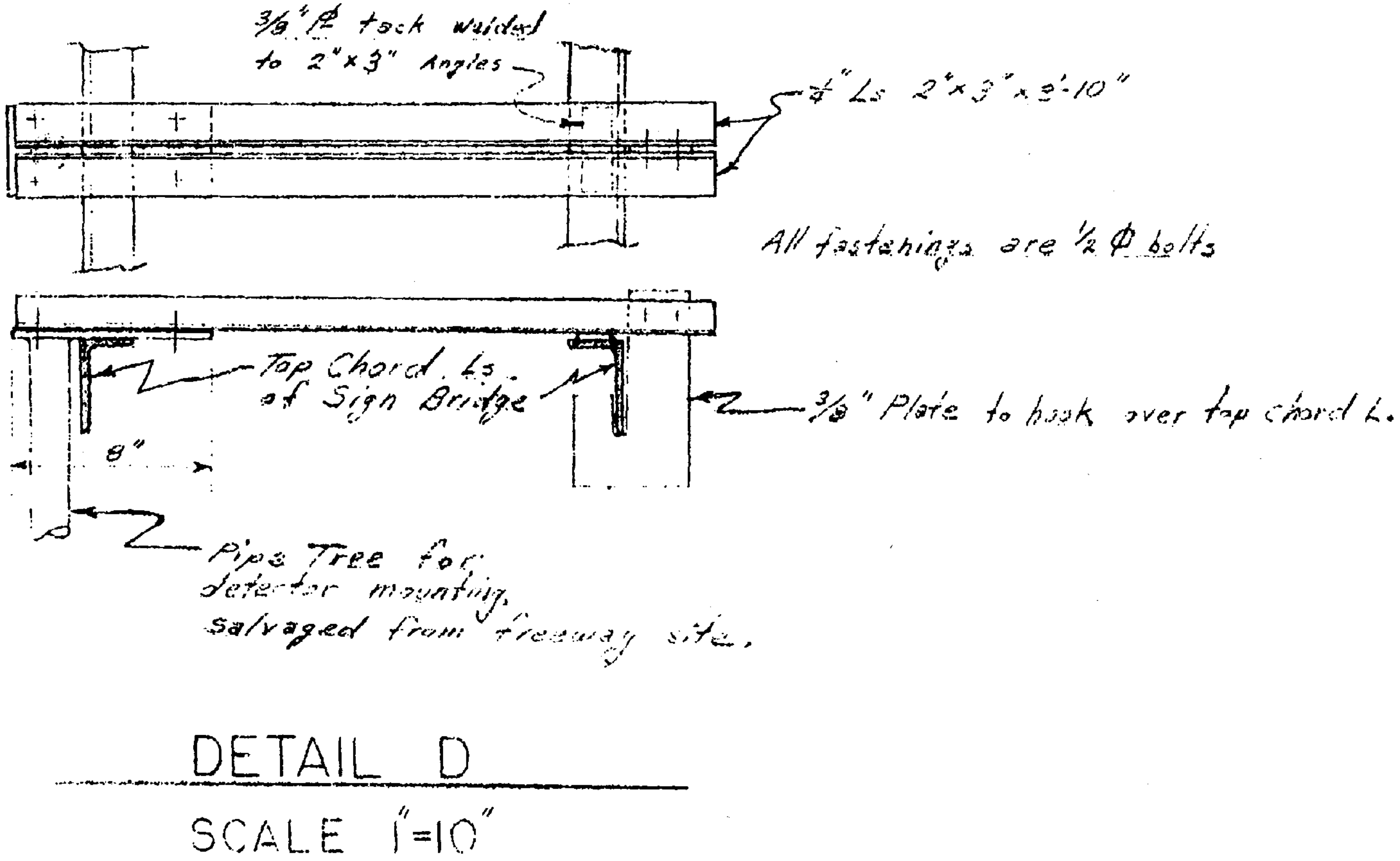
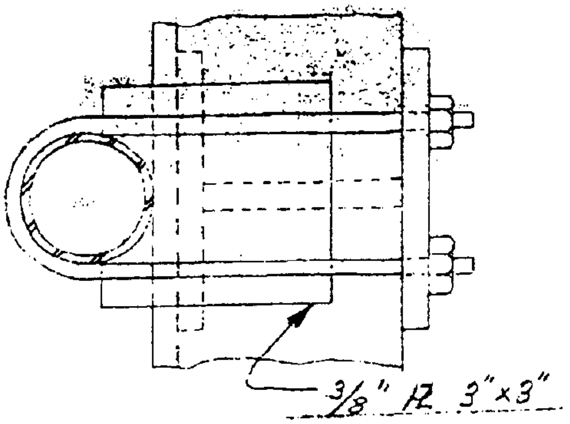
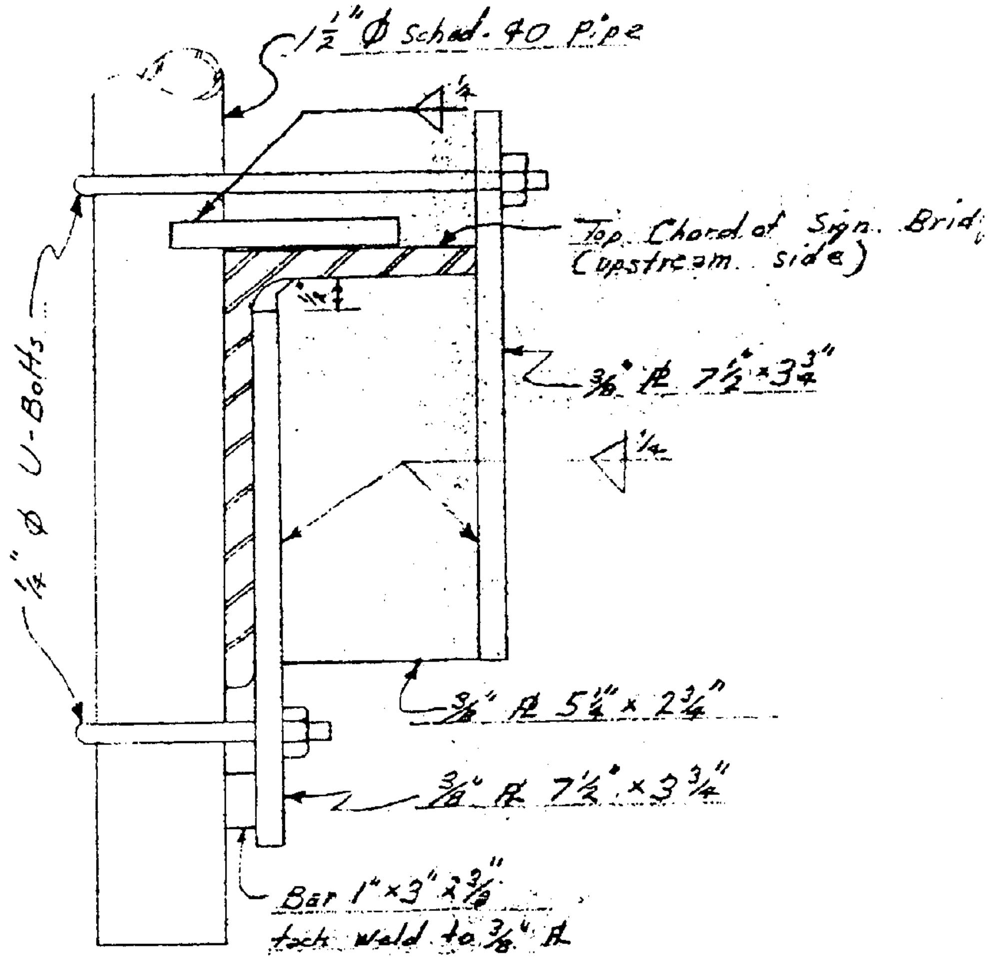


Figure E-7. Detail of Upper Horizontal Bar of Sign Bridge

SCALE 1"=40





DETAIL E

SCALE 1"=2"

1 in = 25.4 mm
1 ft = 0.305 m

Figure E-8. Attachment of Pipe Tree to Upper Horizontal Bar of Sign Bridge

APPENDIX F.

DETECTOR FOOTPRINTS AS A FUNCTION OF APERTURE BEAMWIDTH, MOUNTING HEIGHT, AND ANGLE OF INCIDENCE

The theoretical azimuth and elevation ground footprint areas of the detectors are given in the following tables as a function of mounting height, azimuth and elevation aperture beamwidth, and angle of incidence (with respect to nadir). The detectors for which these data are available are the TC-20, TC-26, TDN-30, TDW-10, RTMS-X1, TC-30C, SDU-200 (RDU-101), SDU-300, and the 780D1000 (Autosense I).

The data in the tables were generated at more viewing angles and mounting heights than were actually used in the laboratory tests so that a database of detector footprints would be available for future applications or tests.

The azimuth footprint length L_{az} is calculated from

$$L_{az} = (2H \tan \theta_{az}/2)/\cos \theta \qquad \text{(F-1)}$$

where

H = detector mounting height above the highway surface,

θ_{az} = 3-dB azimuth beamwidth corresponding to the detector aperture,

θ = viewing angle with respect to nadir.

The elevation footprint length L_{el} is calculated from

$$L_{el} = H[\tan(\theta + \theta_{el}/2) - \tan(\theta - \theta_{el}/2)] \qquad \text{(F-2)}$$

where

θ_{el} = 3-dB elevation beamwidth corresponding to the detector aperture.

The first term in equation F-2 gives the maximum range in the elevation plane and the second term gives the minimum range in the elevation plane.

The 3-dB beamwidths were obtained from the detector manufacturers, either from data sheets or from telephone conversations.

			Microwave Sensors TC-20 & TC-26					
Mounting Height (Feet)	Viewing Angle (deg)	Azimuth 3dB BW (deg)	Azimuth Footprint (Feet)		Elevation 3dB BW (deg)	Maximum Range (Feet)	Minimum Range (Feet)	Elevation Footprint (Feet)
10.0	20.0	16.0	3.0		15.0	5.2	2.2	3.0
12.0	20.0	16.0	3.6		15.0	6.2	2.7	3.6
15.0	20.0	16.0	4.5		15.0	7.8	3.3	4.5
17.0	20.0	16.0	5.1		15.0	8.8	3.8	5.1
20.0	20.0	16.0	6.0		15.0	10.4	4.4	6.0
22.0	20.0	16.0	6.6		15.0	11.5	4.9	6.6
25.0	20.0	16.0	7.5		15.0	13.0	5.5	7.5
30.0	20.0	16.0	9.0		15.0	15.6	6.7	9.0
Mounting Height (Feet)	Viewing Angle (deg)	Azimuth 3dB BW (deg)	Azimuth Footprint (Feet)		Elevation 3dB BW (deg)	Maximum Range (Feet)	Minimum Range (Feet)	Elevation Footprint (Feet)
10.0	30.0	16.0	3.2		15.0	7.7	4.1	3.5
12.0	30.0	16.0	3.9		15.0	9.2	5.0	4.2
15.0	30.0	16.0	4.9		15.0	11.5	6.2	5.3
17.0	30.0	16.0	5.5		15.0	13.0	7.0	6.0
20.0	30.0	16.0	6.5		15.0	15.3	8.3	7.1
22.0	30.0	16.0	7.1		15.0	16.9	9.1	7.8
25.0	30.0	16.0	8.1		15.0	19.2	10.4	8.8
30.0	30.0	16.0	9.7		15.0	23.0	12.4	10.6
Mounting Height (Feet)	Viewing Angle (deg)	Azimuth 3dB BW (deg)	Azimuth Footprint (Feet)		Elevation 3dB BW (deg)	Maximum Range (Feet)	Minimum Range (Feet)	Elevation Footprint (Feet)
10.0	45.0	16.0	4.0		15.0	13.0	7.7	5.4
12.0	45.0	16.0	4.8		15.0	15.6	9.2	6.4
15.0	45.0	16.0	6.0		15.0	19.5	11.5	8.0
17.0	45.0	16.0	6.8		15.0	22.2	13.0	9.1
20.0	45.0	16.0	8.0		15.0	26.1	15.3	10.7
22.0	45.0	16.0	8.7		15.0	28.7	16.9	11.8
25.0	45.0	16.0	9.9		15.0	32.6	19.2	13.4
30.0	45.0	16.0	11.9		15.0	39.1	23.0	16.1
Mounting Height (Feet)	Viewing Angle (deg)	Azimuth 3dB BW (deg)	Azimuth Footprint (Feet)		Elevation 3dB BW (deg)	Maximum Range (Feet)	Minimum Range (Feet)	Elevation Footprint (Feet)
10.0	70.0	16.0	8.2		15.0	45.1	19.2	25.9
12.0	70.0	16.0	9.9		15.0	54.1	23.1	31.1
15.0	70.0	16.0	12.3		15.0	67.7	28.8	38.8
17.0	70.0	16.0	14.0		15.0	76.7	32.7	44.0
20.0	70.0	16.0	16.4		15.0	90.2	38.4	51.8
22.0	70.0	16.0	18.1		15.0	99.2	42.3	57.0
25.0	70.0	16.0	20.5		15.0	112.8	48.0	64.7
30.0	70.0	16.0	24.7		15.0	135.3	57.6	77.7

1 ft = 0.305 m

			Whelen TDN-30					
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	20.0	7.0	1.3		7.0	4.3	3.0	1.4
12.0	20.0	7.0	1.6		7.0	5.2	3.6	1.7
15.0	20.0	7.0	2.0		7.0	6.5	4.4	2.1
17.0	20.0	7.0	2.2		7.0	7.4	5.0	2.4
20.0	20.0	7.0	2.6		7.0	8.7	5.9	2.8
22.0	20.0	7.0	2.9		7.0	9.6	6.5	3.0
25.0	20.0	7.0	3.3		7.0	10.9	7.4	3.5
30.0	20.0	7.0	3.9		7.0	13.0	8.9	4.2
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	30.0	7.0	1.4		7.0	6.6	5.0	1.6
12.0	30.0	7.0	1.7		7.0	7.9	6.0	2.0
15.0	30.0	7.0	2.1		7.0	9.9	7.5	2.4
17.0	30.0	7.0	2.4		7.0	11.3	8.5	2.8
20.0	30.0	7.0	2.8		7.0	13.2	10.0	3.3
22.0	30.0	7.0	3.1		7.0	14.6	11.0	3.6
25.0	30.0	7.0	3.5		7.0	16.5	12.5	4.1
30.0	30.0	7.0	4.2		7.0	19.9	15.0	4.9
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	45.0	7.0	1.7		7.0	11.3	8.8	2.5
12.0	45.0	7.0	2.1		7.0	13.6	10.6	2.9
15.0	45.0	7.0	2.6		7.0	17.0	13.3	3.7
17.0	45.0	7.0	2.9		7.0	19.2	15.0	4.2
20.0	45.0	7.0	3.5		7.0	22.6	17.7	4.9
22.0	45.0	7.0	3.8		7.0	24.9	19.5	5.4
25.0	45.0	7.0	4.3		7.0	28.3	22.1	6.1
30.0	45.0	7.0	5.2		7.0	33.9	26.5	7.4
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	70.0	7.0	3.6		7.0	33.8	23.0	10.8
12.0	70.0	7.0	4.3		7.0	40.5	27.6	12.9
15.0	70.0	7.0	5.4		7.0	50.6	34.5	16.1
17.0	70.0	7.0	6.1		7.0	57.4	39.1	18.3
20.0	70.0	7.0	7.2		7.0	67.5	46.0	21.5
22.0	70.0	7.0	7.9		7.0	74.3	50.6	23.7
25.0	70.0	7.0	8.9		7.0	84.4	57.5	26.9
30.0	70.0	7.0	10.7		7.0	101.3	69.0	32.3

1 ft = 0.305 m

			Whelen TDW-10					
Mounting	**Viewing**	**Azimuth**	**Azimuth**		**Elevation**	**Maximum**	**Minimum**	**Elevation**
Height	**Angle**	**3dB BW**	**Footprint**		**3dB BW**	**Range**	**Range**	**Footprint**
(Feet)	**(deg)**	**(deg)**	**(Feet)**		**(deg)**	**(Feet)**	**(Feet)**	**(Feet)**
10.0	20.0	25.0	4.7		25.0	6.4	1.3	5.1
12.0	20.0	25.0	5.7		25.0	7.6	1.6	6.1
15.0	20.0	25.0	7.1		25.0	9.6	2.0	7.6
17.0	20.0	25.0	8.0		25.0	10.8	2.2	8.6
20.0	20.0	25.0	9.4		25.0	12.7	2.6	10.1
22.0	20.0	25.0	10.4		25.0	14.0	2.9	11.1
25.0	20.0	25.0	11.8		25.0	15.9	3.3	12.6
30.0	20.0	25.0	14.2		25.0	19.1	3.9	15.2
Mounting	**Viewing**	**Azimuth**	**Azimuth**		**Elevation**	**Maximum**	**Minimum**	**Elevation**
Height	**Angle**	**3dB BW**	**Footprint**		**3dB BW**	**Range**	**Range**	**Footprint**
(Feet)	**(deg)**	**(deg)**	**(Feet)**		**(deg)**	**(Feet)**	**(Feet)**	**(Feet)**
10.0	30.0	25.0	5.1		25.0	9.2	3.2	6.0
12.0	30.0	25.0	6.1		25.0	11.0	3.8	7.2
15.0	30.0	25.0	7.7		25.0	13.7	4.7	9.0
17.0	30.0	25.0	8.7		25.0	15.6	5.4	10.2
20.0	30.0	25.0	10.2		25.0	18.3	6.3	12.0
22.0	30.0	25.0	11.3		25.0	20.2	6.9	13.2
25.0	30.0	25.0	12.8		25.0	22.9	7.9	15.0
30.0	30.0	25.0	15.4		25.0	27.5	9.5	18.0
Mounting	**Viewing**	**Azimuth**	**Azimuth**		**Elevation**	**Maximum**	**Minimum**	**Elevation**
Height	**Angle**	**3dB BW**	**Footprint**		**3dB BW**	**Range**	**Range**	**Footprint**
(Feet)	**(deg)**	**(deg)**	**(Feet)**		**(deg)**	**(Feet)**	**(Feet)**	**(Feet)**
10.0	45.0	25.0	6.3		25.0	15.7	6.4	9.3
12.0	45.0	25.0	7.5		25.0	18.8	7.6	11.2
15.0	45.0	25.0	9.4		25.0	23.5	9.6	14.0
17.0	45.0	25.0	10.7		25.0	26.7	10.8	15.9
20.0	45.0	25.0	12.5		25.0	31.4	12.7	18.7
22.0	45.0	25.0	13.8		25.0	34.5	14.0	20.5
25.0	45.0	25.0	15.7		25.0	39.2	15.9	23.3
30.0	45.0	25.0	18.8		25.0	47.1	19.1	28.0
Mounting	**Viewing**	**Azimuth**	**Azimuth**		**Elevation**	**Maximum**	**Minimum**	**Elevation**
Height	**Angle**	**3dB BW**	**Footprint**		**3dB BW**	**Range**	**Range**	**Footprint**
(Feet)	**(deg)**	**(deg)**	**(Feet)**		**(deg)**	**(Feet)**	**(Feet)**	**(Feet)**
10.0	70.0	25.0	13.0		25.0	76.0	15.7	60.3
12.0	70.0	25.0	15.6		25.0	91.1	18.8	72.3
15.0	70.0	25.0	19.4		25.0	113.9	23.5	90.4
17.0	70.0	25.0	22.0		25.0	129.1	26.7	102.4
20.0	70.0	25.0	25.9		25.0	151.9	31.4	120.5
22.0	70.0	25.0	28.5		25.0	167.1	34.5	132.6
25.0	70.0	25.0	32.4		25.0	189.9	39.2	150.7
30.0	70.0	25.0	38.9		25.0	227.9	47.1	180.8

1 ft = 0.305 m

Electronic Integrated Systems RTMS-X1

(Operating range is up to 200 ft (El) with resolution of 7 ft in 12 detection zones)

Mounting Height (Feet)	Viewing Angle (deg)	Azimuth 3dB BW (deg)	Azimuth Footprint (Feet)		Effective Elevation BW (deg)	Maximum Range (Feet)	Minimum Range (Feet)	Elevation Footprint (Feet)
10.0	20.0	15.0	2.8		50.0	10.0	-0.9	10.9
12.0	20.0	15.0	3.4		50.0	12.0	-1.0	13.0
15.0	20.0	15.0	4.2		50.0	15.0	-1.3	16.3
17.0	20.0	15.0	4.8		50.0	17.0	-1.5	18.5
20.0	20.0	15.0	5.6		50.0	20.0	-1.7	21.7
22.0	20.0	15.0	6.2		50.0	22.0	-1.9	23.9
25.0	20.0	15.0	7.0		50.0	25.0	-2.2	27.2
30.0	20.0	15.0	8.4		50.0	30.0	-2.6	32.6
Mounting Height (Feet)	Viewing Angle (deg)	Azimuth 3dB BW (deg)	Azimuth Footprint (Feet)		Effective Elevation BW (deg)	Maximum Range (Feet)	Minimum Range (Feet)	Elevation Footprint (Feet)
10.0	30.0	15.0	3.0		50.0	14.3	0.9	13.4
12.0	30.0	15.0	3.6		50.0	17.1	1.0	16.1
15.0	30.0	15.0	4.6		50.0	21.4	1.3	20.1
17.0	30.0	15.0	5.2		50.0	24.3	1.5	22.8
20.0	30.0	15.0	6.1		50.0	28.6	1.7	26.8
22.0	30.0	15.0	6.7		50.0	31.4	1.9	29.5
25.0	30.0	15.0	7.6		50.0	35.7	2.2	33.5
30.0	30.0	15.0	9.1		50.0	42.8	2.6	40.2
Mounting Height (Feet)	Viewing Angle (deg)	Azimuth 3dB BW (deg)	Azimuth Footprint (Feet)		Effective Elevation BW (deg)	Maximum Range (Feet)	Minimum Range (Feet)	Elevation Footprint (Feet)
10.0	45.0	15.0	3.7		50.0	27.5	3.6	23.8
12.0	45.0	15.0	4.5		50.0	33.0	4.4	28.6
15.0	45.0	15.0	5.6		50.0	41.2	5.5	35.8
17.0	45.0	15.0	6.3		50.0	46.7	6.2	40.5
20.0	45.0	15.0	7.4		50.0	54.9	7.3	47.7
22.0	45.0	15.0	8.2		50.0	60.4	8.0	52.4
25.0	45.0	15.0	9.3		50.0	68.7	9.1	59.6
30.0	45.0	15.0	11.2		50.0	82.4	10.9	71.5
Mounting Height (Feet)	Viewing Angle (deg)	Azimuth 3dB BW (deg)	Azimuth Footprint (Feet)		Effective Elevation BW (deg)	Maximum Range (Feet)	Minimum Range (Feet)	Elevation Footprint (Feet)
10.0	60.0	15.0	5.3		50.0	114.3	7.0	107.3
12.0	60.0	15.0	6.3		50.0	137.2	8.4	128.8
15.0	60.0	15.0	7.9		50.0	171.5	10.5	160.9
17.0	60.0	15.0	9.0		50.0	194.3	11.9	182.4
20.0	60.0	15.0	10.5		50.0	228.6	14.0	214.6
22.0	60.0	15.0	11.6		50.0	251.5	15.4	236.1
25.0	60.0	15.0	13.2		50.0	285.8	17.5	268.2
30.0	60.0	15.0	15.8		50.0	342.9	21.0	321.9

1 ft = 0.305 m

			Microwave Sensors TC-30C					
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	0.0	20.0	3.5		20.0	1.8	-1.8	3.5
12.0	0.0	20.0	4.2		20.0	2.1	-2.1	4.2
15.0	0.0	20.0	5.3		20.0	2.6	-2.6	5.3
17.0	0.0	20.0	6.0		20.0	3.0	-3.0	6.0
20.0	0.0	20.0	7.1		20.0	3.5	-3.5	7.1
22.0	0.0	20.0	7.8		20.0	3.9	-3.9	7.8
25.0	0.0	20.0	8.8		20.0	4.4	-4.4	8.8
30.0	0.0	20.0	10.6		20.0	5.3	-5.3	10.6
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	20.0	20.0	3.8		20.0	5.8	1.8	4.0
12.0	20.0	20.0	4.5		20.0	6.9	2.1	4.8
15.0	20.0	20.0	5.6		20.0	8.7	2.6	6.0
17.0	20.0	20.0	6.4		20.0	9.8	3.0	6.8
20.0	20.0	20.0	7.5		20.0	11.5	3.5	8.0
22.0	20.0	20.0	8.3		20.0	12.7	3.9	8.8
25.0	20.0	20.0	9.4		20.0	14.4	4.4	10.0
30.0	20.0	20.0	11.3		20.0	17.3	5.3	12.0
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	30.0	20.0	4.1		20.0	8.4	3.6	4.8
12.0	30.0	20.0	4.9		20.0	10.1	4.4	5.7
15.0	30.0	20.0	6.1		20.0	12.6	5.5	7.1
17.0	30.0	20.0	6.9		20.0	14.3	6.2	8.1
20.0	30.0	20.0	8.1		20.0	16.8	7.3	9.5
22.0	30.0	20.0	9.0		20.0	18.5	8.0	10.5
25.0	30.0	20.0	10.2		20.0	21.0	9.1	11.9
30.0	30.0	20.0	12.2		20.0	25.2	10.9	14.3
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	45.0	20.0	5.0		20.0	14.3	7.0	7.3
12.0	45.0	20.0	6.0		20.0	17.1	8.4	8.7
15.0	45.0	20.0	7.5		20.0	21.4	10.5	10.9
17.0	45.0	20.0	8.5		20.0	24.3	11.9	12.4
20.0	45.0	20.0	10.0		20.0	28.6	14.0	14.6
22.0	45.0	20.0	11.0		20.0	31.4	15.4	16.0
25.0	45.0	20.0	12.5		20.0	35.7	17.5	18.2
30.0	45.0	20.0	15.0		20.0	42.8	21.0	21.8
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	70.0	20.0	10.3		20.0	56.7	17.3	39.4
12.0	70.0	20.0	12.4		20.0	68.1	20.8	47.3
15.0	70.0	20.0	15.5		20.0	85.1	26.0	59.1
17.0	70.0	20.0	17.5		20.0	96.4	29.4	67.0
20.0	70.0	20.0	20.6		20.0	113.4	34.6	78.8
22.0	70.0	20.0	22.7		20.0	124.8	38.1	86.7
25.0	70.0	20.0	25.8		20.0	141.8	43.3	98.5
30.0	70.0	20.0	30.9		20.0	170.1	52.0	118.2

1 ft = 0.305 m

			Sumitomo Speed Detector SDU-200 (RDU-10					
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	20.0	15.0	2.8		15.0	5.2	2.2	3.0
12.0	20.0	15.0	3.4		15.0	6.2	2.7	3.6
15.0	20.0	15.0	4.2		15.0	7.8	3.3	4.5
17.0	20.0	15.0	4.8		15.0	8.8	3.8	5.1
20.0	20.0	15.0	5.6		15.0	10.4	4.4	6.0
22.0	20.0	15.0	6.2		15.0	11.5	4.9	6.6
25.0	20.0	15.0	7.0		15.0	13.0	5.5	7.5
30.0	20.0	15.0	8.4		15.0	15.6	6.7	9.0
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	30.0	15.0	3.0		15.0	7.7	4.1	3.5
12.0	30.0	15.0	3.6		15.0	9.2	5.0	4.2
15.0	30.0	15.0	4.6		15.0	11.5	6.2	5.3
17.0	30.0	15.0	5.2		15.0	13.0	7.0	6.0
20.0	30.0	15.0	6.1		15.0	15.3	8.3	7.1
22.0	30.0	15.0	6.7		15.0	16.9	9.1	7.8
25.0	30.0	15.0	7.6		15.0	19.2	10.4	8.8
30.0	30.0	15.0	9.1		15.0	23.0	12.4	10.6
Mounting Height (Feet)	Viewing Angle (deg)	Azimuth 3dB BW (deg)	Azimuth Footprint (Feet)		Elevation 3dB BW (deg)	Maximum Range (Feet)	Minimum Range (Feet)	Elevation Footprint (Feet)
10.0	45.0	15.0	3.7		15.0	13.0	7.7	5.4
12.0	45.0	15.0	4.5		15.0	15.6	9.2	6.4
15.0	45.0	15.0	5.6		15.0	19.5	11.5	8.0
17.0	45.0	15.0	6.3		15.0	22.2	13.0	9.1
20.0	45.0	15.0	7.4		15.0	26.1	15.3	10.7
22.0	45.0	15.0	8.2		15.0	28.7	16.9	11.8
25.0	45.0	15.0	9.3		15.0	32.6	19.2	13.4
30.0	45.0	15.0	11.2		15.0	39.1	23.0	16.1
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	70.0	15.0	7.7		15.0	45.1	19.2	25.9
12.0	70.0	15.0	9.2		15.0	54.1	23.1	31.1
15.0	70.0	15.0	11.5		15.0	67.7	28.8	38.8
17.0	70.0	15.0	13.1		15.0	76.7	32.7	44.0
20.0	70.0	15.0	15.4		15.0	90.2	38.4	51.8
22.0	70.0	15.0	16.9		15.0	99.2	42.3	57.0
25.0	70.0	15.0	19.2		15.0	112.8	48.0	64.7
30.0	70.0	15.0	23.1		15.0	135.3	57.6	77.7

1 ft = 0.305 m

			Sumitomo Presence Detector SDU-300					
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	0.0	13.0	2.3		13.0	1.1	-1.1	2.3
12.0	0.0	13.0	2.7		13.0	1.4	-1.4	2.7
15.0	0.0	13.0	3.4		13.0	1.7	-1.7	3.4
17.0	0.0	13.0	3.9		13.0	1.9	-1.9	3.9
20.0	0.0	13.0	4.6		13.0	2.3	-2.3	4.6
22.0	0.0	13.0	5.0		13.0	2.5	-2.5	5.0
25.0	0.0	13.0	5.7		13.0	2.8	-2.8	5.7
30.0	0.0	13.0	6.8		13.0	3.4	-3.4	6.8
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	20.0	13.0	2.4		13.0	5.0	2.4	2.6
12.0	20.0	13.0	2.9		13.0	6.0	2.9	3.1
15.0	20.0	13.0	3.6		13.0	7.5	3.6	3.9
17.0	20.0	13.0	4.1		13.0	8.5	4.1	4.4
20.0	20.0	13.0	4.8		13.0	10.0	4.8	5.2
22.0	20.0	13.0	5.3		13.0	11.0	5.3	5.7
25.0	20.0	13.0	6.1		13.0	12.5	6.0	6.5
30.0	20.0	13.0	7.3		13.0	15.0	7.2	7.8
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	30.0	13.0	2.6		13.0	7.4	4.3	3.1
12.0	30.0	13.0	3.2		13.0	8.9	5.2	3.7
15.0	30.0	13.0	3.9		13.0	11.1	6.5	4.6
17.0	30.0	13.0	4.5		13.0	12.6	7.4	5.2
20.0	30.0	13.0	5.3		13.0	14.8	8.7	6.1
22.0	30.0	13.0	5.8		13.0	16.3	9.6	6.7
25.0	30.0	13.0	6.6		13.0	18.5	10.9	7.6
30.0	30.0	13.0	7.9		13.0	22.2	13.0	9.2
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	45.0	13.0	3.2		13.0	12.6	8.0	4.6
12.0	45.0	13.0	3.9		13.0	15.1	9.5	5.5
15.0	45.0	13.0	4.8		13.0	18.9	11.9	6.9
17.0	45.0	13.0	5.5		13.0	21.4	13.5	7.8
20.0	45.0	13.0	6.4		13.0	25.1	15.9	9.2
22.0	45.0	13.0	7.1		13.0	27.7	17.5	10.2
25.0	45.0	13.0	8.1		13.0	31.4	19.9	11.5
30.0	45.0	13.0	9.7		13.0	37.7	23.9	13.9
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	70.0	13.0	6.7		13.0	41.7	20.1	21.6
12.0	70.0	13.0	8.0		13.0	50.0	24.1	25.9
15.0	70.0	13.0	10.0		13.0	62.5	30.1	32.4
17.0	70.0	13.0	11.3		13.0	70.8	34.1	36.7
20.0	70.0	13.0	13.3		13.0	83.3	40.1	43.2
22.0	70.0	13.0	14.7		13.0	91.6	44.1	47.5
25.0	70.0	13.0	16.7		13.0	104.1	50.1	54.0
30.0	70.0	13.0	20.0		13.0	125.0	60.2	64.8

1 ft = 0.305 m

		Schwartz Electro-Optics 780D1000 (Autosense I)						
	(Two Beams, Each 1 mrad (El) by 9.5 deg (Az) Separated by 10 deg in El)							
Mounting Height (Feet)	Viewing Angle (deg)	Azimuth 3dB BW (deg)	Azimuth Footprint (Feet)		Elevation 3dB BW (deg)	Maximum Range (Feet)	Minimum Range (Feet)	Elevation Footprint (Feet)
10.0	15.0	9.5	1.7		0.057	2.7	2.7	0.0
12.0	15.0	9.5	2.1		0.057	3.2	3.2	0.0
15.0	15.0	9.5	2.6		0.057	4.0	4.0	0.0
17.0	15.0	9.5	2.9		0.057	4.6	4.5	0.0
20.0	15.0	9.5	3.4		0.057	5.4	5.3	0.0
22.0	15.0	9.5	3.8		0.057	5.9	5.9	0.0
25.0	15.0	9.5	4.3		0.057	6.7	6.7	0.0
30.0	15.0	9.5	5.2		0.057	8.1	8.0	0.0
Mounting Height (Feet)	Viewing Angle (deg)	Azimuth 3dB BW (deg)	Azimuth Footprint (Feet)		Elevation 3dB BW (deg)	Maximum Range (Feet)	Minimum Range (Feet)	Elevation Footprint (Feet)
10.0	20.0	9.5	1.8		0.057	3.6	3.6	0.0
12.0	20.0	9.5	2.1		0.057	4.4	4.4	0.0
15.0	20.0	9.5	2.7		0.057	5.5	5.5	0.0
17.0	20.0	9.5	3.0		0.057	6.2	6.2	0.0
20.0	20.0	9.5	3.5		0.057	7.3	7.3	0.0
22.0	20.0	9.5	3.9		0.057	8.0	8.0	0.0
25.0	20.0	9.5	4.4		0.057	9.1	9.1	0.0
30.0	20.0	9.5	5.3		0.057	10.9	10.9	0.0
Mounting Height (Feet)	Viewing Angle (deg)	Azimuth 3dB BW (deg)	Azimuth Footprint (Feet)		Elevation 3dB BW (deg)	Maximum Range (Feet)	Minimum Range (Feet)	Elevation Footprint (Feet)
10.0	25.0	9.5	1.8		0.057	4.7	4.7	0.0
12.0	25.0	9.5	2.2		0.057	5.6	5.6	0.0
15.0	25.0	9.5	2.8		0.057	7.0	7.0	0.0
17.0	25.0	9.5	3.1		0.057	7.9	7.9	0.0
20.0	25.0	9.5	3.7		0.057	9.3	9.3	0.0
22.0	25.0	9.5	4.0		0.057	10.3	10.2	0.0
25.0	25.0	9.5	4.6		0.057	11.7	11.6	0.0
30.0	25.0	9.5	5.5		0.057	14.0	14.0	0.0
Mounting Height (Feet)	Viewing Angle (deg)	Azimuth 3dB BW (deg)	Azimuth Footprint (Feet)		Elevation 3dB BW (deg)	Maximum Range (Feet)	Minimum Range (Feet)	Elevation Footprint (Feet)
10.0	30.0	9.5	1.9		0.057	5.8	5.8	0.0
12.0	30.0	9.5	2.3		0.057	6.9	6.9	0.0
15.0	30.0	9.5	2.9		0.057	8.7	8.7	0.0
17.0	30.0	9.5	3.3		0.057	9.8	9.8	0.0
20.0	30.0	9.5	3.8		0.057	11.6	11.5	0.0
22.0	30.0	9.5	4.2		0.057	12.7	12.7	0.0
25.0	30.0	9.5	4.8		0.057	14.5	14.4	0.0
30.0	30.0	9.5	5.8		0.057	17.3	17.3	0.0

1 ft = 0.305 m

		Schwartz Electro-Optics 780D1000 (Autosense I)						
	(Two Beams, Each 1 mrad (El) by 9.5 deg (Az) Separated by 10 deg in El)							
Mounting Height (Feet)	Viewing Angle (deg)	Azimuth 3dB BW (deg)	Azimuth Footprint (Feet)		Elevation 3dB BW (deg)	Maximum Range (Feet)	Minimum Range (Feet)	Elevation Footprint (Feet)
Mounting Height (Feet)	Viewing Angle (deg)	Azimuth 3dB BW (deg)	Azimuth Footprint (Feet)		Elevation 3dB BW (deg)	Maximum Range (Feet)	Minimum Range (Feet)	Elevation Footprint (Feet)
10.0	35.0	9.5	2.0		0.057	7.0	7.0	0.0
12.0	35.0	9.5	2.4		0.057	8.4	8.4	0.0
15.0	35.0	9.5	3.0		0.057	10.5	10.5	0.0
17.0	35.0	9.5	3.4		0.057	11.9	11.9	0.0
20.0	35.0	9.5	4.1		0.057	14.0	14.0	0.0
22.0	35.0	9.5	4.5		0.057	15.4	15.4	0.0
25.0	35.0	9.5	5.1		0.057	17.5	17.5	0.0
30.0	35.0	9.5	6.1		0.057	21.0	21.0	0.0
10.0	40.0	9.5	2.2		0.057	8.4	8.4	0.0
12.0	40.0	9.5	2.6		0.057	10.1	10.1	0.0
15.0	40.0	9.5	3.3		0.057	12.6	12.6	0.0
17.0	40.0	9.5	3.7		0.057	14.3	14.3	0.0
20.0	40.0	9.5	4.3		0.057	16.8	16.8	0.0
22.0	40.0	9.5	4.8		0.057	18.5	18.4	0.0
25.0	40.0	9.5	5.4		0.057	21.0	21.0	0.0
30.0	40.0	9.5	6.5		0.057	25.2	25.1	0.1
Mounting Height (Feet)	Viewing Angle (deg)	Azimuth 3dB BW (deg)	Azimuth Footprint (Feet)		Elevation 3dB BW (deg)	Maximum Range (Feet)	Minimum Range (Feet)	Elevation Footprint (Feet)
10.0	45.0	9.5	2.4		0.057	10.0	10.0	0.0
12.0	45.0	9.5	2.8		0.057	12.0	12.0	0.0
15.0	45.0	9.5	3.5		0.057	15.0	15.0	0.0
17.0	45.0	9.5	4.0		0.057	17.0	17.0	0.0
20.0	45.0	9.5	4.7		0.057	20.0	20.0	0.0
22.0	45.0	9.5	5.2		0.057	22.0	22.0	0.0
25.0	45.0	9.5	5.9		0.057	25.0	25.0	0.1
30.0	45.0	9.5	7.1		0.057	30.0	30.0	0.1
Mounting Height (Feet)	Viewing Angle (deg)	Azimuth 3dB BW (deg)	Azimuth Footprint (Feet)		Elevation 3dB BW (deg)	Maximum Range (Feet)	Minimum Range (Feet)	Elevation Footprint (Feet)
10.0	50.0	9.5	2.6		0.057	11.9	11.9	0.0
12.0	50.0	9.5	3.1		0.057	14.3	14.3	0.0
15.0	50.0	9.5	3.9		0.057	17.9	17.9	0.0
17.0	50.0	9.5	4.4		0.057	20.3	20.2	0.0
20.0	50.0	9.5	5.2		0.057	23.9	23.8	0.0
22.0	50.0	9.5	5.7		0.057	26.2	26.2	0.1
25.0	50.0	9.5	6.5		0.057	29.8	29.8	0.1
30.0	50.0	9.5	7.8		0.057	35.8	35.7	0.1

1 ft = 0.305 m

		Schwartz Electro-Optics 780D1000 (Autosense I)						
	(Two Beams, Each 1 mrad (El) by 9.5 deg (Az) Separated by 10 deg in El)							
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	65.0	9.5	3.9		0.057	21.5	21.4	0.1
12.0	65.0	9.5	4.7		0.057	25.8	25.7	0.1
15.0	65.0	9.5	5.9		0.057	32.2	32.1	0.1
17.0	65.0	9.5	6.7		0.057	36.5	36.4	0.1
20.0	65.0	9.5	7.9		0.057	42.9	42.8	0.1
22.0	65.0	9.5	8.7		0.057	47.2	47.1	0.1
25.0	65.0	9.5	9.8		0.057	53.7	53.5	0.1
30.0	65.0	9.5	11.8		0.057	64.4	64.3	0.2
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	70.0	9.5	4.9		0.057	27.5	27.4	0.1
12.0	70.0	9.5	5.8		0.057	33.0	32.9	0.1
15.0	70.0	9.5	7.3		0.057	41.3	41.1	0.1
17.0	70.0	9.5	8.3		0.057	46.8	46.6	0.1
20.0	70.0	9.5	9.7		0.057	55.0	54.9	0.2
22.0	70.0	9.5	10.7		0.057	60.5	60.4	0.2
25.0	70.0	9.5	12.1		0.057	68.8	68.6	0.2
30.0	70.0	9.5	14.6		0.057	82.6	82.3	0.3
Mounting Height (Feet)	**Viewing Angle (deg)**	**Azimuth 3dB BW (deg)**	**Azimuth Footprint (Feet)**		**Elevation 3dB BW (deg)**	**Maximum Range (Feet)**	**Minimum Range (Feet)**	**Elevation Footprint (Feet)**
10.0	75.0	9.5	6.4		0.057	37.4	37.2	0.1
12.0	75.0	9.5	7.7		0.057	44.9	44.7	0.2
15.0	75.0	9.5	9.6		0.057	56.1	55.9	0.2
17.0	75.0	9.5	10.9		0.057	63.6	63.3	0.3
20.0	75.0	9.5	12.8		0.057	74.8	74.5	0.3
22.0	75.0	9.5	14.1		0.057	82.3	81.9	0.3
25.0	75.0	9.5	16.1		0.057	93.5	93.1	0.4
30.0	75.0	9.5	19.3		0.057	112.2	111.7	0.4

1 ft = 0.305 m

APPENDIX G.

INDUCTIVE LOOP DETECTOR SPECIFICATIONS FOR LOOPS INSTALLED DURING THE DETECTOR FIELD EVALUATIONS

Table G-1. Inductive Loop Detector Installation Information for I-394 in Minneapolis, Minnesota

Location of Loop: I-394 and Penn Avenue

Wire Loop Information:

Manufacturer: Triangle Cable Company   Model________________________

Shape and Size: 6 ft x 6 ft (1.8 m x 1.8 m) Date loop installed: 11/17/92

Loop Construction (wire laid in pavement, wire in conduit laid in pavement, wire encased in epoxy or other compound and then laid in pavement, etc.): Sawcut concrete, 1-1/2 inches (38.1 mm) deep

Gauge of wire used in loop: #12 AWG   Number of turns: 3

Type of insulation: RHW   Type of conduit used, if any: PVC

Lead-in cable length: 65 ft (19.8 m)   Type of splice: 3M and soldered

Description or drawing of cross section of road where loop is installed. Indicate at what depth loop is located.

Please supply a set of loop installation specifications if not already supplied.

Detector Amplifier Information:

Manufacturer: Detector Systems   Model: 222B

Number of Channels: 2   Date last tuned: Unknown

Settings of switches, jumpers, etc. on amplifier:

Sensitivity: 4 = Medium, Response time = 2 ms

Medium pulse mode

Oscillator Frequency

	Lane 1	**Lane 2**	**Lane 3**
First Loop Encountered	MED LO	MED HI	MED HI
Second Loop Encountered	MED LO	MED HI	MED LO

Table G-2. Inductive Loop Detector Installation Information for TH 55 in Minneapolis, Minnesota

Location of Loop: Westbound Olson Highway (TH 55) at Northbound Lyndale Avenue North

Wire Loop Information:

Manufacturer: ____________ Model ________________

Shape and Size: 6 ft x 6 ft (1.8 m x 1.8 m) Date loop installed: 11/3/92, Tested 11/9/92

Loop Construction (wire laid in pavement, wire in conduit laid in pavement, wire encased in epoxy or other compound and then laid in pavement, etc.): Wire laid in pavement

Gauge of wire used in loop: #12 AWG Number of turns: 3

Type of insulation: XLP - U.S.E. Type of conduit used, if any: ____________

Lead-in cable length: ____________ Type of splice: Soldered

Description or drawing of cross section of road where loop is installed. Indicate at what depth loop is located.

Sawcut depth: 2 inches (50.8 mm); Roadway condition: poor, asphalt severely cracked.

Please supply a set of loop installation specifications if not already supplied.

Detector Amplifier Information:

Manufacturer: Detector Systems Model: 222B

Number of Channels: 2 Date last tuned: Unknown

Settings of switches, jumpers, etc. on amplifier:

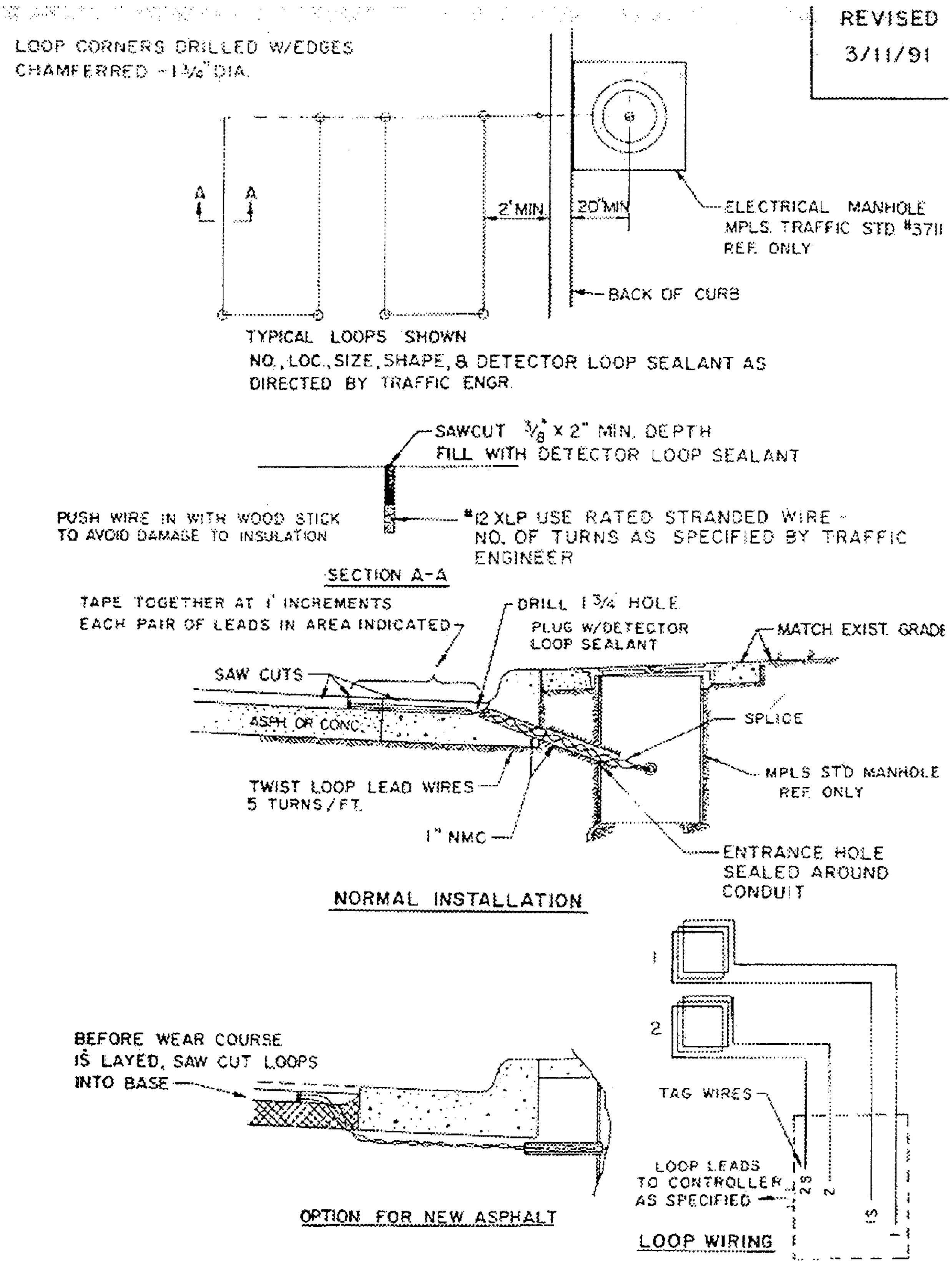
Sensitivity: 4 = Medium (detects automobiles on all size loops up to 600 ft^2 [55.7 m^2])

Response time = 2 ms

Long presence mode

Oscillator Frequency

	Lane 1	Lane 2
First Loop Encountered	MED LO	LO
Second Loop Encountered	MED LO	LO



1 in = 25.4 mm
1 ft = 0.305 m

Figure G-1. City of Minneapolis Inductive Loop Installation Specification

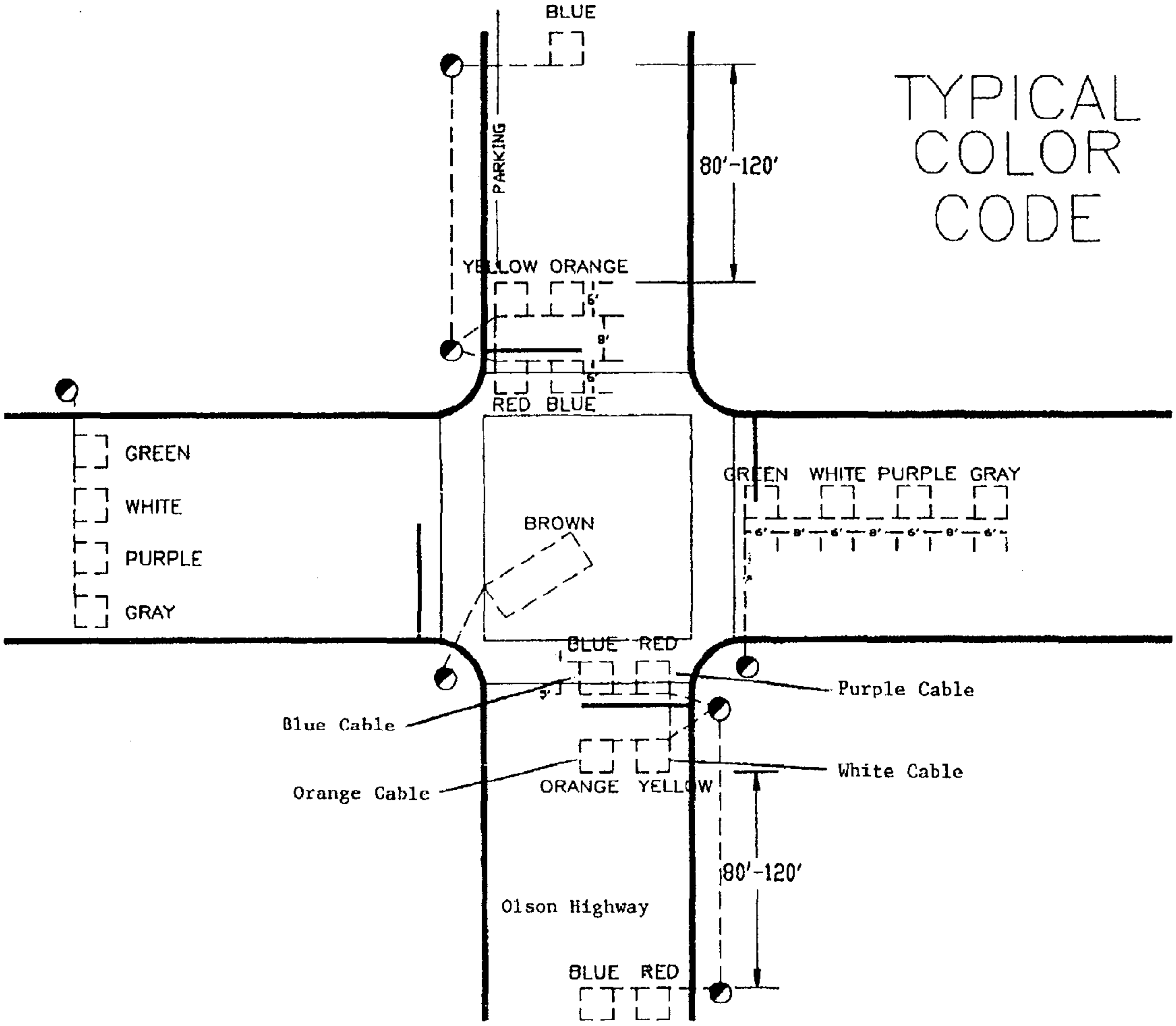


Figure G-2. Wire Color Codes Used to Connect Inductive Loops to Pull Box at Olson Highway Site

Table G-3. Inductive Loop Detector Installation Information for I-4 and SR 436 in Altamonte Springs, Florida

Location of Loop: I-4 at SR 436

Wire Loop Information:

Manufacturer: Rome Cable

Model: Rome XHHW stranded copper wire per spec 2100 for Rome Cable

Shape and Size: 6 ft x 6 ft (1.8 m x 1.8 m)

Date loop installed: 5/19/93

Loop Construction (wire laid in pavement, wire in conduit laid in pavement, wire encased in epoxy or other compound and then laid in pavement, etc.): Wire laid in pavement, encased in GAF Type III steep asphalt.

Gauge of wire used in loop: #14 AWG

Number of turns: 3

Type of insulation: XLPE

Type of conduit used, if any: PVC

Lead-in cable length: 210 inches (5.3 m)

Type of splice: per FDOT Std. Index 17781

Lead-in cable for each loop used 1 pair of a multi-pair C2550 cable manufactured by Carol Cable to IMSA 50-2 specification

Description or drawing of cross section of road where loop is installed. Indicate at what depth loop is located.

Sawcut depth: 2 inches (50.8 mm).

Please supply a set of loop installation specifications if not already supplied.

Detector Amplifier Information:

Manufacturer: Detector Systems

Model: 222D

Number of Channels: 2

Date last tuned: Unknown

Settings of switches, jumpers, etc. on amplifier:

Sensitivity: 1, Response time = 1 ms

Presence Mode: 7/7, 7/8, 7/9

Pulse Mode: 7/13 till end of test. Pulse specification is 125 ± 25 ms. Detector resumes full sensitivity within 0.75 second.

Oscillator Frequency

	Lane 1	Lane 2	Lane 3*
First Loop Encountered	HI	MED HI	HI
Second Loop Encountere	HI	MED HI	HI

* Lane 3 loops used on I-4 freeway only.

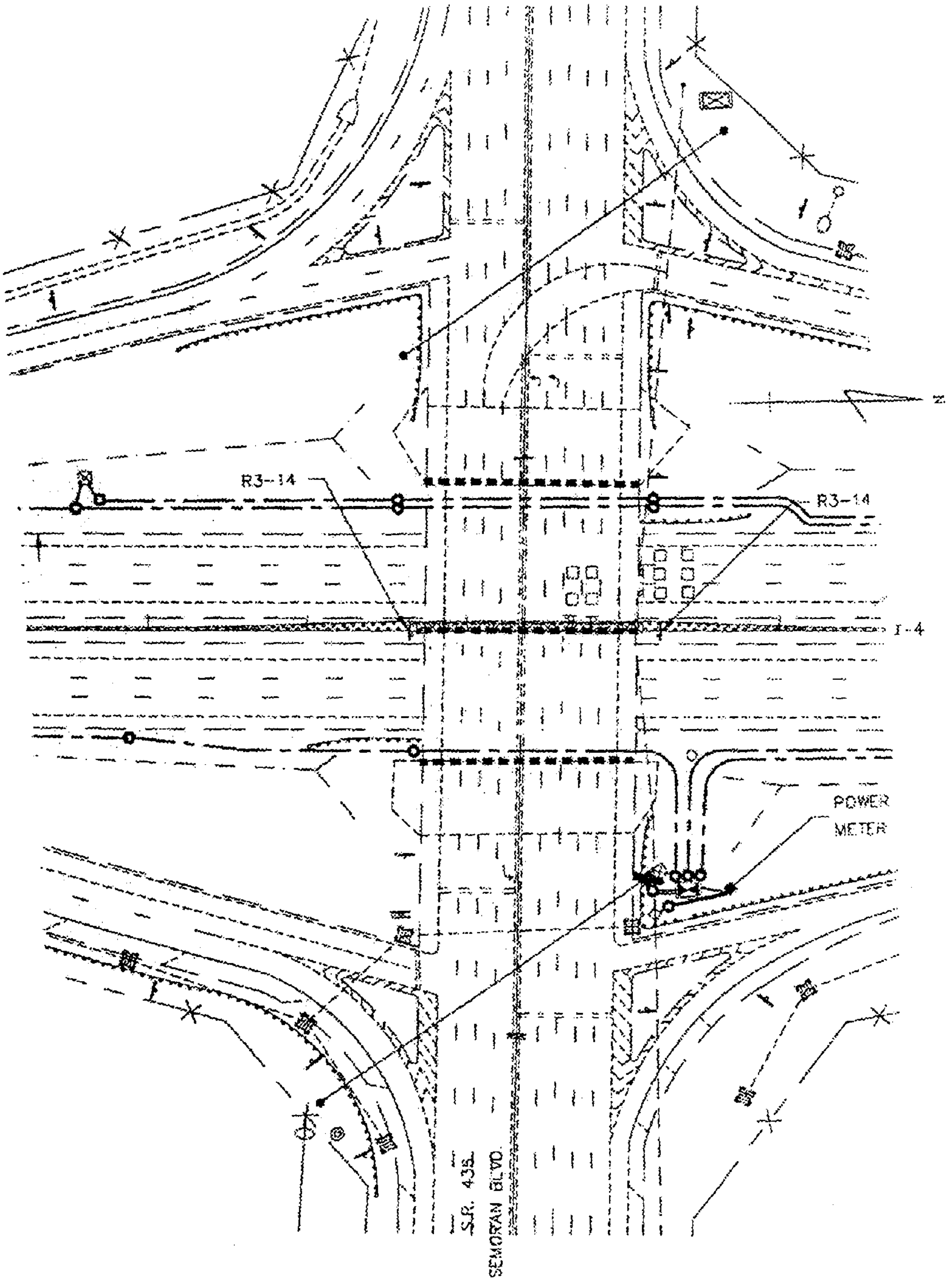


Figure G-3. I-4 and SR 436 Intersection In Altamonte Springs, Florida Showing Locations of Inductive Loops

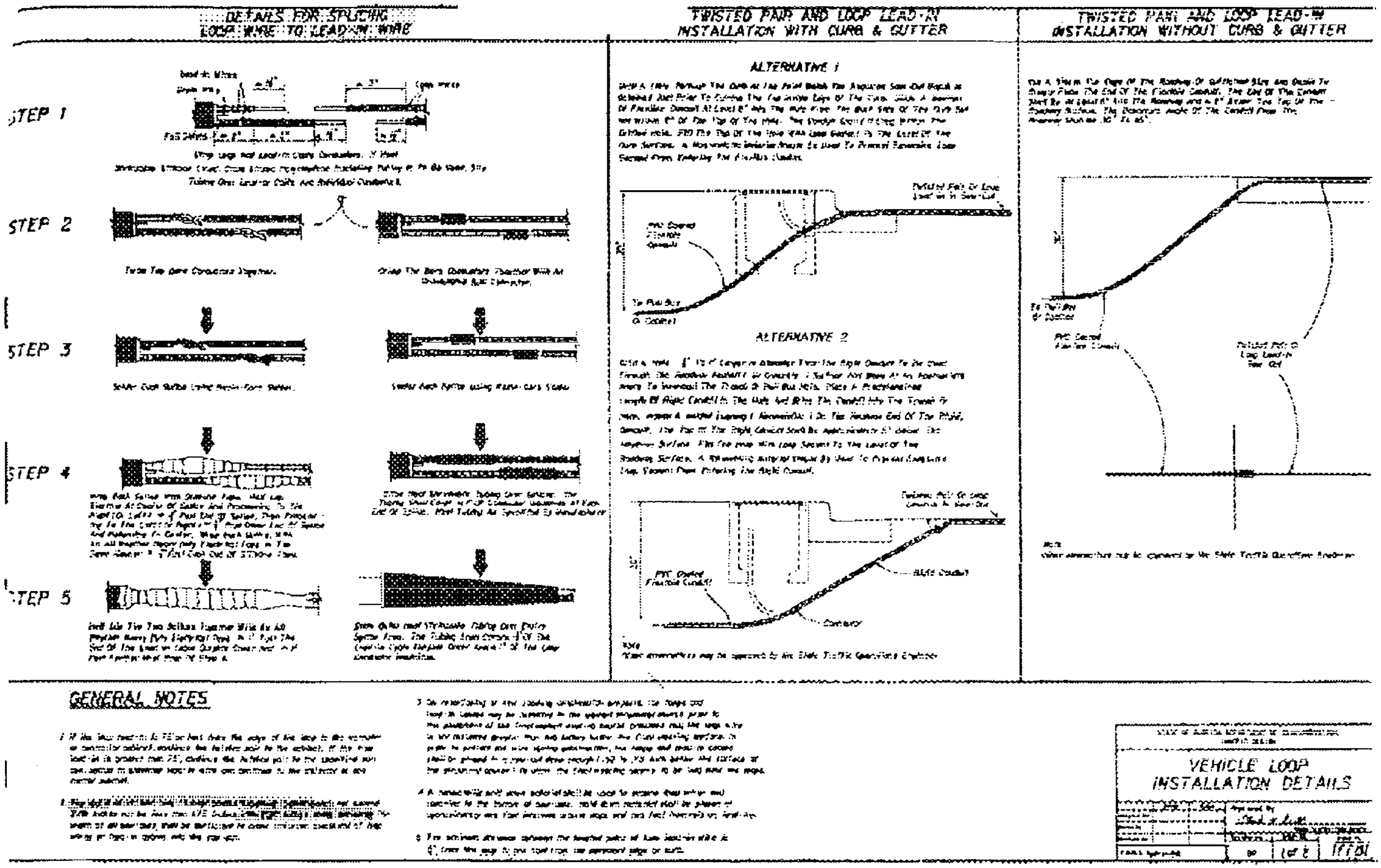


Figure G-4. FDOT Standard Index 17781 for Inductive Loop Installation

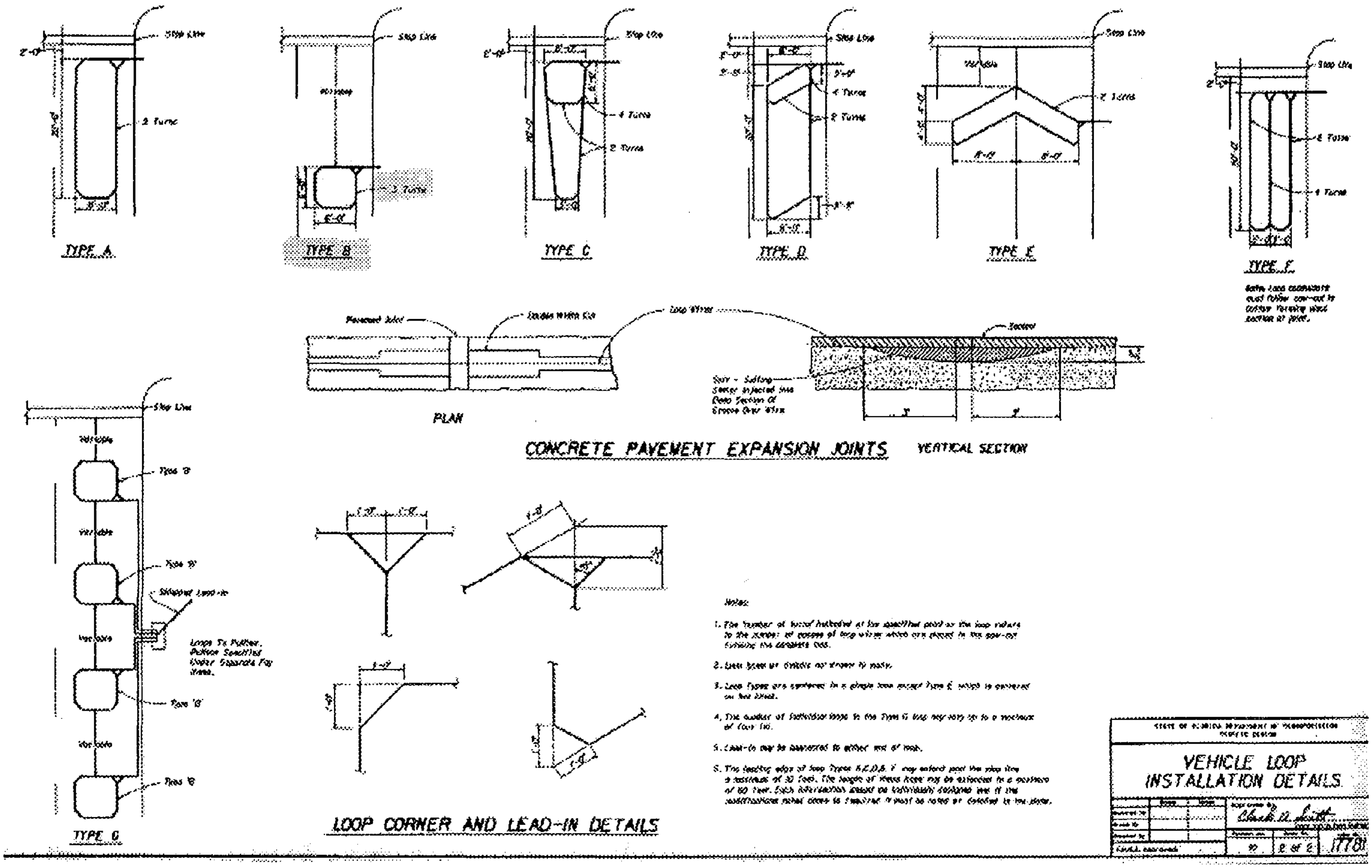


Figure G-4. FDOT Standard Index 17781 for Inductive Loop Installation (continued)

Rome Cable
CORPORATION

SUBMITTAL No. 1-661-70-112
THIS SUBMISSION HAS BEEN REVIEWED AND APPEARS TO COMPLY WITH THE INTENTION OF THE CONTRACT DRAWINGS AND SPECIFICATIONS, AND IS SUBMITTED FOR DESIGNER APPROVAL.

HUBBARD CONSTRUCTION COMPANY
By CB Date 2/1/93

SPEC 2100
April 1, 1987
Supersedes Issue
1-1-87

ROME XHHW

Rome-XLP Insulation, 600 Volts

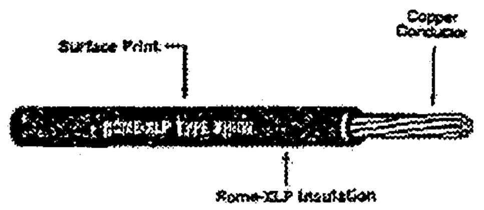
APPLICATION:

1. General purpose wiring for lighting and power—residential, commercial, industrial buildings in accordance with National Electrical Code, maximum conductor temperature of 90°C in dry locations and 75°C in wet locations, 600 volts, for installation in conduit or other recognized raceways.
2. Suitable for use in low leakage circuits requiring a dielectric constant of 3.5 or less, such as isolated circuits supplying anesthetizing locations per Article 517-104 of the NEC.
3. Suitable for use as low leakage inductive (loop) vehicle detector wire in accordance with state and municipal requirements.

STANDARDS:

1. Listed by Underwriters Laboratories as Type XHHW per UL Standard 44 for Rubber-Insulated Wires and Cables.
2. Conforms to ICEA Pub. No. S-66-524, utilizing Column B thicknesses.
3. Conforms to Federal Specification J-C-30A.
4. Cable complies with the requirements of OSHA when installed and used in accordance with the NEC.

CONSTRUCTION: Annealed copper conductor, Rome-XLP thermosetting chemically crosslinked polyethylene insulation, surface printed.



Size AWG or MCM	No. of Strands	Insulation Thickness Mils	Nom. Diam. Inches	Copper Conductor													
				NEC Ampacity*		Approx. Wt. Lbs/1000 Ft.		Standard Package		Stock Items②							
				75°C Wet	90°C Dry	Net	Shipping	Length	Put-up	1	2	3	4	5	6	7	8
Stranded																	
14	7	30	.15	20†	25†	16	19	500' CL	Cln	S	S	S	S	S			
							19	2500'	NR reel	S	S	S	S	S	S	S	S
12	7	30	.16	25†	30†	27	28	500' CL	Cln	S	S	S	S	S			
							29	2500'	NR reel	S	S	S	S	S	S	S	S
10	7	30	.18	35†	40†	40	41	500' CL	Cln	S	S	S	S	S			
							43	2500'	NR reel	S	S	S	S	S	S	S	S
8	7	45	.24	50	55	66	67	500' CL	Cln	S							
							69	2500'	NR reel	S							
6	7	45	.28	65	75	97	105	1000'	NR reel	S							
4	7	45	.32	85③	95③	145	160	1000'	NR reel	S							
2	7	45	.38	115③	130③	225	245	1000'	NR reel	S							
1	19	55	.44	130③	150③	290	310	1000'	NR reel	S							
1/0	19	55	.48	150③	170③	360	380	1000'	NR reel	S							
2/0	19	55	.52	175③	195③	450	470	1000'	NR reel	S							
3/0	19	55	.56	200	225	560	580	1000'	NR reel	S							
4/0	19	55	.63	230	260	700	730	1000'	NR reel	S							
250	37	65	.70	255	290	830	865	1000'	NR reel	S							
300	37	65	.75	285	320	990	1050	NS	NR reel	S							
350	37	65	.80	310	350	1150	1210	1000'	NR reel	S							
400	37	65	.85	335	380	1310	1370	NS	NR reel	S							
500	37	65	.93	380	430	1620	1710	1000'	NR reel	S							
600	61	80	1.04	420	475	1950	2080	NS	NR reel	S							
750	61	80	1.14	475	535	2445	2545	NS	NR reel	S							
1000	61	80	1.29	545	615	3240	3380	—	—								

*Ampacity in accordance with NEC for not more than three conductors in raceway, 75°C conductor temperature for wet locations, 90°C conductor temperature for dry locations, 30°C ambient temperature.

†The over current protection shall not exceed 15 amperes for 14 AWG, 20 amperes for 12 AWG and 30 amperes for 10 AWG copper.

NOTES: ① Color Code: 1 black, 2 white, 3 red, 4 blue, 5 green, 6 yellow, 7 orange, 8 brown.
② On non-stocking items, contact Rome Cable for minimum acceptable manufacturing quantities.
③ For three wire, single phase dwelling services, the allowable ampacities are as follows:

Size AWG	Copper-Amps
4	100
2	125
1	150
1/0	175
2/0	200

Figure G-5. Rome Cable Spec 2100

me Cable
RPORATION

SPEC 2100
4-1-87

Specification

ROME XHHW

Rome-XLP Insulation, 600 Volts

1. SCOPE

1.1 This specification describes single conductor Rome XHHW, a general purpose building wire insulated with crosslinked polyethylene (XLPE) intended for lighting and power circuits at 600 volts or less, in residential, commercial and industrial buildings. The wire may be operated at 90°C maximum continuous conductor temperature in dry locations and 75°C in wet locations and is listed by Underwriters Laboratories for use in accordance with Article 310 of the National Electrical Code.

2. APPLICABLE SPECIFICATIONS

2.1 The following specifications form a part of this specification to the extent specified herein:

2.1.1 Underwriters Laboratories Standard 44 for Rubber-Insulated Wires and Cables.

2.1.2 ICEA Pub. No. S-66-524, NEMA Pub. No. WC7 for Crosslinked-Polyethylene-Insulated Wire and Cable.

2.1.3 Federal Specification J-C-30A.

3. CONDUCTORS

3.1 Conductors shall be Class B stranded annealed uncoated copper per UL Standard 44.

4. SEPARATOR

4.1 A suitable separator over the conductor may be used at the option of the manufacturer.

5. INSULATION

5.1 Each conductor shall be insulated with Rome-XLP, a crosslinked polyethylene complying with the physical and electrical requirements of UL Standard 44 for Type XHHW.

5.2 The average thickness of insulation, for a given conductor size, shall be as specified in UL Standard 44 for Type XHHW. The minimum thickness at any point shall be not less than 90% of the specified average thickness. The insulation shall be applied tightly to the conductor and shall be free-stripping.

6. IDENTIFICATION

6.1 The wire shall be identified by surface marking indicating manufacturer's identification, conductor size and metal, voltage rating, UL Symbol and type designation.

7. TESTS

7.1 Wire shall be tested in accordance with the requirements of UL Standard 44 for Type XHHW wire.

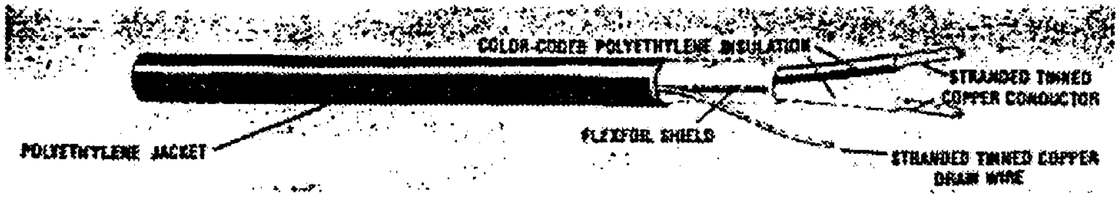
8. LABELS

8.1 The wire shall bear the Underwriters Laboratories labels for Type XHHW.

—

Figure G-5. Rome Cable Spec 2100 (continued)

Traffic Loop Lead-in Control Cable



CATALOG NUMBER	NO. OF COND.	COND. SIZE	COND. STRAND	NOM. INSULATION THICKNESS		NOM. JACKET THICKNESS		NOMINAL O.D.	
				INCHES	MM	INCHES	MM	INCHES	MM
C2551	2	18	16	.030	0.76	.030	0.76	.285	7.24
C2553	2	16	26	.030	0.76	.030	0.76	.310	7.87
C2550	2	14	19	.030	0.76	.030	0.76	.340	8.64
C2552	2	12	65	.030	0.76	.030	0.76	.380	9.65

Product Construction

Conductor:

- Stranded tinned copper per ASTM-B-33
- Insulation: Premium grade low density polyethylene

Shield

- Flexfoil® Aluminum/Polyester/Aluminum Foil
- 100% coverage, 25% overlap, foil facing out
- Stranded tinned copper drain wire one gauge size smaller than the conductor size

Jacket:

- Premium grade black polyethylene -20°C to +60°C

Application:

- Interface cable between traffic loop and signal control station

Industry Approvals:

- Meets IMSA 50-2 specifications

Packaging:

2500 ft (762 M)

Distributed by:

Cablematic Communication
5750 Edgewater Dr.
Orlando, FL 32810

CAROL

PAWTUCKET, RI 02862

Figure G-6. Carol Cable Lead-In Cable Specifications

Table G-4. Physical Requirements of GAF Type III Steep Roofing Asphalt

Requirement	Minimum Value	Maximum Value	Test Method
Softening Point (°F)	185	205	ASTM D36
Flash Point (°F)	475	-	ASTM D92
Penetration Units:			
at 32°F	6	-	
at 77°F	15	35	
at 115°F	-	90	
Ductility at 77°F (cm)	2.5	-	ASTM D113
Solubility in Trichloroethylene (%)	99	-	ASTM D2042

(F - 32)/1.8 = °C

Asphalts shall be homogenous and free of water and shall conform to the physical properties in the table. Product meets ASTM D312, giving assurance each shipment meets or exceeds the physical requirements of roofing asphalts for softening point, flash, penetration, and ductility.

Table G-5. Inductive Loop Detector Installation Information for I-10 in Phoenix, Arizona (Autumn 1993)

Location of Loop: I-10 near 13th Street in downtown Phoenix

Wire Loop Information:

Manufacturer: ______________ Model: Detectaduct

Shape and Size: 6 ft x 6 ft (1.8 m x 1.8 m) Date loop installed: 8/21/93

Loop Construction (wire laid in pavement, wire in conduit laid in pavement, wire encased in epoxy or other compound and then laid in pavement, etc.): Wire laid in pavement, encased in 3M sealant.

Gauge of wire used in loop: #14 AWG Number of turns: 4

Type of insulation: TNNN Type of conduit used, if any: PVC sleeve

Lead-in cable length: 60+ ft (18.3+ m) Type of splice: solder

Description or drawing of cross section of road where loop is installed. Indicate at what depth loop is located.

Sawcut depth: 3 inches (76.2 mm); wire lies 2-1/2 inches (63.5 mm) below surface. Road surface concrete is PCCP.

Please supply a set of loop installation specifications if not already supplied.

Detector Amplifier Information:

Manufacturer: Detector Systems Model: 272

Number of Channels: 2 Date last tuned: Unknown

Settings of switches, jumpers, etc. on amplifier:

Sensitivity: 3, Response time = 5 ms

Pulse Mode

Oscillator Frequency

	Lane 1*	Lane 2*	Lane 3
First Loop Encountered	HI	LO	HI
Second Loop Encountered	LO	MED	LO

* Could not eliminate cross talk between pairs of loops in lanes 1 and 2.

Self-Powered Magnetometer Data Used Receiver Channels 1 (47.140 MHz) and 4 (47.060 MHz)

Table G-6. Inductive Loop Detector Installation Information for I-10 in Phoenix, Arizona (Summer 1994)

Location of Loop: I-10 near 13th Street in downtown Phoenix

Wire Loop Information:

Manufacturer: ______________

Model: Detectaduct

Shape and Size: 6 ft x 6 ft (1.8 m x 1.8 m)

Date loop installed: 8/21/93

Loop Construction (wire laid in pavement, wire in conduit laid in pavement, wire encased in epoxy or other compound and then laid in pavement, etc.): Wire laid in pavement, encased in 3M sealant.

Gauge of wire used in loop: #14 AWG

Number of turns: 4

Type of insulation: TNNN

Type of conduit used, if any: PVC sleeve

Lead-in cable length: 60+ ft (18.3+ m)

Type of splice: solder

Description or drawing of cross section of road where loop is installed. Indicate at what depth loop is located.

Sawcut depth: 3 inches (76.2 mm); wire lies 2-1/2 inches (63.5 mm) below surface. Road surface concrete is PCCP.

Please supply a set of loop installation specifications if not already supplied.

Detector Amplifier Information:

Manufacturer	Model	Number Channels	Sens.	Response Time	Mode	Where Used
Detector Systems	613-SS	1	3	1 ms	Pulse	First loop, lane 1
Detector Systems	613-SS	1	3	1 ms	Pulse	First loop, lane 2
Detector Systems	272	2	3	5 ms	Pulse	First loop, lane 3
Detector Systems	272	2	3	5 ms	Pulse	Second loop, lane 3

* Only used one loop in each of lanes 1 and 2 because of cross talk.

Self-Powered Magnetometer Data: Used Receiver Channels 1 (47.140 MHz) and 4 (47.060 MHz)

Table G-7. Inductive Loop Detector Installation Information for Oracle Road in Tucson, Arizona

Location of Loop: Oracle Road at Auto Mall Drive in Tucson

Wire Loop Information:

Manufacturer: Sun State Wire

Model: Detectaduct, round cross section, 1/4-inch (6.4-mm) diameter

Shape and Size: 6 ft x 6 ft (1.8 m x 1.8 m)

Date loop installed: ____________

Loop Construction (wire laid in pavement, wire in conduit laid in pavement, wire encased in epoxy or other compound and then laid in pavement, etc.): Wire laid in asphalt, 1/4-inch (6.4-mm) wide saw cut with epoxy seal, Briggs loop.

Gauge of wire used in loop: #14 AWG

Number of turns: 3

Type of insulation: THHN-THWN

Type of conduit used, if any: Home run to pull box, 3-inch (76.2-mm) PVC

Lead-in cable length: 8 ft (2.4 m)

Type of splice: Heat-shrink insulation, solder splice

Description or drawing of cross section of road where loop is installed. Indicate at what depth loop is located.

Sawcut depth: 1 inch (25.4 mm). First loop (northern loop) encountered in curb lane is number 4, second loop (southern loop) in curb lane is number 3, first loop in middle lane is number 2, second loop in middle lane is number 1.

6-ft (1.8-m) diameter round loops in lane 3 were installed by Max Kutter to their specifications. 3M microloops in lane 3 were installed according to 3M specifications.

Detector Amplifier Information:

Manufacturer	Model	Number Channels	Sens.	Response Time	Mode	Where Used
Detector Systems	613-SS	1	3	1 ms	Pulse	First sq. loop, lane 2
Detector Systems	613-SS	1	3	1 ms	Pulse	Second sq. loop, lane 2
Detector Systems	613-SS	1	3	1 ms	Pulse	First sq. loop, lane 3
Detector Systems	262A	2	4	10 ms, min 20 ms, max	Pulse	Second sq. loop, lane 3
Detector Systems	262A	2	4	10 ms, min 20 ms, max	Pulse	First round loop, lane 3
Detector Systems	262A	2	4	10 ms, min 20 ms, max	Pulse	Second round lop, lane 3
Detector Systems	262A	2	4	10 ms, min 20 ms, max	Pulse	3M microloop in lane 2
Detector Systems	262A	2	4	10 ms, min 20 ms, max	Pulse	3M microloop in lane 3

Oscillator Frequency

	Amplifier	Lane 2	Lane 3
First 6-ft x 6-ft Loop Encountered	613-SS	MED	MED
Second 6-ft x 6-ft Loop Encountered	613-SS	LO	-
Second 6-ft x 6-ft Loop Encountered	262A	-	
First 6-ft Diameter Round Loop Encountered	262A	-	LO
Second 6-ft Diameter Round Loop Encountered	262A	-	MED HI
3M Microloop	262A	HI	HI

6 ft = 1.8 m

APPENDIX H.

DETECTOR CONNECTIONS TO DATA LOGGER AND POWER SUPPLIES AT THE FIELD SITES

This appendix contains tabulations of the connections from the detector output data terminals to the terminals on the data distribution panel and the data logger, and connections from the power supplies to the detector power input terminals for the configurations used in Minneapolis, Orlando, Phoenix, and Tucson.

HOOKUP1A.DAT

FEBRUARY 10, 1993
MINNEAPOLIS I-394 & PENN AVE. SITE

LANE 1 IS HOV
LANE 2 IS EAST BOUND FAR
LANE 3 IS EAST BOUND NEAR

FIRST CONFIGURATION
NAME OF LOG FILE:

DETECTOR NAME	SIGNAL			DATA LOGGER PORT
M5A	LANE 1 (HOV)			
	RS232GND	1A	ORG	RS232 # 2 (COM 6)
	RS232XMIT	2A	ORG/GRN	RS232 # 2 (COM 6)
	RS232REC	4A	ORG/BLK	RS232 # 3 (COM 6)
	OPTO1 +	5A	ORG/WHT/BLU	NOT CONNECTED
	OPTO2 +	7A	ORG/BLK/GRN	NOT CONNECTED
M1B	LANE 1 (HOV)			
	RELAY 1 N.O.	10A	ORG/BLK/WHT	RR # 1
M2B	LANE 1 (HOV)			
	RELAY N.C.	23A	RED	RR # 2
	<35 MPH	24A	RED/GRN	
	36-45 MPH	25A	RED/BLK	NOT CONNECTED
	46-55 MPH	26A	RED/WHT	NOT CONNECTED
	56-65 MPH	27A	RED/BLK/GRN	NOT CONNECTED
	66 + MPH	28A	RED/BLK/WHT	NOT CONNECTED
	DOPP FREQ	29A	GRN	NOT CONNECTED
	GROUND	30A	GRN/WHT	NOT CONNECTED
IR1	LANE 1 (HOV)			

NOTE: THIS DETECTOR NEEDS TO BE CONNECTED TO COM PORT 20
WHICH IS RS232 #16 ON DIGICHANNEL BOX

	RECEIVE	33A	GRN/BLK	RS232 #16 (COM 20)
	RELAY N.O.	36A	GRN/BLK/WHT	RR # 3
	RX/XMT GND	37A	GRN/BLK/ORG	RS232 #16 (COM 20)
	XMT	38A	WHT	RS232 #16 (COM 20)
M4	LANE 2			
	RS232 GND	41A	WHT/BLK	RS232 # 4 (COM 8)
	TRANSMIT	42A	WHT/RED	RS232 # 4 (COM 8)
	DATA CARRIER	43A	WHT/RED/ORG	NOT USED
	RECEIVE DATA	44A	WHT/RED/BLK	RS232 # 4 (COM 8)
	OPTO #1 +	45A	WHT/RED/GRN	NOT CONNECTED
	OPTO #2 +	47A	WHT/RED/BLU	NOT CONNECTED
M2A	LANE 2			
	RELAY N.C.	52A	BLU	RR # 4
	<35 MPH	53A	BLU/BLK	

	36-45 MPH	54A	BLU/WHT	OR #16
	46-55 MPH	55A	BLU/RED	OR #15
	56-65 MPH	56A	BLU/WHT/ORG	
	66+ MPH	57A	BLU/WHT/BLK	
	DOPPLER SIGNAL	58A	BLK	AR # 3+
	GROUND	59A	BLK/WHT	AR # 3-
U3	LANE 2			
	RELAY N.O.	63A	BLK/WHT/ORG	RR # 5
M1A	LANE 3			
	RELAY 1 N.O.	81A	BLK/RED	RR # 6
IR3	LANE 3			
	RELAY N.C.	89A	BLK/RED/WHT	RR # 7
M5B	LANE 3			
	RS232 GND	93A	GREEN (CABLE B)	RS232 # 3 (COM 7)
	RS232 XMIT	94A	RED (CABLE B)	RS232 # 3 (COM 7)
	RS232 REC	96A	WHT (CABLE B)	RS232 # 3 (COM 7)
	OPTO1 +	97A	GREEN	NOT CONNECTED
	OPTO2 +	99A	RED	NOT CONNECTED
U2	LANE 3			
	RELAY N.O.	106A	YELLOW (CABLE A)	RR # 9
IR2	LANE 3			
	RELAY N.O.	101A	BLACK (CABLE A)	RR # 8

****

LOOPS
DETECTOR SYSTEMS 222B

HOV EAST OPTO +	161A	GREEN	OR # 1
HOV WEST OPTO +	162A	WHITE	OR # 2
LANE 2 (EAST) OPTO +	163A	GREEN	OR # 3
LANE 2 (WEST) OPTO +	164A	WHITE	OR # 4
LANE 3 (EAST) OPTO +	165A	GREEN	OR # 5
LANE 3 (WEST) OPTO +	166A	WHITE	OR # 6

****

AUTOSCOPE 2003

EIM-2 CONNECTOR

DB 37 PINOUT

PIN 1 24 VDC GROUND

PIN 18 24 VDC POWER

PIN 29	DET 109	LANE 3	GREEN	OR #10
30	DET 105	LANE 3	WHITE	OR # 9
31	DET 108	LANE 2	GREEN	OR # 8
32	DET 104	LANE 2	WHITE	OR # 7

****

COMPUTER RECOGNITION SYSTEMS

TRAFFIC ANALYSIS SYSTEM (TAS):

PIN 16	ZONE 1 (W LOOP ON LANE 2)	RED	OR #11
14	ZONE 2 (W LOOP ON LANE 3)	RED	OR #12
10	ZONE 3 (E LOOP ON LANE 2)	RED	OR #13
8	ZONE 4 (E LOOP ON LANE 3)	RED	OR #14

PINS 7, 9, 13, AND 15 (OF THE WIEDEMULLER CONNECTOR) ARE TIED TOGETHER (BLACK) AND CONNECTED TO THE 24 VOLT GROUND ON THE TERMINAL STRIP

****

TEMP PROBES ARE CONNECTED ON THE	BRIDGE	AR #10
	TRAILER	AR #11

WEATHER	WIND SPEED	AR # 8
	WIND DIRECTION	AR # 7

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HOOKUP02.DAT

JANUARY 23, 1993
MINNEAPOLIS I-394 & PENN AVE. SITE

LANE 1 IS HOV
LANE 2 IS EAST BOUND FAR
LANE 3 IS EAST BOUND NEAR

FIRST CONFIGURATION
NAME OF LOG FILE:

DETECTOR    SIGNAL                    DATA LOGGER
NAME                           CONNECTION

M5A        LANE 1 (HOV)
       RS232GND      1A    ORG          RS232 (2)
       RS232XMIT     2A    ORG/GRN        (COM 6)
       RS232REC      4A    ORG/BLK
       OPTO1 +       5A    ORG/WHT/BLU   NOT CONNECTED
       OPTO2 +       7A    ORG/BLK/GRN   NOT CONNECTED

M1B        LANE 1 (HOV)
       RELAY 1 N.O.   10A   ORG/BLK/WHT   RR #2

M2B        LANE 1 (HOV)
       RELAY N.C.    23A   RED          RR #4
       <35 MPH       24A   RED/GRN
       36-45 MPH     25A   RED/BLK
       46-55 MPH     26A   RED/WHT
       56-65 MPH     27A   RED/BLK/GRN
       66 + MPH      28A   RED/BLK/WHT
       DOPPLER FREQ  29A   GRN
       GROUND        30A   GRN/WHT

IR1        LANE 1 (HOV)

NOTE:  THIS DETECTOR NEEDS TO BE CONNECTED TO COM PORT 20
    OR RS232 # 16 (ONLY).

       RECEIVE       33A   GRN/BLK       RS232 #16
       RELAY N.O.    36A   GRN/BLK/WHT   RR #6
       RX/XMT GND    37A   GRN/BLK/ORG   RS232 #16
       XMT           38A   WHT          RS232 #16

M4         LANE 2
       RS232 GND     41A   WHT/BLK       RS232 # 4
       TRANSMIT      42A   WHT/RED       RS232 # 4
       DATA CARRIER  43A   WHT/RED/ORG   NOT CONNECTED
       RECEIVE DATA  44A   WHT/RED/BLK   RS232 # 4
       OPTO #1 +     45A   WHT/RED/GRN   NOT CONNECTED
       OPTO #2 +     47A   WHT/RED/BLU   NOT CONNECTED

M2A        LANE 2
       RELAY N.C.    52A   BLU          RR # 8
       <35 MPH       53A   BLU/BLK
       36-45 MPH     54A   BLU/WHT
       46-55 MPH     55A   BLU/RED
```

56-65 MPH 56A BLU/WHT/ORG
66+ MPH 57A BLU/WHT/BLK
DOPPLER SIGNAL 58A BLK AR # 3
GROUND 59A BLK/WHT RETURN LINE

U3 LANE 2
RELAY N.O. 63A BLK/WHT/ORG RR # 10

M1A LANE 3
RELAY 1 N.O. 81A BLK/RED RR # 12

IR3 LANE 3
RELAY N.C. 89A BLK/RED/WHT RR # 14

M5B LANE 3
RS232 GND 93A GREEN (CABLE B) RS232 #3
RS232 XMIT 94A RED (CABLE B) RS232 #3
RS232 REC 96A WHT (CABLE B) RS232 #3

U2 LANE 3
RELAY N.O. 106A YELLOW (CABLE A) RR # 18

IR2 LANE 3
RELAY N.O. 101A BLACK (CABLE A) RR # 16

****

LOOPS
DETECTOR SYSTEMS 222B

HOV EAST	OPTO +	161A	GREEN	OR #2
HOV WEST	OPTO +	162A	WHITE	OR #4
LANE 2 (EAST)	OPTO +	163A	GREEN	OR #6
LANE 2 (WEST)	OPTO +	164A	WHITE	OR #8
LANE 3 (EAST)	OPTO +	165A	GREEN	OR #10
LANE 3 (WEST)	OPTO +	166A	WHITE	OR #12

****

AUTOSCOPE 2003

EIM-2 CONNECTOR

DB 37 PINOUT

PIN 1 24 VDC GROUND
PIN 18 24 VDC POWER

PIN 29 DET 109 LANE 3
30 DET 105 LANE 3 OR #20
31 DET 108 LANE 2 OR #19
32 DET 104 LANE 2 OR #18
OR #16

****

COMPUTER RECOGNITION SYSTEMS

TAS

****

TEMPERATURE PROBES ARE CONNECTED ON THE BRIDGE AR 10
TRAILER AR 11

WEATHER WIND SPEED AR 8
WIND DIRECTION AR 7

```
HOOKUP4A.DAT

FEBRUARY 10, 1993
MINNEAPOLIS I-394 & PENN AVE. SITE

LANE 1 IS HOV
LANE 2 IS EAST BOUND FAR
LANE 3 IS EAST BOUND NEAR

FIRST CONFIGURATION
NAME OF LOG FILE:

DETECTOR     SIGNAL                    DATA LOGGER
NAME                                CONNECTION

M5A       LANE 1 (HOV)
       RS232GND      1A    ORG          RS232 # 2 (COM 6)
       RS232XMIT     2A    ORG/GRN      RS232 # 2 (COM 6)
       RS232REC      4A    ORG/BLK      RS232 # 3 (COM 6)
       OPTO1 +       5A    ORG/WHT/BLU  NOT CONNECTED
       OPTO2 +       7A    ORG/BLK/GRN  NOT CONNECTED

M1B       LANE 1 (HOV)
       RELAY 1 N.O.  10A   ORG/BLK/WHT  RR # 2

M2B       LANE 1 (HOV)
       RELAY N.C.    23A   RED          RR # 4
       <35 MPH       24A   RED/GRN
       36-45 MPH     25A   RED/BLK      NOT CONNECTED
       46-55 MPH     26A   RED/WHT      OR #29
       56-65 MPH     27A   RED/BLK/GRN  OR #31
       66 + MPH      28A   RED/BLK/WHT  NOT CONNECTED
       DOPPLER FREQ  29A   GRN          AR # 3+
       GROUND        30A   GRN/WHT      AR # 3-

IR1       LANE 1 (HOV)

NOTE:  THIS DETECTOR NEEDS TO BE CONNECTED TO COM PORT 20
    WHICH IS RS232 #16 ON DIGICHANNEL BOX

       RECEIVE       33A   GRN/BLK      RS232 #16 (COM 20)
       RELAY N.O.    36A   GRN/BLK/WHT  RR # 6
       RX/XMT GND    37A   GRN/BLK/ORG  RS232 #16 (COM 20)
       XMT           38A   WHT          RS232 #16 (COM 20)

M4        LANE 2
       RS232 GND     41A   WHT/BLK      RS232 # 4
       TRANSMIT      42A   WHT/RED      RS232 # 4
       DATA CARRIER  43A   WHT/RED/ORG  NOT USED
       RECEIVE DATA  44A   WHT/RED/BLK  RS232 # 4
       OPTO #1 +     45A   WHT/RED/GRN  NOT CONNECTED
       OPTO #2 +     47A   WHT/RED/BLU  NOT CONNECTED

M2A       LANE 2
       RELAY N.C.    52A   BLU          RR # 8
       <35 MPH       53A   BLU/BLK
       36-45 MPH     54A   BLU/WHT      NOT CONNECTED
       46-55 MPH     55A   BLU/RED      NOT CONNECTED
```

	56-65 MPH	56A	BLU/WHT/ORG	NOT CONNECTED
	66+ MPH	57A	BLU/WHT/BLK	NOT CONNECTED
	DOPPLER SIGNAL	58A	BLK	NOT CONNECTED
	GROUND	59A	BLK/WHT	NOT CONNECTED
U3	LANE 2			
	RELAY N.O.	63A	BLK/WHT/ORG	RR #10
M1A	LANE 3			
	RELAY 1 N.O.	81A	BLK/RED	RR #12
IR3	LANE 3			
	RELAY N.C.	89A	BLK/RED/WHT	RR #14
M5B	LANE 3			
	RS232 GND	93A	GREEN (CABLE B)	RS232 # 3 (COM 7)
	RS232 XMIT	94A	RED (CABLE B)	RS232 # 3 (COM 7)
	RS232 REC	96A	WHT (CABLE B)	RS232 # 3 (COM 7)
	OPTO1 +	97A	GREEN	NOT CONNECTED
	OPTO2 +	99A	RED	NOT CONNECTED
U2	LANE 3			
	RELAY N.O.	106A	YELLOW (CABLE A)	RR #18
IR2	LANE 3			
	RELAY N.O.	101A	BLACK (CABLE A)	RR #16

****

LOOPS
DETECTOR SYSTEMS 222B

HOV EAST	OPTO +	161A	GREEN	OR # 2
HOV WEST	OPTO +	162A	WHITE	OR # 4
LANE 2 (EAST)	OPTO +	163A	GREEN	OR # 6
LANE 2 (WEST)	OPTO +	164A	WHITE	OR # 8
LANE 3 (EAST)	OPTO +	165A	GREEN	OR #10
LANE 3 (WEST)	OPTO +	166A	WHITE	OR #12

****

AUTOSCOPE 2003

EIM-2 CONNECTOR

DB 37 PINOUT

PIN 1 24 VDC GROUND
PIN 18 24 VDC POWER

PIN 29	DET 109	LANE 3	GREEN	OR #20
30	DET 105	LANE 3	WHITE	OR #18
31	DET 108	LANE 2	GREEN	OR #16
32	DET 104	LANE 2	WHITE	OR #14

****

COMPUTER RECOGNITION SYSTEMS

TRAFFIC ANALYSIS SYSTEM (TAS):

PIN 16	ZONE 1 (WEST LOOP ON LANE 2)	OR #22
14	ZONE 2 (WEST LOOP ON LANE 3)	OR #24
10	ZONE 3 (EAST LOOP ON LANE 2)	OR #26
8	ZONE 4 (EAST LOOP ON LANE 3)	OR #28

PINS 7, 9, 13, AND 15 (OF THE WIEDEMULLER CONNECTOR) ARE TIED TOGETHER AND CONNECTED TO THE 24 VOLT GROUND ON THE TERMINAL STRIP

****

TEMPERATURE PROBES ARE CONNECTED ON THE BRIDGE AR #10
TRAILER AR #11

WEATHER WIND SPEED AR # 8
WIND DIRECTION AR # 7

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HOOKUP6.TXT

MARCH 6, 1993
OLSON HIGHWAY (TH 55) AND E.LYNDALE AVE. N. SITE

LANE 1 IS SOUTHMOST THROUGH LANE WESTBOUND
LANE 2 IS MIDDLE THROUGH LANE WESTBOUND
LANE 3 REPRESENTS DETECTORS MOUNTED ON POLE 25 FT EAST OF SIGN BRIDGE

FIRST CONFIGURATION
NAME OF LOG FILE:

DETECTOR     SIGNAL                    DATA LOGGER
SYMBOL                              CONNECTION

M-1B       LANE 1 (SOUTHMOST THRU LANE WESTBOUND)
        RELAY 1 N.O.   9A    ORG/BLK/WHT    RR # 2

M-2B       LANE 1
        RELAY N.C.     23A    RED           RR # 4
        <35 MPH        24A    RED/GRN       NOT CONNECTED
        36-45 MPH      25A    RED/BLK       NOT CONNECTED
        46-55 MPH      26A    RED/WHT       NOT CONNECTED
        56-65 MPH      27A    RED/BLK/GRN   NOT CONNECTED
        66 + MPH       28A    RED/BLK/WHT   NOT CONNECTED
        DOPPLER FREQ   29A    GRN           AR # 3+
        GROUND         30A    GRN/WHT       AR # 3-

M-4B       LANE 1
        RS232 GND      1A     WHT/BLK       RS232 # 4 (COM 8)
        TRANSMIT       2A     WHT/RED       RS232 # 4 (COM 8)
        DATA CARRIER   3A     WHT/RED/ORG   NOT USED
        RECEIVE DATA   4A     WHT/RED/BLK   RS232 # 4 (COM 8)
        OPTO #1 +      5A     WHT/RED/GRN   NOT CONNECTED
        OPTO #2 +      7A     WHT/RED/BLU   NOT CONNECTED

IR-1       LANE 1
        RELAY N.O.     36A    GRN/BLK/WHT   RR # 6
        RECEIVE        33A    GRN/BLK       RS232 #16 (COM 20)
        XMT            38A    WHT           RS232 #16 (COM 20)
        RX/XMT GND     37A    GRN/BLK/ORG   RS232 #16 (COM 20)

IR-2       LANE 1
        RELAY N.O.     18A    BLACK (CABLE A) RR #16

U-2A       LANE 1
        RELAY N.O.     106A   YELLOW (CBL A)  RR #18

U-3A       LANE 1
        RELAY N.O.     17A    BLK/WHT/ORG   RR #10

M-4A       LANE 2 (MIDDLE THRU LANE WESTBOUND)
        RS232 GND      41A    WHT/BLK       RS232 # 3 (COM 7)
        TRANSMIT       42A    WHT/RED       RS232 # 3 (COM 7)
        DATA CARRIER   43A    WHT/RED/ORG   NOT USED
        RECEIVE DATA   44A    WHT/RED/BLK   RS232 # 3 (COM 7)
        OPTO 1+        45A    WHT/RED/GRN   NOT CONNECTED
        OPTO 2+        47A    WHT/RED/BLU   NOT CONNECTED
```

M-5A LANE 2

RS232 XMIT	54A	ORG/GRN	RS232 # 2 (COM 6)
RS232 REC	56A	ORG/BLK	RS232 # 2 (COM 6)
RS232 GND	53A	ORG	RS232 # 2 (COM 6)

M-6A LANE 2

OPTO 1+	61A	BLU/WHT/ORG	OR #10
OPTO 2+	63A	BLU/WHT/BLK	OR #12
OPTO 3+			NOT CONNECTED
OPTO 4+			NOT CONNECTED
OPTO 5+			NOT CONNECTED
TX	67A		RS232 # 7 (COM 11)
RX	68A		RS232 # 7 (COM 11)
SERIAL GROUND	69A		RS232 # 7 (COM 11)

IR-3 LANE 2

RELAY N.C.	51A	BLK/RED/WHT	RR #22

U-2B LANE 2

RELAY N.O.	108A	BLUE	RR #24

M-1A LANE 3 (SIDE VIEW OF WESTBOUND LANES - MIDDLE DETECTOR ON POLE)

RELAY 1 N.O.	149A	BLK/RED	RR #8

M-6B LANE 3 (SIDE VIEW OF WESTBOUND LANES - TOP DETECTOR ON POLE)

OPTO 1+	121A	RED/WHT	OR #30
OPTO 2+	122A	RED/BLK/GRN	OR #32
OPTO 3+			NOT CONNECTED
OPTO 4+			NOT CONNECTED
OPTO 5+			NOT CONNECTED
TX	128A		RS232 # 8 (COM 12)
RX	127A		RS232 # 8 (COM 12)
SERIAL GROUND	129A		RS232 # 8 (COM 12)

U-3B LANE 3 (SIDE VIEW OF RIGHT-TURN POCKET LANE - BOTTOM DETECTOR ON POLE)

RELAY N.O.	143A	BLU/WHT	RR #20

****

INDUCTIVE LOOPS
DETECTOR SYSTEMS 222B AMPLIFIERS

LANE 1 EAST ILD OPTO +	161A	GREEN	OR # 2
LANE 1 WEST ILD OPTO +	162A	WHITE	OR # 4
LANE 2 EAST ILD OPTO +	163A	GREEN	OR # 6
LANE 2 WEST ILD OPTO +	164A	WHITE	OR # 8

****

MAGNETOMETERS
SPVD MFG BY MIDIAN ELECTRONICS

LANE 1 EAST ILD	WHITE	RR #12
LANE 1 WEST ILD	GREEN	RR #14

****

AUTOSCOPE 2003 ENTER SOFTWARE RELEASE NUMBER AND DATE:______________

EIM-2 CONNECTOR
DB 37 PINOUT

PIN 1 24 VDC GROUND
PIN 18 24 VDC POWER

PIN 29	DET 109	LANE 1	GREEN	OR #14
30	DET 105	LANE 1	WHITE	OR #16
31	DET 108	LANE 2	GREEN	OR #18
32	DET 104	LANE 2	WHITE	OR #20

****

COMPUTER RECOGNITION SYSTEMS: TRAFFIC ANALYSIS SYSTEM (TAS):

PIN 16	ZONE 1 (EAST LOOP ON LANE 1)	OR #22
14	ZONE 2 (EAST LOOP ON LANE 2)	OR #24
10	ZONE 3 (WEST LOOP ON LANE 1)	OR #26
8	ZONE 4 (WEST LOOP ON LANE 2)	OR #28

OUTPUT FROM TAS SERIAL PORT 2 RS232 # 5 (COM 9)

PINS 7, 9, 13, AND 15 (OF THE WIEDEMULLER CONNECTOR) ARE TIED TOGETHER AND CONNECTED TO THE 24 VOLT GROUND ON THE TERMINAL STRIP

****

TIMEMARK VC-1 VEHICLE CLASSIFIER
LANES 1, 2, 3 (THE 3 THRU WESTBOUND LANES)

RECEIVE TO DELTA RECORDER	145A	RS232 # 6 (C0M 10)
TRANSMIT FROM DELTA RECORDER	146A	RS232 # 6 (COM 10)
RS232 GROUND	147A	RS232 # 6 (COM 10)

****

GREEN SIGNAL PHASE FROM WESTRBOUND SIGNAL AT INTERSECTION OF OLSON HWY AND
E. LYNDALE AVE. N (NORTHEAST CORNER OF INTERSECTION)

GREEN PHASE	71A	ORG/BLU/WHT	RR #26
GROUND OR REFERENCE	72A		

****

TEMPERATURE PROBES ARE CONNECTED ON THE BRIDGE AR #10
TRAILER AR #11

WEATHER WIND SPEED AR # 8
WIND DIRECTION AR # 7

****

HOOKUPI4.TXT

JUNE 29, 1993
I-4 @ SR-436, Altamonte Springs, Fla.

LANE 1 IS INSIDE LANE WESTBOUND I-4 (Fast Lane)
LANE 2 IS MIDDLE LANE WESTBOUND I-4
LANE 3 IS OUTSIDE LANE WESTBOUND I-4 (Slow Lane)

FIRST CONFIGURATION
NAME OF LOG FILE:

DETECTOR SYMBOL	SIGNAL		WIRE COLOR INTO PANEL B	CONNECTION
M-1B	LANE 1 (Semi-sidefiring, Detector mounted on support beam)			
	RELAY 1 N.O.	130A	YELLOW	RR #6
	RELAY COM	131A	ORANGE	+24 V GND
M-2B	LANE 1			
	RELAY COM	22A	VIOLET	+24 V GND
	RELAY N.C.	23A	BLUE	RR #12
	<35 MPH	24A	VIOLET	OR2 #20
	36-45 MPH	25A	GRAY	OR2 #21
	46-55 MPH	26A	RED	OR2 #22
	56-65 MPH	27A	BROWN	OR2 #23
	66 + MPH	28A	RED	OR2 #24
	DOPP. FREQ	29A	ORANGE	AR #3+
	GROUND	30A	RED	AR #3-
M-4B	LANE 1			
	RS232 GND	1A	WHITE	RS232 # 3 (COM 7)
	TRANSMIT	2A	ORANGE	RS232 # 3 (COM 7)
	DATA CARR.	3A	WHITE	NOT USED
	RECEIVE DATA	4A	GREEN	RS232 # 3 (COM 7)
	OPTO #1 +	5A	WHITE	OR1 #7
	OPTO #1 -	6A	BLUE	+24 V GND
	OPTO #2 +	7A	WHITE	OR1 #8
	OPTO #2 -	8A	GRAY	+24 V GND
IR-1	LANE 1			
	RELAY N.O.	36A	BLACK	RR #13
	RELAY COM	35A	BROWN	+24 V GND
	RECEIVE	33A	GRAY	RS232 #9 (COM 13)
	XMT	38A	BLACK	RS232 #9 (COM 13)
	RX/XMT GND	37A	GREEN	RS232 #9 (COM 13)
IR-2	LANE 1			
	RELAY N.O.	18A	GREEN	RR #14
	RELAY COM	19A	RED	+24 V GND
U-2A	LANE 1			
	RELAY N.O.	136B	WHITE	RR #10
	RELAY COM	137B	RED	+24 V GND
U-3	LANE 1			
	RELAY COM	16A	BROWN	+24 V GND
	RELAY N.O.	17A	VIOLET	RR #11

U-1 LANE 2

RLY N.C. (S)	112B	RED	RR #5
RELAY COM	113B	GREEN	+24 V GND
RLY N.C. (L)	114B	GREEN	RR #4

*NOTE: WE ARE RECORDING BOTH THE LONG VEHICLE AND SHORT VEHICLE OUTPUTS FROM THE SUMITOMO SDU-200, PENDING MORE INFORMATION FROM THE VENDOR.

M-4A LANE 2

RS232 GND	41A	WHITE	RS232 #4 (COM 8)
TRANSMIT	42A	ORANGE	RS232 #4 (COM 8)
DATA CARR	43A	WHITE	NOT USED
RCV DATA	44A	GREEN	RS232 #4 (COM 8)
OPTO 1+	45A	WHITE	OR1 #11
OPTO 1-	46A	BLUE	+24 V GND
OPTO 2+	47A	WHITE	OR1 #12
OPTO 2-	48A	GRAY	+24 V GND

M-5A LANE 2

RS232 XMIT	54A	ORANGE	RS232 #2 (COM 6)
RS232 REC	56A	GREEN	RS232 #2 (COM 6)
RS232 GND	53A	VIOLET	RS232 #2 (COM 6)
OPTO 1+	57A	VIOLET	OR1 #13
OPTO 1-	58A	BLUE	+24 V GND
OPTO 2+	59A	VIOLET	OR1 #14
OPTO 2-	60A	GRAY	+24 V GND

M-6A LANE 2

OPTO 1+	61A	VIOLET	OR1 #9
OPTO 1-	62A	YELLOW	+24 V GND
OPTO 2+	63A	RED	OR1 #10
OPTO 2-	64A	CREAM	+24 V GND
OPTO 3+	65A	ORANGE	NOT CONNECTED
OPTO 3-	66A	WHITE	NOT CONNECTED
TX	67A	BROWN	RS232 # 7 (COM 11)
RX	68A	GRAY	RS232 # 7 (COM 11)
SERIAL GND	69A	PINK	RS232 # 7 (COM 11)

IR-3 LANE 2

RELAY N.C.	51A	YELLOW	RR #15
RELAY COM	50A	GREEN	+24 V GND

U-2B LANE 2

RELAY N.O.	140B	BLACK	RR #9
RELAY COM	139B	WHT/BLK	+24 V GND

M-1A LANE 2

RELAY 1 N.O.	10A	YELLOW	RR #16
RLY 1 COM	11A	ORANGE	+24 V GND

M-6B SIDE-FIRING ACROSS ALL 6 LANES, MOUNTED ON POLE

OPTO 1+	86A	VIOLET	OR2 #1 (EB SLOW)
OPTO 1-	87A	YELLOW	+24 V GND
OPTO 2+	88A	RED	OR2 #2 (EB MIDDLE)
OPTO 2-	89A	CREAM	+24 V GND
OPTO 3+	90A	ORANGE	OR2 #3 (EB FAST)
OPTO 3-	91A	WHITE	+24 V GND

OPTO 4+	92A	VIOLET	OR2 #4 (WB FAST)
OPTO 4-	93A	YELLOW	+24 V GND
OPTO 5+	94A	RED	OR2 #5 (WB MIDDLE)
OPTO 5-	95A	CREAM	+24 V GND
OPTO 6+	96A	ORANGE	OR2 #6 (WB SLOW)
OPTO 6-	97A	WHITE	+24 V GND
TX	83A	BROWN	RS232 # 8 (COM 12)
RX	84A	GRAY	RS232 # 8 (COM 12)
SERIAL GND	85A	PINK	RS232 # 8 (COM 12)

****

INDUCTIVE LOOPS
DETECTOR SYSTEMS 222D AMPLIFIERS

LN 1 OPTO 1+ (Fast)	161A	WHITE	OR1 #1
LN 1 OPTO 2+ (Fast)	162A	GREEN	OR1 #2
LN 2 OPTO 1+ (Middle)	163A	WHITE	OR1 #3
LN 2 OPTO 2+ (Middle)	164A	GREEN	OR1 #4
LN 3 OPTO 1+ (Slow)	165A	WHITE	OR1 #5
LN 3 OPTO 2+ (Slow)	166A	GREEN	OR1 #6

****

MAGNETOMETERS
SPVD MFG BY MIDIAN ELECTRONICS

LN 1 (Fast) Unit 1 (Ch4)	121A	ORANGE	RR #8	
CHANNEL 4 COMMON	122A	VIOLET		+24 V GND
LN 1 (Fast) Unit 2 (Ch3)	123A	BLUE	RR #7	
CHANNEL 3 COMMON	124A	GREEN		+24 V GND

****

AUTOSCOPE 2003 ENTER SOFTWARE RELEASE NUMBER: 3.2.1

PIN	29	DET 116	LANE 3 (SLOW)	OR2 #7
	30	DET 113	LANE 3 (SLOW)	OR2 #8
	31	DET 110	LANE 3 (SLOW)	OR2 #9
	32			
	33	DET 117	LANE 2 (MIDDLE)	OR2 #10
	34	DET 114	LANE 2 (MIDDLE)	OR2 #11
	35	DET 111	LANE 3 (MIDDLE)	OR2 #12
	36			
	10	DET 118	LANE 1 (FAST)	OR2 #13
	11	DET 115	LANE 1 (FAST)	OR2 #14
	12	DET 112	LANE 1 (FAST)	OR2 #15
18&37		+24 V dc		
20 & 1		+24 V GND		

****

COMPUTER RECOGNITION SYSTEMS: TRAFFIC ANALYSIS SYSTEM (TAS):

PIN	16 ZONE 1	OR2 #
	14 ZONE 2	OR2 #
	10 ZONE 3	OR2 #
	8 ZONE 4	OR2 #

OUTPUT FROM TAS SERIAL PORT 2 RS232 #5 (COM 9)

PINS 7, 9, 13, AND 15 (OF THE WIEDEMULLER CONNECTOR) ARE TIED TOGETHER AND CONNECTED TO THE 24 VOLT GROUND

****

TIMEMARK VC-1 VEHICLE CLASSIFIER

RECEIVE TO DELTA RECORDER	NOT CONNECTED
TRANSMIT FROM DELTA RECORDER	NOT CONNECTED
RS232 GROUND	NOT CONNECTED

****

GREEN SIGNAL PHASE

GREEN PHASE	N/A
GROUND OR REFERENCE	N/A

****

TEMPERATURE PROBE IS CONNECTED ON THE BRIDGE AR #10

WEATHER	WIND SPEED	AR # 8
	WIND	AR # 7

****

SR436.TXT

Aug. 29, 1993
I-4 @ SR-436, Altamonte Springs, Fla.

LANE 1 IS INSIDE LANE WESTBOUND I-4 (Fast Lane)
LANE 2 IS MIDDLE LANE WESTBOUND I-4
LANE 3 IS OUTSIDE LANE WESTBOUND I-4 (Slow Lane)

FIRST CONFIGURATION
NAME OF LOG FILE:

DETECTOR SYMBOL	SIGNAL		WIRE COLOR INTO PANEL B	CONNECTION
M-2B	LANE 1			
	RELAY COM	22A	VIOLET	+24 V GND
	RELAY N.C.	23A	BLUE	RR #12
	<35 MPH	24A	VIOLET	OR2 #20
	36-45 MPH	25A	GRAY	OR2 #21
	46-55 MPH	26A	RED	OR2 #22
	56-65 MPH	27A	BROWN	OR2 #23
	66 + MPH	28A	RED	OR2 #24
	DOPP. FREQ	29A	ORANGE	AR #3+
	GROUND	30A	RED	AR #3-
M-4B	LANE 1			
	RS232 GND	1A	WHITE	RS232 # 3 (COM 7)
	TRANSMIT	2A	ORANGE	RS232 # 3 (COM 7)
	DATA CARR.	3A	WHITE	NOT USED
	RECEIVE DATA	4A	GREEN	RS232 # 3 (COM 7)
	OPTO #1 +	5A	WHITE	OR1 #7
	OPTO #1 -	6A	BLUE	+24 V GND
	OPTO #2 +	7A	WHITE	OR1 #8
	OPTO #2 -	8A	GRAY	+24 V GND
IR-1	LANE 1			
	RELAY N.O.	36A	BLACK	RR #13
	RELAY COM	35A	BROWN	+24 V GND
	RECEIVE	33A	GRAY	RS232 #9 (COM 13)
	XMT	38A	BLACK	RS232 #9 (COM 13)
	RX/XMT GND	37A	GREEN	RS232 #9 (COM 13)
IR-2	LANE 1 (Mounted in lane 2, looking at lane 1)			
	RELAY N.O.	18A	GREEN	RR #14
	RELAY COM	19A	RED	+24 V GND
U-2A	LANE 1			
	RELAY N.O.	136B	WHITE	RR #10
	RELAY COM	137B	RED	+24 V GND
U-3	LANE 1			
	RELAY COM	16A	BROWN	+24 V GND
	RELAY N.O.	17A	VIOLET	RR #11
U-1	LANE 2			
	RLY N.C. (S)	112B	RED	RR #5
	RELAY COM	113B	GREEN	+24 V GND

RLY N.C. (L)	114B	GREEN	RR #4

*NOTE: WE ARE RECORDING BOTH THE LONG VEHICLE AND SHORT VEHICLE OUTPUTS FROM THE SUMITOMO SDU-200, PENDING MORE INFORMATION FROM THE VENDOR.

M-5A LANE 2

RS232 XMIT	54A	ORANGE	RS232 #2 (COM 6)
RS232 REC	56A	GREEN	RS232 #2 (COM 6)
RS232 GND	53A	VIOLET	RS232 #2 (COM 6)
OPTO 1+	57A	VIOLET	OR1 #13
OPTO 1-	58A	BLUE	+24 V GND
OPTO 2+	59A	VIOLET	OR1 #14
OPTO 2-	60A	GRAY	+24 V GND

M-6A LANE 2

OPTO 1+	61A	VIOLET	OR1 #9
OPTO 1-	62A	YELLOW	+24 V GND
OPTO 2+	63A	RED	OR1 #10
OPTO 2-	64A	CREAM	+24 V GND
OPTO 3+	65A	ORANGE	NOT CONNECTED
OPTO 3-	66A	WHITE	NOT CONNECTED
TX	67A	BROWN	RS232 # 7 (COM 11)
RX	68A	GRAY	RS232 # 7 (COM 11)
SERIAL GND	69A	PINK	RS232 # 7 (COM 11)

IR-3 LANE 2

RELAY N.C.	51A	YELLOW	RR #15
RELAY COM	50A	GREEN	+24 V GND

U-2B LANE 2

RELAY N.O.	140B	BLACK	RR #9
RELAY COM	139B	WHT/BLK	+24 V GND

M-1A LANE 2

RELAY 1 N.O.	10A	YELLOW	RR #16
RLY 1 COM	11A	ORANGE	+24 V GND

M-6B SIDE-FIRING ACROSS ALL 6 LANES, MOUNTED ON POLE

OPTO 1+	86A	VIOLET	OR2 #1 (EB SLOW)
OPTO 1-	87A	YELLOW	+24 V GND
OPTO 2+	88A	RED	OR2 #2 (EB MIDDLE)
OPTO 2-	89A	CREAM	+24 V GND
OPTO 3+	90A	ORANGE	OR2 #3 (EB FAST)
OPTO 3-	91A	WHITE	+24 V GND
OPTO 4+	92A	VIOLET	OR2 #4 (WB FAST)
OPTO 4-	93A	YELLOW	+24 V GND
OPTO 5+	94A	RED	OR2 #5 (WB MIDDLE)
OPTO 5-	95A	CREAM	+24 V GND
OPTO 6+	96A	ORANGE	OR2 #6 (WB SLOW)
OPTO 6-	97A	WHITE	+24 V GND
TX	83A	BROWN	RS232 # 8 (COM 12)
RX	84A	GRAY	RS232 # 8 (COM 12)
SERIAL GND	85A	PINK	RS232 # 8 (COM 12)

****

INDUCTIVE LOOPS
DETECTOR SYSTEMS 222D AMPLIFIERS

LN 1 OPTO 1+ (Fast)	161A	WHITE	OR1 #1
LN 1 OPTO 2+ (Fast)	162A	GREEN	OR1 #2
LN 2 OPTO 1+ (Middle)	163A	WHITE	OR1 #3
LN 2 OPTO 2+ (Middle)	164A	GREEN	OR1 #4
LN 3 OPTO 1+ (Slow)	165A	WHITE	OR1 #5
LN 3 OPTO 2+ (Slow)	166A	GREEN	OR1 #6

****

MAGNETOMETERS
SPVD MFG BY MIDIAN ELECTRONICS

LN 1 (Fast) Unit 1 (Ch4)	121A	ORANGE	RR #8	
CHANNEL 4 COMMON	122A	VIOLET		+24 V GND
LN 1 (Fast) Unit 2 (Ch3)	123A	BLUE	RR #7	
CHANNEL 3 COMMON	124A	GREEN		+24 V GND

****

AUTOSCOPE 2003 ENTER SOFTWARE RELEASE NUMBER: 3.2.1

EIM-2 CONNECTOR
DB 37 PINOUT

PIN 1 24 VDC GROUND
PIN 18 24 VDC POWER

PIN	29	DET 109	LANE 1 (FAST)	OR2 #
	30	DET 105	LANE 1 (FAST)	OR2 #
	31	DET 108	LANE 2 (MIDDLE)	OR2 #
	32	DET 104	LANE 2 (MIDDLE)	OR2 #

****

COMPUTER RECOGNITION SYSTEMS: TRAFFIC ANALYSIS SYSTEM (TAS):

PIN	16 ZONE 1	OR2 #
	14 ZONE 2	OR2 #
	10 ZONE 3	OR2 #
	8 ZONE 4	OR2 #

OUTPUT FROM TAS SERIAL PORT 2 RS232 #5 (COM 9)

PINS 7, 9, 13, AND 15 (OF THE WIEDEMULLER CONNECTOR) ARE TIED TOGETHER AND CONNECTED TO THE 24 VOLT GROUND

****

TIMEMARK VC-1 VEHICLE CLASSIFIER

RECEIVE TO DELTA RECORDER	NOT CONNECTED
TRANSMIT FROM DELTA RECORDER	NOT CONNECTED
RS232 GROUND	NOT CONNECTED

****

GREEN SIGNAL PHASE

GREEN PHASE	RR #1
GROUND OR REFERENCE	+24 V GND

****

TEMPERATURE PROBE IS CONNECTED ON THE BRIDGE AR #10

WEATHER	WIND SPEED	AR # 8
	WIND	AR # 7

****

I-10 West at 13th Street (Phoenix Autumn 1993)

Lane 1 (Inside General Traffic Lane)

Detector	Trmnl #	Wire Color	Panel A # (Power)	Panel B # (Data)	Function	Data Logger	Notes
M4B	1	White	128		Ground		
	2	Brown	99		12 VDC		Fuse 10
	3	White		1A	RS232 Ground	COM #7	Digiboard #3
	4	Orange		2A	RS232 Transmit	COM #7	Digiboard #3
	5	White		3A	Data Carrier	Not used	
	6	Green		4A	RS232 Receive	COM #7	Digiboard #3
	7	White		5A	Opto #1 +	OR1 #7	
	8	Blue		6A	Opto #1 -		24 V GND
	9	White		7A	Opto #2 +	OR1 #8	
	10	Grey		8A	Opto #2 -		24 V GND
U3A	11	Yellow	95		12 VDC		Fuse 12
	12	Brown	126		Ground		
	13	Yellow		71A	Relay N.C.	Not used	
	14	Orange		72A	Relay Common		24 V GND
	15	Yellow		73A	Relay N.O.	RR #6	
M2B	21	Violet	77		24 VDC		Fuse 8
	22	Brown	107		Ground		
	23	Violet		21A	Relay N.O.	RR #12	
	24	Orange		22A	Relay Common		24 V GND
	25	Violet		23A	Relay N.C.	Not used	
	26	Green		24A	<35 mi/h	OR2 #20	
	27	Violet		25A	36-45 mi/h	OR2 #21	
	28	Blue		26A	46-55 mi/h	OR2 #22	
	29	Violet		27A	56 -65 mi/h	OR2 #23	
	30	Grey		28A	66+ mi/h	OR2 #24	
	31	Red		29A	Doppler Freq.		
	32	Brown		30A	Doppler Ground		
IR1	33	Red		32A	RS232 Receive	COM #13	Digiboard #9
	34	Orange		33A	RS232 Transmit	COM #13	Digiboard #9
	35	Red		34A	RS232 Ground	COM #13	Digiboard #9
	36	Green		35A	Relay N.O.	RR #13	
	37	Red		36A	Relay Common		24 V GND
	38	Blue			Ground		
	39	BLK	T1/1		115 VAC		Fuse 1
	40	CLR			AC Neutral		

1 mi/h = 1.61 km/h

I-10 Westbound at 13th Street (Phoenix Autumn 1993)

Lane 1 (Inside General Traffic Lane)

Detector	Trmnl #	Wire Color	Panel A # (Power)	Panel B # (Data)	Function	Data Logger	Notes
IR2	46	Orange		19A	Relay N.O.	RR #14	
	47	Black		20A	Relay Common		24 V GND
	48	Green			Ground		
	49	Black	T1/2		115 VAC		Fuse 2
	50	Blue			AC Neutral		
U1	L1	Red		112		RR #4	
	Com	Green		113			24 V GND
	S1	Green		114	Small Veh Count	RR #5	
U2A		White/Black		139	Relay Common		24 V GND
		Black		140	Relay N.O.	RR #10	
M6A		Green	T1/4		115 VAC		Fuse 4
		Black			AC Neutral		
		Violet		61	Range Bin 1	OR1 #9	
		Yellow		62	Opto 1 return		24 V GND
		Red		63	Range Bin 2	OR1 #10	
		Cream		64	Opto 2 return		24 V GND
		Orange		65	Range Bin 3	Not used	
		White		66	Opto 3 return		24 V GND
		Brown		67	RS232 TX	COM #11	Digiboard #7
		Gray		68	RS232 RCV	COM #11	Digiboard #7
		Pink		69	RS232 Ground	COM #11	Digiboard #7
ILD (back-1A)		White		161	Opto +	OR1 #1	
ILD (front-1B)		White		162	Opto +	OR1 #2	
Vehicle ID		Black		127	Relay N.O.	RR #3	
Camera	16	Green	T1/6		115 VAC		Fuse 14
(Autoscope)	17	Yellow			AC Neutral		
	18	Blue			Ground		

I-10 Westbound at 13th Street (Phoenix Autumn 1993)

Lane 2 (Middle General Traffic Lane)

Detector	Trmnl #	Wire Color	Panel A # (Power)	Panel B # (Data)	Function	Data Logger	Notes
M4A	1	White	127		Ground		
	2	Brown	75		12 VDC		Fuse 9
	3	White		41A	RS232 Ground	COM #8	Digiboard #4
	4	Orange		42A	RS232 Transmit	COM #8	Digiboard #4
	5	White		43A	Data Carrier	Not used	
	6	Green		44A	RS232 Receive	COM #8	Digiboard #4
	7	White		45A	Opto #1 +	OR1 #11	
	8	Blue		46A	Opto #1 -		24 V GND
	9	White		47A	Opto #2 +	OR1 #12	
	10	Grey		48A	Opto #2 -		24 V GND
U3B	11	Yellow	79		12 VDC		Fuse 7
	12	Brown	124		Ground		
	13	Yellow		15A	Relay N.C.	Not used	
	14	Orange		16A	Relay Common		24 V GND
	15	Yellow		17A	Relay N.O.	RR #11	
	16	Green			Spare		
	17	Yellow			Spare		
M5A	21	Violet	125		Ground		
	22	Brown	97		12 VDC		Fuse 11
	23	Violet		53A	RS232 Ground	COM #6	Digiboard #2
	24	Orange		54A	RS232 Transmit	COM #6	Digiboard #2
	25	Violet		55A	Data Carrier	Not used	
	26	Green		56A	RS232 Receive	COM #6	Digiboard #2
	27	Violet		57A	Opto #1 +	OR1 #13	
	28	Blue		58A	Opto #1 -		24 V GND
	29	Violet		59A	Opto #2 +	OR1 #14	
	30	Grey		60A	Opto #2 -		24 V GND
M1A	31	Red			12 VAC		12 V Xformer
	32	Brown			Ground		
	33	Red		10A	Relay N.O.	RR #16	
	34	Orange		11A	Relay Common		24 V GND
	35	Red			Spare		
IR3	36	Green		51A	Relay N.O.	RR #15	
	37	Red		50A	Relay Common		24 V GND
	38	Blue			Ground		
	39	Black	T1/3		115 VAC		Fuse 3
	40	Clear			AC Neutral		

I-10 Westbound at 13th Street (Phoenix Autumn 1993)

Lane 2 (Middle General Traffic Lane)

Detector	Trmnl #	Wire Color	Panel A # (Power)	Panel B # (Data)	Function	Data Logger	Notes
S1 (AT&T)		Red/Orange	57		24 VDC		Fuse 6
		Black/Black	109		Ground		
		Red		167	Ch 1	OR1 #15	
		Green		168	Ch 2	OR1 #16	
U2B		Red		137	Relay Common		24 V GND
		White		138	Relay N.O.	RR #9	
Mag 4		Orange		141	Relay N.O.	RR #8	
(in ILD 2A)		Purple		142			
Mag 1		Red		143	Relay N.O.	RR #7	
(in ILD 2B)		Black		144			
Temperature				133		Analog T1A	
				134		Analog T1B	
ILD (back-2A)		White		163	Opto +	OR1 #3	
ILD (front-2B)		White		164	Opto +	OR1 #4	
Vehicle ID		Black		128	Relay N.O.	RR #2	
Camera	18	Blue	T1/5		115 VAC		Fuse 13
(ADOT-Burle)	19	Yellow			AC Neutral		
	20	Grey			Ground		

Lane 3 (Outside General Traffic Lane)

Detector	Trmnl #	Wire Color	Panel A # (Power)	Panel B # (Data)	Function	Data Logger	Notes
ILD (back-3A)		White		165	Opto +	OR1 #5	
ILD (front-3B)		Green		166	Opto +	OR1 #6	

I-10 Westbound at 13th Street (Phoenix Autumn 1993)

Multilane Detectors

Detector	Trmnl #	Wire Color	Panel A # (Power)	Panel B # (Data)	Function	Data Logger	Notes
M6B		Green	T2/4		115 VAC		
(Side-firing		Black			AC Neutral		
on Lns 1,2,3)		Brown		83	RS232 TX	COM #12	Digiboard #8
		Gray		84	RS232 RCV	COM #12	Digiboard #8
		Pink		85	RS232 Ground	COM #12	Digiboard #8
		Purple		86	Range Bin 1	OR2 #2	
		Yellow		87	Opto 1 return		24 V GND
		Red		88	Range Bin 2	OR2 #3	
		Cream		89	Opto 2 return		24 V GND
		Orange		90	Range Bin 3	OR2 #4	
		White		91	Opto 3 return		24 V GND
VIP 1		Black 31			1st det zone	OR2 #5	Lane 1
(Econolite/		Black 29			1st speed zone	OR2 #6	Lane 1
Autoscope		Black 30			2nd speed zone	OR2 #7	Lane 1
2003)		Black 35			1st det zone	OR2 #8	Lane 2
		Black 33			1st speed zone	OR2 #9	Lane 2
		Black 34			2nd speed zone	OR2 #0	Lane 2
		Black 18	114		+24 VDC		
		White 20	108		24 Volt Ground		
		White 1	108		24 Volt Ground		
VIP 2						COM #9	Digiboard # 5
(CRS/TAS)						COM #9	Digiboard # 5
						COM #9	Digiboard # 5
VIP 3						COM #15	Digiboard #11
(Traficon						COM #15	Digiboard #11
CCATS-VIP2)						COM #15	Digiboard #11
VIP 4						COM #18	Digiboard #14
(Sumitomo/						COM #18	Digiboard #14
IDET-100)						COM #18	Digiboard #14

I-10 West at 13th Street (Phoenix Summer 1994)

Lane 1 (Inside General Traffic Lane)

Detector	Trmnl #	Wire Color	Panel A # (Power)	Panel B # (Data)	Function	Data Logger	Notes
M4B	1	White	128		Ground		
	2	Brown	99		12 VDC		Fuse 10
	3	White		1A	RS232 Ground	COM #7	Digiboard #3
	4	Orange		2A	RS232 Transmit	COM #7	Digiboard #3
	5	White		3A	Data Carrier	Not used	
	6	Green		4A	RS232 Receive	COM #7	Digiboard #3
	7	White		5A	Opto #1 +	OR1 #7	
	8	Blue		6A	Opto #1 -		24 V GND
	9	White		7A	Opto #2 +	OR1 #8	
	10	Grey		3A	Opto #2 -		24 V GND
U3A	11	Yellow	95		12 VDC		Fuse 12
	12	Brown	126		Ground		
	13	Yellow		71A	Relay N.C.	Not used	
	14	Orange		72A	Relay Common		24 V GND
	15	Yellow		73A	Relay N.O.	RR #6	
M2B	21	Violet	77		24 VDC		Fuse 8
	22	Brown	107		Ground		
	23	Violet		21A	Relay N.O.	RR #12	
	24	Orange		22A	Relay Common		24 V GND
	25	Violet		23A	Relay N.C.	Not used	
	26	Green		24A	<35 mi/h	OR2 #20	
	27	Violet		25A	36-45 mi/h	OR2 #21	
	28	Blue		26A	46-55 mi/h	OR2 #22	
	29	Violet		27A	56 -65 mi/h	OR2 #23	
	30	Grey		28A	66+ mi/h	OR2 #24	
	31	Red		29A	Doppler Freq.		
	32	Brown		30A	Doppler Ground		
IR1	33	Red		32A	RS232 Receive	COM #13	Digiboard #9
	34	Orange		33A	RS232 Transmit	COM #13	Digiboard #9
	35	Red		34A	RS232 Ground	COM #13	Digiboard #9
	36	Green		35A	Relay N.O.	RR #13	
	37	Red		36A	Relay Common		24 V GND
	38	Blue			Ground		
	39	Black	T1/1		115 VAC		Fuse 1
	40	Clear			AC Neutral		

1 mi/h = 1.61 km/h

I-10 Westbound at 13th Street (Phoenix Summer 1994)

Lane 1 (Inside General Traffic Lane)

Detector	Trmnl #	Wire Color	Panel A # (Power)	Panel B # (Data)	Function	Data Logger	Notes
IR2	46	Orange		19A	Relay N.O.	RR #14	
	47	Black		20A	Relay Common		24 V GND
	48	Green			Ground		
	49	Black	T1/2		115 VAC		Fuse 2
	50	Blue			AC Neutral		
U1	L1	Red		112		RR #4	
	Com	Green		113			24 V GND
	S1	Green		114	Small Veh Count	RR #5	
U2A		White/Black		139	Relay Common		24 V GND
		Black		140	Relay N.O.	RR #10	
M6A		Green	T1/4		115 VAC		Fuse 4
		Black			AC Neutral		
		Violet		61	Range Bin 1	OR1 #9	
		Yellow		62	Opto 1 return		24 V GND
		Red		63	Range Bin 2	OR1 #10	
		Cream		64	Opto 2 return		24 V GND
		Orange		65	Range Bin 3	Not used	
		White		66	Opto 3 return		24 V GND
		Brown		67	RS232 TX	COM #11	Digiboard #7
		Gray		68	RS232 RCV	COM #11	Digiboard #7
		Pink		69	RS232 Ground	COM #11	Digiboard #7
ILD		White		162	Opto +	OR1 #1	
Vehicle ID		Black		127	Relay N.O.	RR #3	
Camera	16	Green	T1/6		115 VAC		Fuse 14
(Autoscope)	17	Yellow			AC Neutral		
	18	Blue			Ground		

I-10 Westbound at 13th Street (Phoenix Summer 1994)

Lane 2 (Middle General Traffic Lane)

Detector	Trmnl #	Wire Color	Panel A # (Power)	Panel B # (Data)	Function	Data Logger	Notes
M4A	1	White	127		Ground		
	2	Brown	75		12 VDC		Fuse 9
	3	White		41A	RS232 Ground	COM #8	Digiboard #4
	4	Orange		42A	RS232 Transmit	COM #8	Digiboard #4
	5	White		43A	Data Carrier	Not used	
	6	Green		44A	RS232 Receive	COM #8	Digiboard #4
	7	White		45A	Opto #1 +	OR1 #11	
	8	Blue		46A	Opto #1 -		24 V GND
	9	White		47A	Opto #2 +	OR1 #12	
	10	Grey		48A	Opto #2 -		24 V GND
U3B	11	Yellow	79		12 VDC		Fuse 7
	12	Brown	124		Ground		
	13	Yellow		15A	Relay N.C.	Not used	
	14	Orange		16A	Relay Common		24 V GND
	15	Yellow		17A	Relay N.O.	RR #11	
	16	Green			Spare		
	17	Yellow			Spare		
M5A	21	Violet	125		Ground		
	22	Brown	97		12 VDC		Fuse 11
	23	Violet		53A	RS232 Ground	COM #6	Digiboard #2
	24	Orange		54A	RS232 Transmit	COM #6	Digiboard #2
	25	Violet		55A	Data Carrier	Not used	
	26	Green		56A	RS232 Receive	COM #6	Digiboard #2
	27	Violet		57A	Opto #1 +	OR1 #13	
	28	Blue		58A	Opto #1 -		24 V GND
	29	Violet		59A	Opto #2 +	OR1 #14	
	30	Grey		60A	Opto #2 -		24 V GND
M1A	31	Red			12 VAC		12 V Xformer
	32	Brown			Ground		
	33	Red		10A	Relay N.O.	RR #16	
	34	Orange		11A	Relay Common		24 V GND
	35	Red			Spare		
IR3	36	Green		51A	Relay N.O.	RR #15	
	37	Red		50A	Relay Common		24 V GND
	38	Blue			Ground		
	39	Black	T1/3		115 VAC		Fuse 3
	40	Clear			AC Neutral		

I-10 Westbound at 13th Street (Phoenix Summer 1994)

Lane 2 (Middle General Traffic Lane)

Detector	Trmnl #	Wire Color	Panel A # (Power)	Panel B # (Data)	Function	Data Logger	Notes
U2B		Red		137	Relay Common		24 V GND
		White		138	Relay N.O.	RR #9	
Mag 4		Orange		141	Relay N.O.	RR #8	
(in ILD 2A)		Purple		142			
Mag 1		Red		143	Relay N.O.	RR #7	
(in ILD 2B)		Black		144			
Temperature				133		Analog T1A	
				134		Analog T1B	
ILD		White		164	Opto +	OR1 #2	
Vehicle ID		Black		128	Relay N.O.	RR #2	
Camera	18	Blue	T1/5		115 VAC		Fuse 13
(ADOT-Burle)	19	Yellow			AC Neutral		
	20	Grey			Ground		

Lane 3 (Outside General Traffic Lane)

Detector	Trmnl #	Wire Color	Panel A # (Power)	Panel B # (Data)	Function	Data Logger	Notes
ILD (back-3A)		White		165	Opto +	OR1 #3	
ILD (front-3B)		Green		166	Opto +	OR1 #4	

I-10 Westbound at 13th Street (Phoenix Summer 1994)

Multilane Detectors

Detector	Trmnl #	Wire Color	Panel A # (Power)	Panel B # (Data)	Function	Data Logger	Notes
M6B		Green	T2/4		115 VAC		
(Side-firing		Black			AC Neutral		
on Lns 1,2,3)		Brown		83	RS232 TX	COM #12	Digiboard #8
		Gray		84	RS232 RCV	COM #12	Digiboard #8
		Pink		85	RS232 Ground	COM #12	Digiboard #8
		Purple		86	Range Bin 1	OR2 #2	
		Yellow		87	Opto 1 return		24 V GND
		Red		88	Range Bin 2	OR2 #3	
		Cream		89	Opto 2 return		24 V GND
		Orange		90	Range Bin 3	OR2 #4	
		White		91	Opto 3 return		24 V GND
VIP 1		Black 31			1st det zone	OR2 # 5	Lane 1
(Econolite/		Black 29			1st speed zone	OR2 # 6	Lane 1
Autoscope		Black 30			2nd speed zone	OR2 # 7	Lane 1
2003)		Black 35			1st det zone	OR2 # 8	Lane 2
		Black 33			1st speed zone	OR2 # 9	Lane 2
		Black 34			2nd speed zone	OR2 #10	Lane 2
		Black 18	114		+24 VDC		
		White 20	108		24 Volt Ground		
		White 1	108		24 Volt Ground		
VIP 3						COM #15	Digiboard #11
(Traficon/							
CCATS-VIP2)							
VIP 5						COM #14	Digiboard #10
(EVA 2000)							

Oracle Road Southbound at Auto Mall Drive

Tucson Lane 2 (Middle Lane)

Detector	Trmnl #	Wire Color	Panel A# (Power)	Panel B# (Data)	Function	Data Logger	Notes
M4A	1	White	127		12V Ground		
	2	Brown	75		12 VDC		Fuse 9
	3	White		41A	RS232 Ground	COM #8	Digiboard #4
	4	Orange		42A	RS232 Transmit	COM #8	Digiboard #4
	5	White		43A	Data Carrier	Not used	
	6	Green		44A	RS232 Receive	COM #8	Digiboard #4
	7	White		45A	Opto #1 +	OR1 #11	
	8	Blue		46A	Opto #1 -		24 V GND
	9	White		47A	Opto #2 +	OR1 #12	
	10	Grey		48A	Opto #2 -		24 V GND
U3B	11	Yellow	79		12 VDC		Fuse 7
	12	Brown	124		12V Ground		
	13	Yellow		15A	Relay N.C.	Not used	
	14	Orange		16A	Relay Common		24 V GND
	15	Yellow		17A	Relay N.O.	RR #11	
	16	Green			Spare		
	17	Yellow			Spare		
Camera	18	Blue	T1/5		115 VAC		Fuse 13
(Sumitomo)	19	Yellow			AC Neutral		
	20	Grey			Ground		
M5A	21	Violet	125		12V Ground		
	22	Brown	97		12 VDC		Fuse 11
	23	Violet		53A	RS232 Ground	COM #6	Digiboard #2
	24	Orange		54A	RS232 Transmit	COM #6	Digiboard #2
	25	Violet		55A	Data Carrier	Not used	
	26	Green		56A	RS232 Receive	COM #6	Digiboard #2
	27	Violet		57A	Opto #1 +	OR1 #13	
	28	Blue		58A	Opto #1 -		24 V GND
	29	Violet		59A	Opto #2 +	OR1 #14	
	30	Grey		60A	Opto #2 -		24 V GND
M1A	31	Red			12 VAC		12 V Xformer
	32	Brown			Ground		
	33	Red		10A	Relay N.O.	RR #16	
	34	Orange		11A	Relay Common		24 V GND
	35	Red			Spare		
IR3	36	Green		51A	Relay N.O.	RR #15	
	37	Red		50A	Relay Common		24 V GND
	38	Blue			Ground		
	39	Red	T1/3		115 VAC		Fuse 3
	40	Grey			AC Neutral		

Oracle Road Southbound at Auto Mall Drive

Tucson Lane 2 (Middle Lane)

Detector	Trmnl #	Wire Color	Panel A# (Power)	Panel B# (Data)	Function	Data Logger	Notes
IR2	46	Orange		19A	Relay N.O.	RR #14	
	47	Black		20A	Relay Common		24 V GND
	48	Green			Ground		
	49	Black	T1/2		115 VAC		Fuse 2
	50	Blue			AC Neutral		
U2A		Red		137	Relay Common		24 V GND
		White		138	Relay N.O.	RR #9	
M6A		Green	T1/4		115 VAC		Fuse 4
		Black			AC Neutral		
		Violet		61	Range Bin 1	OR1 #9	
		Yellow		62	Opto 1 Return		24 V GND
		Red		63	Range Bin 2	OR1 #10	
		Cream		64	Opto 2 Return		24 V GND
		Orange		65	Range Bin 3	Not used	
		White		66	Opto 3 Return	Not used	24 V GND
		Brown			RS232 Transmit	COM #11	Digiboard #7
		Gray		68	RS232 Receive	COM #11	Digiboard #7
		Pink		69	RS232 Ground	COM #11	Digiboard #7
Temperature				133		Analog T1A	
				134		Analog T1B	
ILD-Square		Yellow		161	2A	OR1 #1	
(front-2A)		Purple		127	(613-SS detector)	RR #3	
		Red-to-Red		181	Vehicle ID		
		Orange-to-Green		182			
ILD-Square		Yellow		162	2B	OR1 #2	
(back-2B)					(613-SS detector)		
		Red-to-Red		183			
		Orange-to-Green		184			
3M Micro Loop		Green		Direct	2C	OR2 #5	
					(272 detector)		

Oracle Road Southbound at Auto Mall Drive

Tucson Lane 3 (Curb Lane)

Detector	Trmnl #	Wire Color	Panel A# (Power)	Panel B# (Data)	Function	Data Logger	Notes
M4B	1	White	128		12V Ground		
	2	Brown	99		12 VDC		Fuse 10
	3	White		1A	RS232 Ground	COM #7	Digiboard #3
	4	Orange		2A	RS232 Transmit	COM #7	Digiboard #3
	5	White		3A	Data Carrier	Not used	
	6	Green		4A	RS232 Receive	COM #7	Digiboard #3
	7	White		5A	Opto #1 +	OR1 #7	
	8	Blue		6A	Opto #1 -		24 V GND
	9	White		7A	Opto #2 +	OR1 #8	
	10	Grey		8A	Opto #2 -		24 V GND
U3A	11	Yellow	95		12 VDC		Fuse 12
	12	Brown	126		12V Ground		
	13	Yellow		71A	Relay N.C.	N/U	
	14	Orange		72A	Relay Common		24 V GND
	15	Yellow		73A	Relay N.O.	RR #6	
Camera	16	Green	T1/6		115 VAC	Fuse 14	
(Autoscope)	17	Yellow			AC Neutral		
	18	Blue			Ground		
	19	Yellow			Spare		
	20	Grey			Spare		
M2B	21	Violet	77		24 VDC		Fuse 8
	22	Brown	107		24V Ground		
	23	Violet		21A	Relay N.C.	Not used	
	24	Orange		22A	Relay Common		24 V GND
	25	Violet		23A	Relay N.O.	RR #12	
	26	Green		24A	<35 mi/h	OR2 #20	
	27	Violet		25A	36-45 mi/h	OR2 #21	
	28	Blue		26A	46-55 mi/h	OR2 #22	
	29	Violet		27A	56-65 mi/h	OR2 #23	
	30	Grey		28A	66+ mi/h	OR2 #24	
	31	Red		29A	Doppler Freq.		
	32	Brown		30A	Doppler Ground		
IR1	33	Red		32A	RS232 Receive	COM #13	Digiboard #9
	34	Orange		33A	RS232 Transmit	COM #13	Digiboard #9
	35	Red		34A	RS232 Ground	COM #13	Digiboard #9
	36	Green		35A	Relay N.O.	RR #13	
	37	Red		36A	Relay Common		24 V GND
	38	Blue			Ground		
	39	BLK	T1/1		115 VAC		Fuse 1
	40	CLR			AC Neutral		

1 mi/h = 1.61 km/h

Oracle Road Southbound at Auto Mall Drive

Tucson Lane 3 (Curb Lane)

Detector	Trmnl #	Wire Color	Panel A# (Power)	Panel B# (Data)	Function	Data Logger	Notes
U1	L1	Red		112	Large Veh Count	RR #4	Not used
	Com	Green		113			
	S1	Green		114	Small Veh Count	RR #5	Not used
U2B		Red		137			
		White		138			
	C-/2	White/Black		139	Relay Common		24 V GND
	B+/2	Black		140	Relay N.O.	RR #10	
ILD-Square		White		163	3A	OR1 #3	
(front-3A)		Red-to-Red		185	(613-SS detector)		
		Orange-to-Green		186			
		Purple		128	Veh ID	RR #2	
ILD-Square		White		162	3B	OR1 #4	
(back-3B)					(3M 2020 detector)	COM #17	Digiboard #13
ILD-Round		White		165	3C	OR1 #5	
(back)					(272 detector)		
ILD-Round		Green		166	3D	OR1 #6	
(front)					(272 detector)		
3M MicroLoop		Green		Direct	3E	OR2 #6	
					(272 detector)		
A1 (AT&T)		Red/Orange	57		24 VDC		Fuse 6
		Black/Black	109		Ground		
		Red		167	Ch 1	OR1 #15	
		Green		168	Ch 2	OR1 #16	
Mag 1		Red		121	Relay N.O.	RR #8	
		Black		122	Relay Common		24 V GND
Mag 4		Orange		123	Relay N.O.	RR #7	
		Purple		124	Relay Common		24 V GND
Timemark		Red		76	RS232 Transmit	COM #10	Digiboard #6
Delta 1		White		77	RS232 Receive	COM #10	Digiboard #6
		Green		78	RS232 Ground	COM #10	Digiboard #6

Oracle Road Southbound at Auto Mall Drive

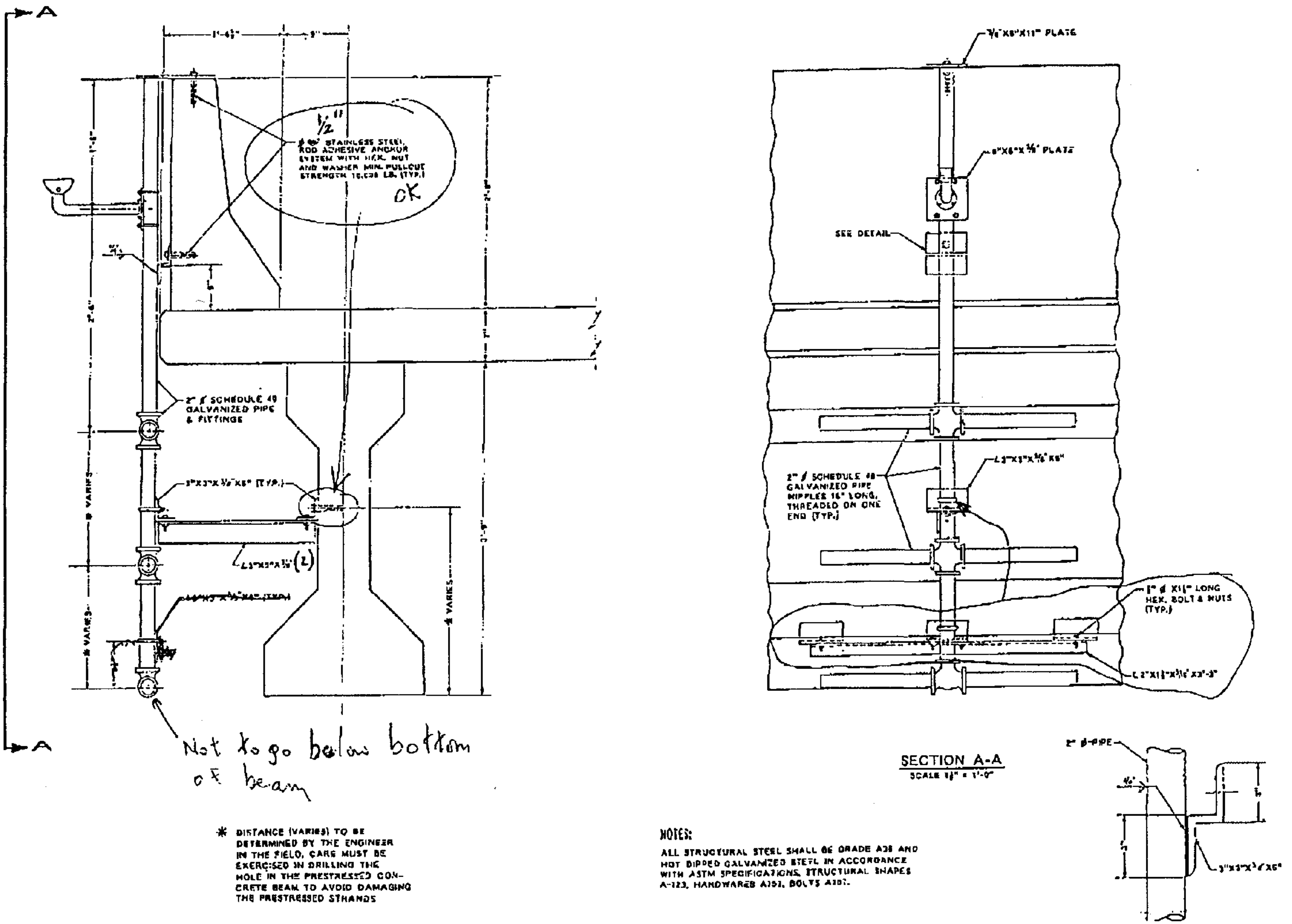
Tucson Multilane Detectors (Lanes 2 & 3)

Detector	Trmnl #	Wire Color	Panel A# (Power)	Panel B# (Data)	Function	Data Logger	Notes
M6B		Green	T2/4		115 VAC		
(side-firing		Black			AC Neutral		
on Lanes 2 & 3)		Brown		83	RS232 Transmit	COM #12	Digiboard #8
		Gray		84	RS232 Receive	COM #12	Digiboard #8
		Pink		85	RS232 Ground	COM #12	Digiboard #8
		Purple		86	Range Bin 1	OR2 #2	
		Yellow		87			24 V GND
		Red		88	Range Bin 2	OR2 #3	
		Cream		89			24 V GND
		Orange		90	Range Bin 3	OR2 #4	
		White		91			24 V GND
3-axis Fluxgate						COM #14	Digiboard #10
Mag Array							
Autoscope		Black			Lane 2 Near	OR2 #7	Det 101
2003		Black			Ln 2 Speed Trap	OR2 #8	Det 111
		Black			Lane 2 Far	OR2 #9	Det 103
		Black			Lane 3 Near	OR2 #10	Det 102
		Black			Ln 3 Speed Trap	OR2 #11	Det 112
		Black			Lane 3 Far	OR2 #12	Det 104
Traficon						COM #15	Digiboard #11
CCATS-VIP2							
Sumitomo						COM #18	Digiboard #14
IDET-100							
Grumman IIR						COM #16	Digiboard #12
Traffic Sensor							

APPENDIX I.

PIPE TREE INSTALLATION AND SR 436 AT I-4 OVERPASS CONSTRUCTION PLANS

This appendix contains the design for attaching the pipe trees to the SR 436 bridge structure above the I-4 westbound lanes, as-built drawing for I-4 at SR 436, plan view for the traffic signals at the I-4 exit ramp at SR 436, truss design for overhead signs, standard bar bending details, plan and elevation boring data for the widening of SR 436, superstructure spans for the widening of SR 436, and reinforcing bar list for the widening of SR 436.



* DISTANCE (VARIES) TO BE DETERMINED BY THE ENGINEER IN THE FIELD. CARE MUST BE EXERCISED IN DRILLING THE HOLE IN THE PRESTRESSED CONCRETE BEAM TO AVOID DAMAGING THE PRESTRESSED STRANDS

NOTES:

ALL STRUCTURAL STEEL SHALL BE GRADE A36 AND HOT DIPPED GALVANIZED STEEL IN ACCORDANCE WITH ASTM SPECIFICATIONS. STRUCTURAL SHAPES A-123, HARDWARE A153, BOLTS A307.

Figure I-1. Pipe Tree Attachment to SR 436 Overpass

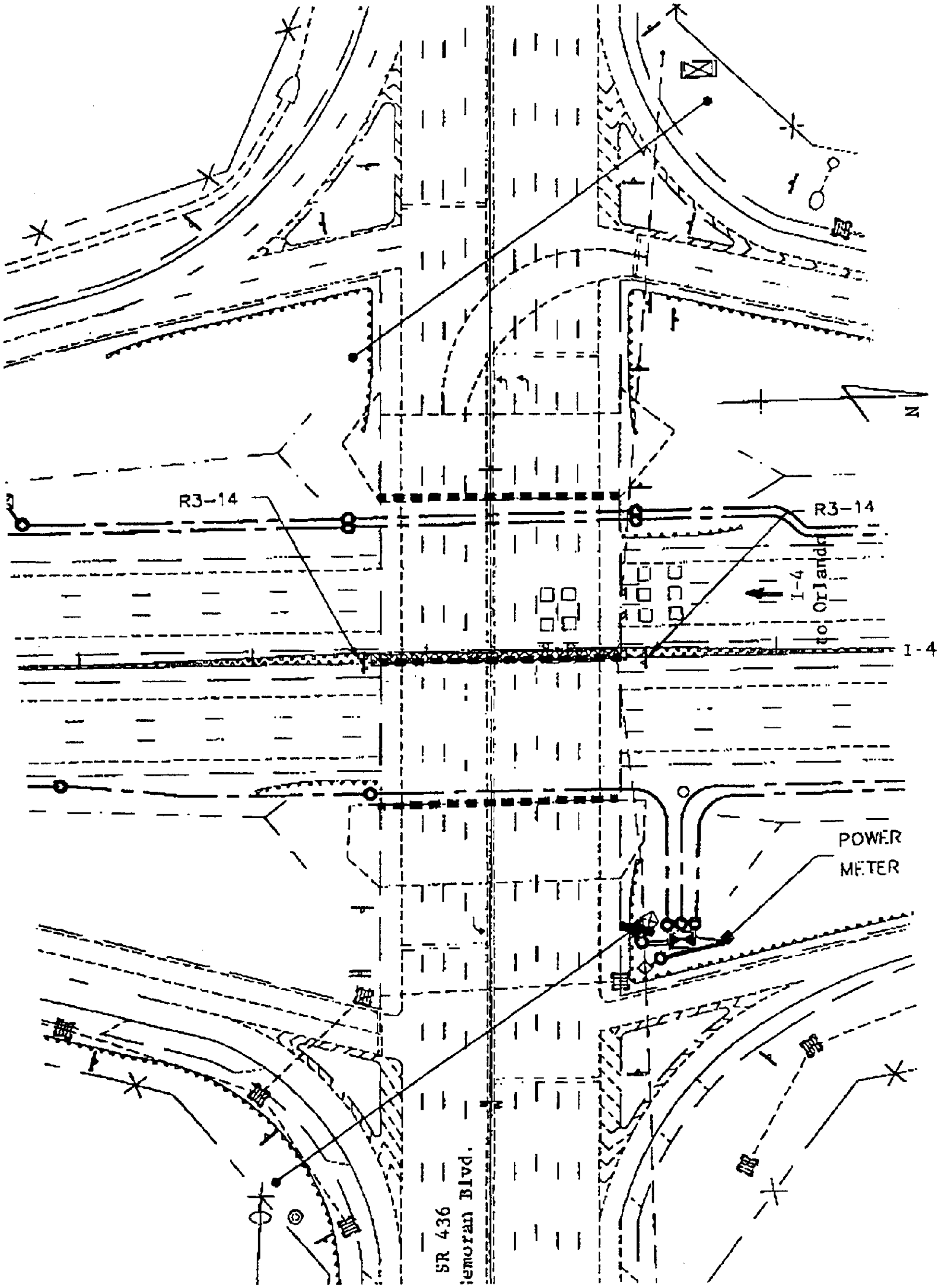


Figure I-2. As-Built Drawing for the I-4 Freeway at SR 436 in Altamonte Springs, FL

]

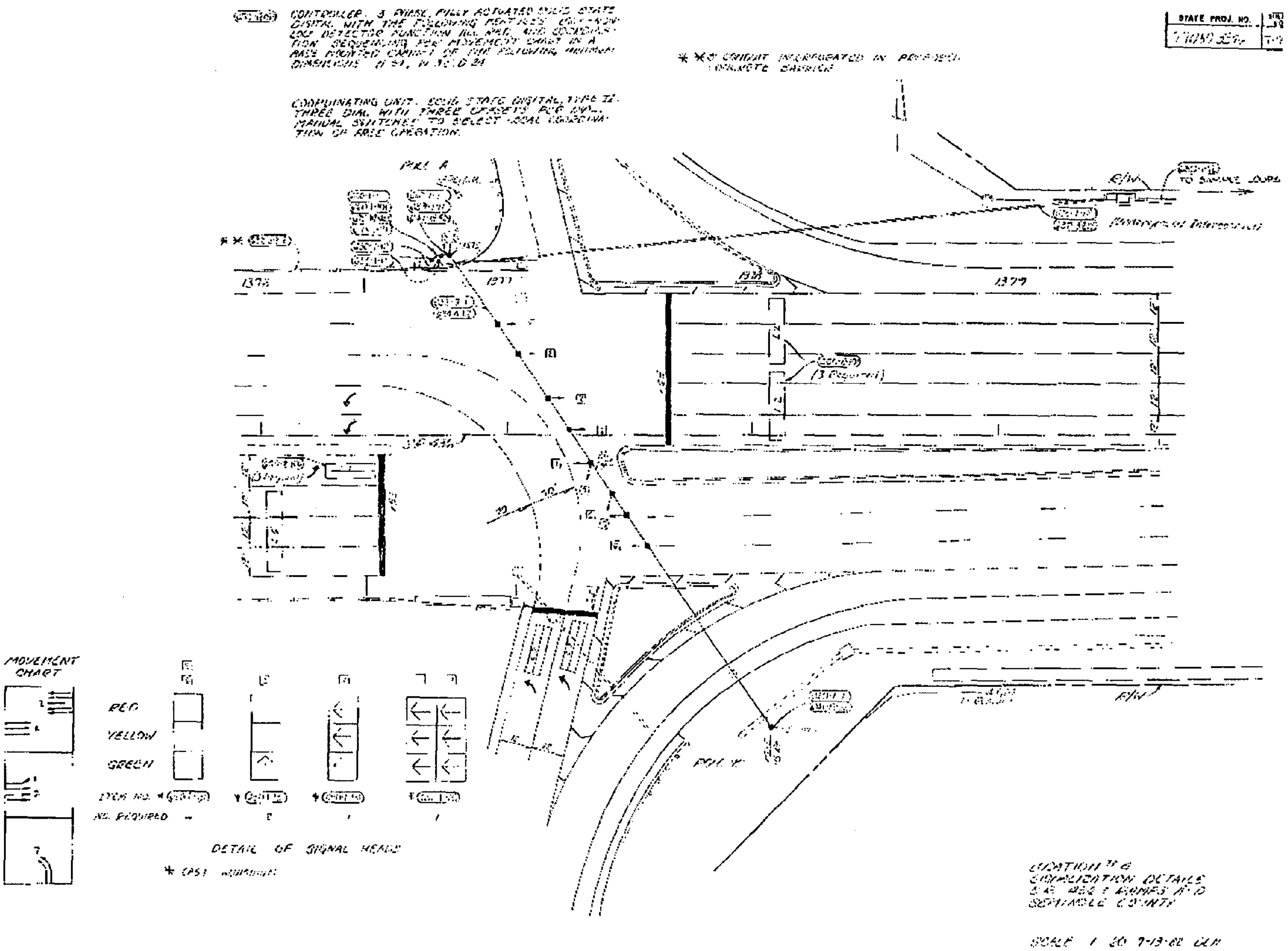
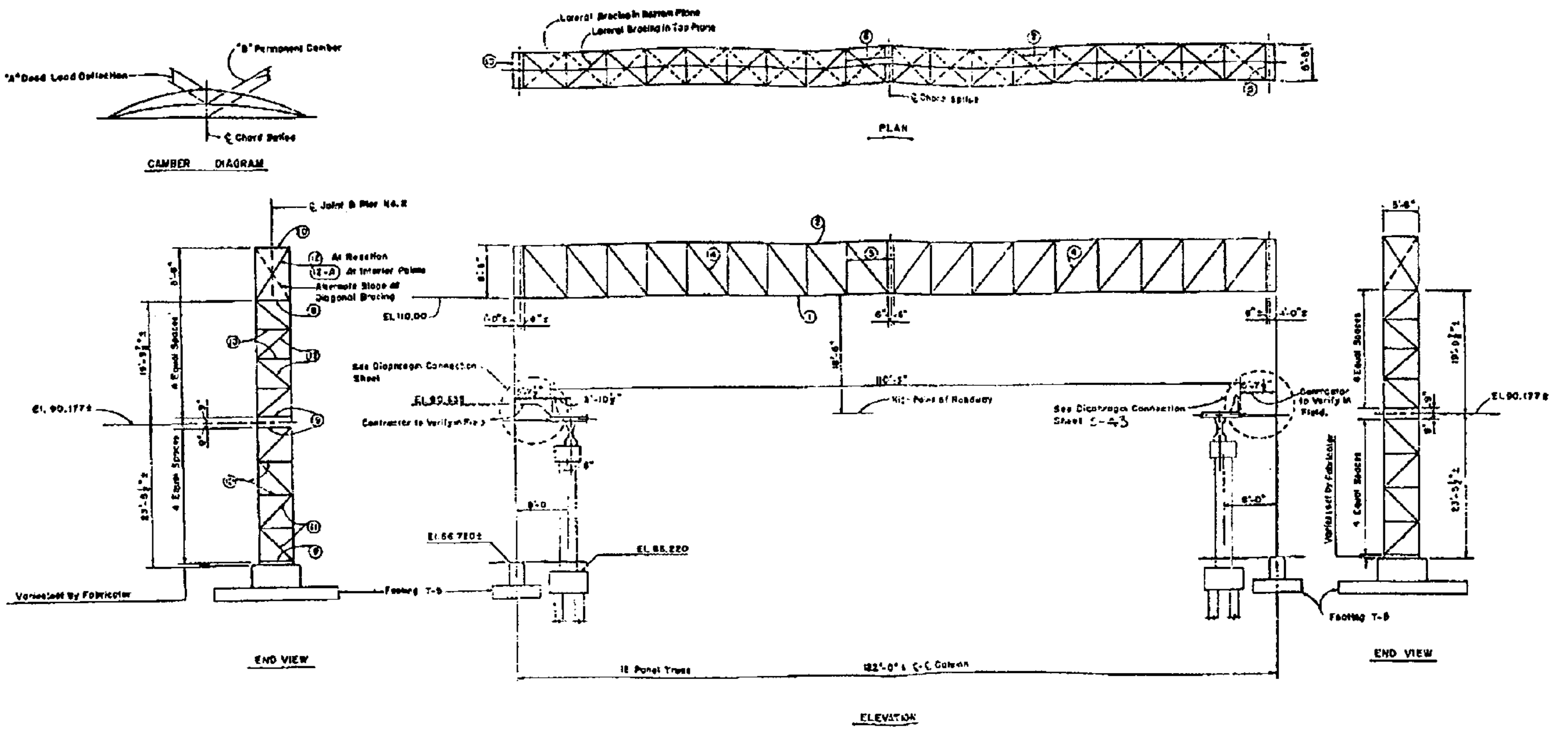


Figure I-3. Plan View of Traffic Signals at I-4 Westbound Exit Ramp at SR 436



SHEET ACCORD 5-22-73

SR 436 OVER I-4

BRIDGE NO 770006

CAMBER TABLE			SCHEDULE OF MEMBER SIZES											
A	B	TOTAL CAMBER	STA. LOCATION	1 & 2	3	4	5 & 9	6	7	8	10	11	12	12-A
1 13/16"	1 1/4"	3 1/16"	Pier No 2	6½"Ø x ½"	2¾"Ø x ⅛"	2¾"Ø x ⅛"	2½"Ø x ⅛"	1½"Ø x ⅛"	4"Ø x ⅛"	2"Ø x ¼"	1¾"Ø x ⅛"	4½"Ø x ½"	4½"Ø x ¼"	3"Ø x ⅛"

ALUMINUM TRUSS at PIER NO. 2

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION
STRUCTURES

TRUSS FOR OVERHEAD SIGNS

	SEMINOLE	77080-3520
	HBV	5-73
	CWB	5-73
	AJH	

T. Allard, Jr.

1 of 6 | 11260

Figure I-4. Truss Design for SR 436 Sign Bridge Structure

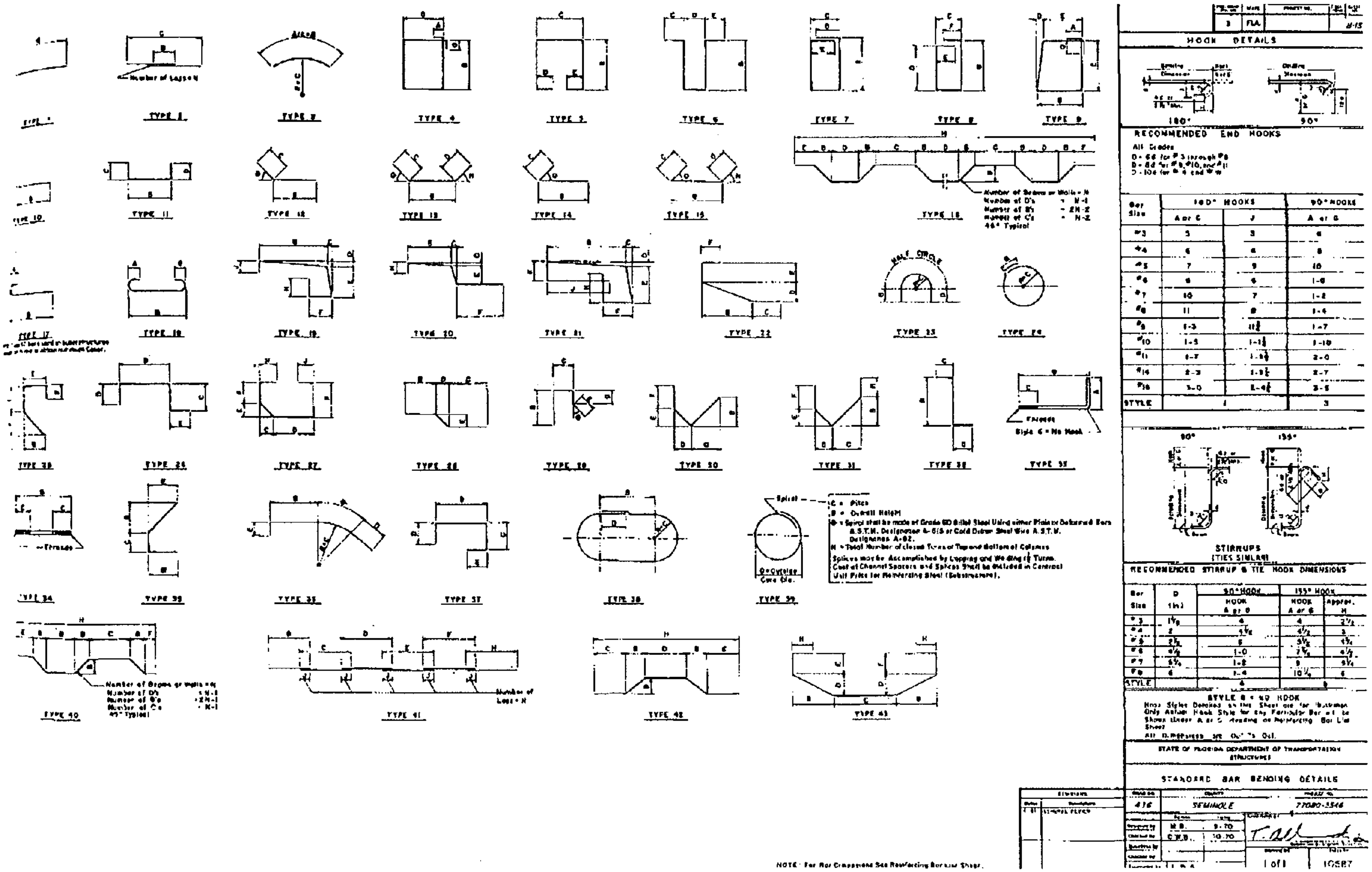


Figure I-5. Standard Bar-Bending Details

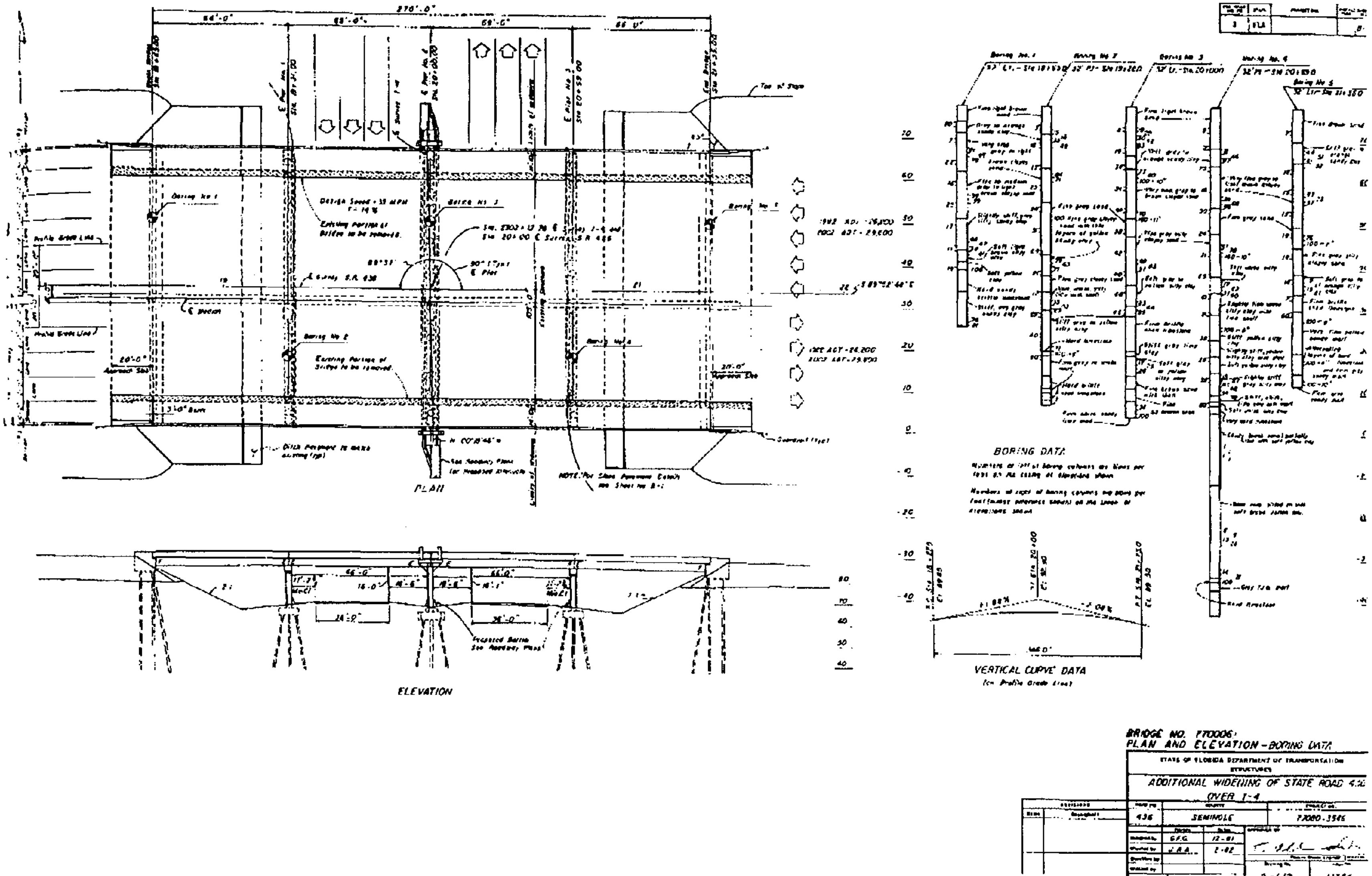


Figure I-6. Plan and Elevation Boring Data for the Widening of SR 436

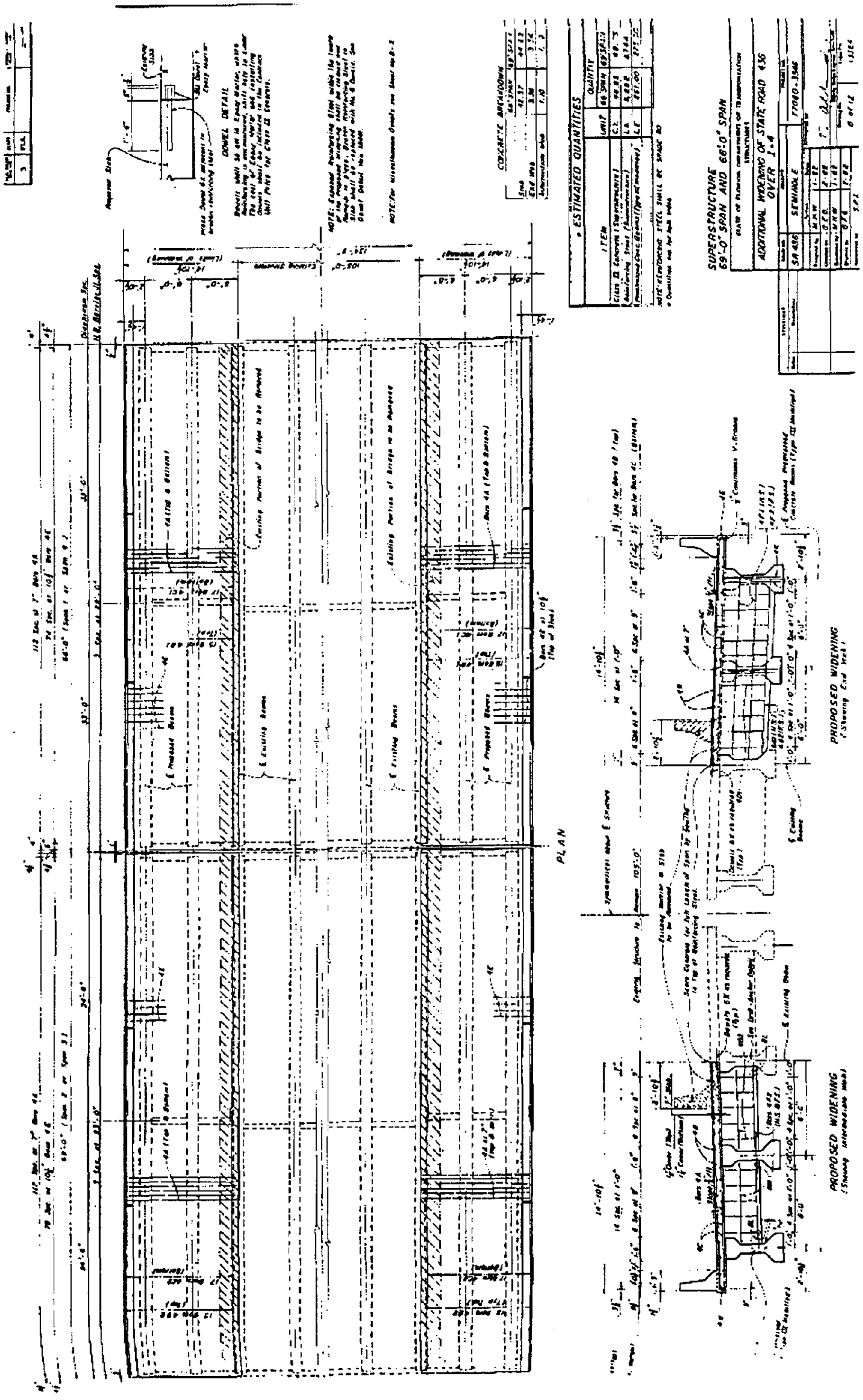
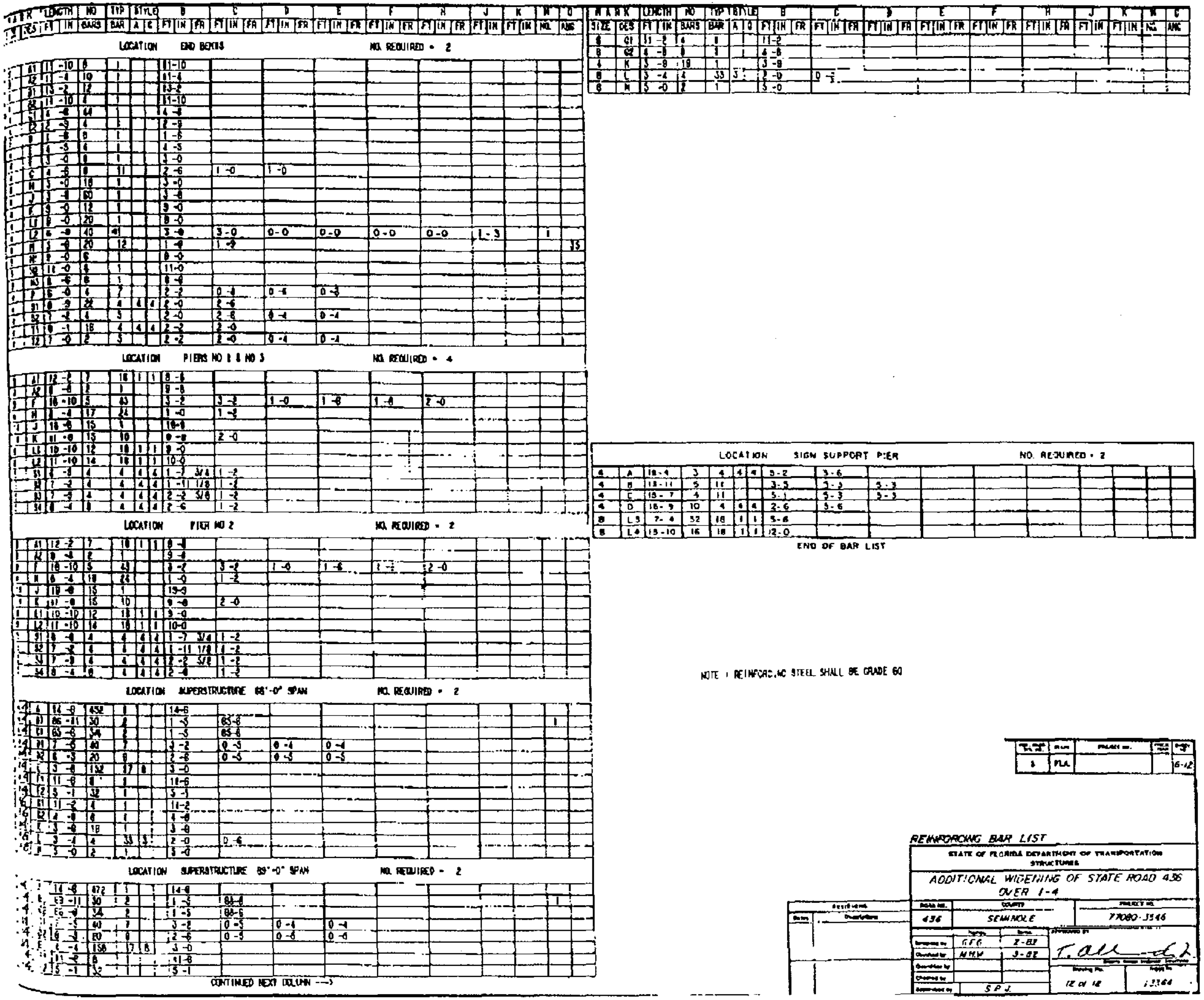


Figure I-7. Superstructure Spans for the Widening of SR 436



LOCATION END BENTS NO. REQUIRED = 2

LOCATION PIERS NO 1 & NO 3 NO. REQUIRED = 4

LOCATION PIER NO 2 NO. REQUIRED = 2

LOCATION SUPERSTRUCTURE 88'-0" SPAN NO. REQUIRED = 2

LOCATION SUPERSTRUCTURE 89'-0" SPAN NO. REQUIRED = 2

CONTINUED NEXT COLUMN —→

MARK SIZE	MARK DES	LENGTH FT IN	NO BARS	TYP BAR	STYLE A	STYLE C	B FT IN FR	C FT IN FR
6	Q1	11-2	4	1			11-2	
8	Q2	4-8	8	1			4-8	
4	K	3-8	19	1			3-8	
8	L	3-4	4	33	3		2-0	[illegible]
6	M	5-0	2	1			5-0	

LOCATION SIGN SUPPORT PIER NO. REQUIRED = 2

4	A	18-4	3	4	4	4	5-2	3-6	
4	B	18-11	5	11			3-5	3-3	5-3
4	C	18-7	4	11			5-1	5-3	5-3
4	D	16-9	10	4	4	4	2-6	5-6	
8	L3	7-4	32	18	1	1	5-6		
8	L4	15-10	16	18	1	1	12-0		

END OF BAR LIST

NOTE : REINFORCING STEEL SHALL BE GRADE 60

1	FLA.			6-12

REINFORCING BAR LIST

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION
STRUCTURES

ADDITIONAL WIDENING OF STATE ROAD 436
OVER I-4

ROAD NO.	COUNTY	PROJECT NO.
436	SEMINOLE	77080-3546

	Name	Date
Designed by	G.F.G.	2-82
Checked by	M.H.M.	3-82
Quantities by		
Checked by		
Supervised by	S.P.J.	

APPROVED BY T. All

Drawing No. 12 of 12

13344

Figure I-8. Reinforcing Bar List Used for the Widening of SR 436

APPENDIX J.

LOCAL CLIMATOLOGICAL DATA FROM FIELD SITES

Climatological data from the Minneapolis, Orlando-Altamonte Springs, Phoenix, and Tucson field sites are contained in this appendix. The data include monthly summaries of temperature, snow accumulation, precipitation, wind, sunshine, and sky cover, as well as sky cover, visibility, temperature, and wind measured in 3-hour intervals on a daily basis. The data were tabulated by the National Oceanic and Atmospheric Administration (NOAA) through the National Climatic Data Center in Asheville, North Carolina. Their address and telephone number are:

National Climatic Data Center
Federal Building
37 Battery Park Avenue
Asheville, NC 28801-2733

(704) 271-4800

Conversion factors for climatological data:

1 in = 25.4 mm
1 ft = 0.305 m
1 kn = 1852 m/h
(F-32)/1.8 = °C

NOV 1992
MINNEAPOLIS-ST.PAUL, MN
NAT'L WEA SER FCST OFC
FEDERAL AVIATION BUILDING

INTERNATIONAL AIRPORT

ISSN 0198-2745

LOCAL CLIMATOLOGICAL DATA
Monthly Summary

NOV 1992 MINNEAPOLIS–ST.PAUL, MN

LATITUDE 44° 53'N LONGITUDE 93° 13'W ELEVATION (GROUND) 834 FEET TIME ZONE CENTRAL 14922

	TEMPERATURE °F					DEGREE DAYS BASE 65°F		WEATHER TYPES 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	SNOW ICE PELLETS OR ICE ON GROUND AT 0600 INCHES	PRECIPITATION		AVERAGE STATION PRESSURE IN INCHES ELEV. 838 FEET ABOVE M.S.L.	WIND (M.P.H.)							SUNSHINE		SKY COVER (TENTHS)	
																PEAK GUST		FASTEST 1-MIN					
DATE	MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	HEATING (SEASON BEGINS WITH JUL)	COOLING (SEASON BEGINS WITH JAN)			WATER EQUIVALENT (INCHES)	SNOW, ICE PELLETS (INCHES)		RESULTANT DIR.	RESULTANT SPEED	AVERAGE SPEED	SPEED	DIRECTION	SPEED	DIRECTION	MINUTES	PERCENT OF TOTAL POSSIBLE	SUNRISE TO SUNSET	MIDNIGHT TO MIDNIGHT
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
01	42	33	38	-3	32	27	0	1 4	0	0.57	2.5	29.010	07	15.1	15.5	28	NE	20	06	0	0	10	10
02	35	33	34	-7	32	31	0	1	4	0.63	5.3	28.440	35	7.2	10.3	21	N	15	04	0	0	10	10
03	34	32	33	-7	29	32	0	1	6	0.22	1.2	28.720	27	8.5	9.0	15	W	12	25	0	0	10	10
04	33	29	31	-8	25	34	0		5	0.04	0.4	29.010	32	11.9	12.1	26	NW	16	31	2	0	10	10
05	31	26	29	-10	22	36	0		5	T	0.1	29.210	33	8.6	9.0	23	N	13	32	0	0	10	10
06	28	23	26	-12	17	39	0		5	T	0.2	29.420	04	4.1	6.9	13	E	9	06	0	0	10	10
07	27	21	24*	-14	18	41	0		5	T	T	29.370	16	5.2	6.2	13	SE	9	14	57	10	10	10
08	36	25	31	-6	26	34	0	1	5	T	T	29.170	12	10.9	11.0	21	E	15	12	2	0	10	10
09	48	35	42	5	38	23	0	1	4	0.02	0.0	29.020	14	9.2	9.6	20	SE	15	14	74	13	10	9
10	48*	35	42*	6	33	23	0	1	T	T	0.0	29.135	27	10.8	12.0	26	NW	17	30	6	1	10	10
11	46	25	36	1	28	29	0		0	0.00	0.0	29.200	21	8.9	9.5	20	SW	15	22	438	75	0	1
12	41	29	35	0	24	30	0	1 6	0	0.02	T	28.915	30	14.9	16.0	41	NW	28	31	322	56	4	5
13	32	24	28	-6	18	37	0		T	T	0.1	29.080	29	13.4	13.6	28	NW	18	31	1	0	10	8
14	30	20	25	-9	17	40	0		T	T	T	29.300	30	8.0	8.5	16	W	13	29	66	11	9	9
15	33	16	25	-8	15	40	0		0	0.00	0.0	29.375	19	2.5	4.9	12	SE	9	15	425	74	4	5
16	38	28	33	0	25	32	0		0	0.00	0.0	29.110	08	6.0	10.7	16	N	14	01	17	3	10	10
17	35	28	32	0	25	33	0	1	0	T	T	29.310	36	3.6	5.9	14	N	13	36	0	0	10	10
18	38	32	35	3	29	30	0	1	0	0.11	1.8	29.430	09	5.2	7.3			10	09	0	0	10	10
19	39	31	35	4	30	30	0	4	2	0.17	0.5	29.350	08	11.1	11.3	21	E	18	09	0	0	10	10
20	39	34	37	6	34	28	0	1 4	0	0.15	T	28.990	02	7.3	9.8	21	N	14	35	0	0	10	10
21	36	32	34	4	27	31	0		0	0.00	0.0	29.110	32	11.3	11.8	22	N	20	31	0	0	10	10
22	34	31	33	3	25	32	0		0	0.00	0.0	29.025	05	8.7	9.4	21	E	14	06	0	0	10	10
23	32	30	31	2	25	34	0		0	T	T	29.090	08	3.8	4.8	12	NE	9	08	0	0	10	10
24	36	30	33	4	26	32	0	8	T	T	T	29.250	36	3.2	4.6	10	N	7	36	0	0	10	10
25	35	27	31	3	25	34	0		0	T	T	29.225	01	12.5	13.3	26	NE	18	36	0	0	10	10
26	34	22	28	0	20	37	0		0	T	T	29.220	32	9.1	10.1	21	NW	16	35	287	52	7	7
27	36	16*	26	-1	19	39	0		0	0.00	0.0	29.260	26	4.2	4.8	12	NW	7	25	419	76	0	0
28	41	18	30	3	22	35	0	1	0	0.00	0.0	29.085	19	6.2	6.7	15	SW	13	20	398	73	1	0
29	30	19	25	-1	23	40	0	1 6	0	0.01	T	29.055	29	5.3	8.1	17	NW	13	33	0	0	9	7
30	30	19	25	-1	20	40	0	1 6	T	0.01	0.1	29.050	27	3.1	8.3	16	SW	12	16	0	0	10	8

SUM	SUM	——	——	——	TOTAL	TOTAL	NUMBER OF DAYS	TOTAL	TOTAL	FOR THE MONTH:								TOTAL	%	SUM	SUM
1077	803	——	——	——	1003	0		1.95	12.2	29.130	34	2.4	9.4	41	NW	28	31	2514	FOR	254	249
AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION	DEP.	——	——	——	——	——	DATE:12		DATE: 12		POSSIBLE	MONTH	AVG.	AVG.
35.9	26.8	31.4	-1.8	25.0	49	0	≥ .01 INCH. 11	0.66	——	——	——	——	——					17241	15	8.5	8.3

NUMBER OF DAYS				SEASON TO DATE		SNOW, ICE PELLETS	GREATEST IN 24 HOURS AND DATES				GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE	
				TOTAL	TOTAL	≥ 1.0 INCH 4						
MAXIMUM TEMP.		MINIMUM TEMP.		1811	337	THUNDERSTORMS 0	PRECIPITATION		SNOW, ICE PELLETS			
≥ 90°	≤ 32°	≤ 32°	≤ 0°	DEP.	DEP.	HEAVY FOG 0	0.74	01-02	6.5	01-02	6	03+
0	8	25	0	181	-325	CLEAR 3 PARTLY CLOUDY 3 CLOUDY 24						

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS COLS 16 & 17: PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED ONE OF TWO WIND SPEEDS IS GIVEN UNDER COLS 18 & 19: FASTEST MILE - HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTION IN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES). ERRORS WILL BE CORRECTED IN SUBSEQUENT PUBLICATIONS.

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER

Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

noaa
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE
NATIONAL CLIMATIC DATA CENTER ASHEVILLE NORTH CAROLINA

OBSERVATIONS AT 3-HOUR INTERVALS

NOV 1992 14922
MINNEAPOLIS-ST.PAUL, MN

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					NOV 1st											NOV 2nd											NOV 3rd						
03	10	50	12			41	37	31	68	08	12	10	10	5		RS	33	33	32	96	01	12	10	6	1		SF	33	33	32	96	26	9
06	10	45	7		RIP	37	35	31	79	06	12	10	5	2	8	LF	33	33	32	96	03	12	10	8	1	4	SF	33	33	32	96	26	9
09	10	14	5		RF	38	35	30	73	08	12	10	5	1	8	SPWF	33	33	32	96	01	11	10	14	15			34	32	30	85	26	9
12	10	13	2	4	RF	38	36	32	79	06	14	10	6	2	8	SF	34	34	33	96	36	10	10	17	15			34	32	29	82	28	7
15	10	14	5		RS	36	35	33	89	06	15	10	4	2	8	SF	34	34	33	96	33	7	10	23	15			34	31	27	76	27	7
18	10	9	1	8	S	33	33	32	96	07	14	10	4	1	8	SF	33	33	32	96	30	6	10	23	15			33	31	28	82	28	7
21	10	8	1	4	S	33	33	32	96	05	16	10	4	3		SF	33	33	32	96	26	6	10	13	15		S	33	31	28	82	29	6
24	10	5	1	8	S	33	33	32	96	04	12	10	3	1	8	SF	33	33	32	96	24	8	10	11	10		S	32	31	28	85	31	7
					NOV 4th											NOV 5th											NOV 6th						
03	10	10	3		S	31	30	28	89	30	9	10	39	15			28	27	24	85	31	6	10	22	12		S	26	24	19	75	30	6
06	10	10	10		S	31	30	27	85	31	11	10	27	15			28	26	23	82	34	8	10	23	15		S	25	24	23	92	31	7
09	10	19	15		S	32	29	25	75	33	12	10	41	15		S	29	27	22	75	33	9	10	17	2		S	25	23	20	81	08	6
12	10	20	15			32	29	24	72	34	13	10	31	15		S	30	26	19	64	33	9	10	36	7		SW	28	24	16	61	02	7
15	10	23	15			32	29	24	72	31	11	10	17	10		S	29	27	23	78	34	10	10	36	7		SW	26	23	17	69	36	7
18	10	25	20			31	29	24	75	31	9	10	20	15		S	28	25	20	72	32	8	10	32	10		S	25	22	15	66	07	7
21	10	29	15		S	30	28	24	78	31	7	10	20	15		S	27	25	20	75	32	6	10	38	10			24	21	14	66	07	7
24	10	37	15			29	27	24	82	33	8	10	20	12		S	26	24	20	78	29	7	10	40	10			23	21	16	75	11	4
					NOV 7th											NOV 8th											NOV 9th						
03	10	41	12			22	21	17	81	15	4	10	27	15			27	25	20	75	13	7	10	49	4		F	36	35	33	89	11	8
06	10	36	10		S	23	21	17	78	17	4	10	65	15			28	26	22	78	13	9	9	48	4		F	35	34	33	92	12	6
09	10	43	8			24	22	16	72	14	6	10	95	7			30	28	24	78	12	9	10	19	7			40	38	36	86	14	6
12	10	19	8			27	24	19	72	14	8	10	17	7		SW	32	30	26	79	11	12	10	60	7			44	41	37	77	15	9
15	10	35	8		SW	27	24	19	72	22	6	10	20	4		SW	34	32	29	82	12	11	10	33	10			47	43	39	74	12	8
18	10	39	12			25	23	19	78	14	5	10	15	6		F	34	32	30	85	11	10	10	31	10			46	44	41	83	15	8
21	10	33	10			26	24	20	78	14	6	10	18	5		F	35	33	31	85	12	11	10	28	10			47	45	42	83	14	13
24	10	38	12			25	23	18	75	13	5	10	36	4		F	36	34	32	85	12	8	10	5	4		F	46	46	45	96	17	9
					NOV 10th											NOV 11th											NOV 12th						
03	10	5	3		LF	48	48	47	96	21	8	1	UNL	20			30	28	25	82	23	5	4	UNL	7			30	30	29	96	25	4
06	10	11	10			45	44	42	89	26	8	0	UNL	12			25	24	23	92	18	7	10	7	5		RSF	34	34	33	96	33	9
09	10	17	15			39	37	33	79	28	8	0	UNL	10			32	31	28	85	21	11	9	220	12			36	34	31	82	30	16
12	10	24	15			39	35	30	70	28	14	0	UNL	15			43	37	29	58	21	11	2	UNL	12			39	33	23	53	31	24
15	10	29	15			40	35	28	62	28	10	0	UNL	15			46	39	30	54	20	12	1	UNL	12			39	32	19	45	32	20
18	10	36	10			39	34	27	62	28	9	1	UNL	15			35	33	30	82	20	9	1	UNL	15			34	29	20	57	30	12
21	10	27	10			38	34	27	65	29	9	4	UNL	15			35	33	31	85	18	5	8	UNL	15			32	27	18	56	29	14
24	9	23	15			35	31	25	67	29	8	0	UNL	15			31	30	29	92	19	8	3	UNL	15			30	26	18	61	30	15
					NOV 13th											NOV 14th											NOV 15th						
03	9	31	20			29	26	19	66	30	12	10	95	15			24	22	18	78	31	8	0	UNL	20			22	20	15	74	28	3
06	10	55	10		SW	28	25	20	72	28	13	4	UNL	15			21	20	17	85	34	7	0	UNL	20			20	19	15	81	31	4
09	10	38	8		SW	28	25	19	69	29	12	7	31	15			25	23	19	78	30	7	4	UNL	15			24	22	16	72	06	4
12	10	37	12			31	27	18	59	28	16	10	27	15			29	25	17	61	25	8	0	UNL	20			30	25	15	54	12	4
15	10	31	10		SW	30	26	18	61	31	12	10	31	15			27	23	15	61	29	11	7	UNL	20			32	26	14	47	25	7
18	10	50	15			29	25	17	61	29	12	10	29	15		S	27	24	16	63	31	8	9	UNL	15			27	24	16	63	20	5
21	8	200	15			26	24	19	75	29	9	10	36	15		S	26	23	16	66	30	8	10	250	15			28	25	17	63	14	7
24	10	200	15			25	23	17	72	29	8	9	75	15			24	21	14	66	33	6	10	100	15			29	26	19	66	15	8
					NOV 16th											NOV 17th											NOV 18th						
03	10	75	15			30	27	20	66	13	8	10	31	7			30	29	26	85	36	8	10	23	7			33	30	26	76	02	5
06	10	110	15			29	27	22	75	11	11	10	17	6		F	29	28	25	85	04	5	10	22	7			33	30	25	73	05	5
09	10	14	7			31	29	26	82	11	11	10	17	8			31	29	26	82	02	3	10	21	6		F	33	32	29	85	12	6
12	10	16	7			36	33	28	73	12	8	10	20	10			34	31	25	70	20	3	10	26	7		S	35	33	30	82	15	7
15	10	21	7			38	34	28	67	07	7	10	21	10			34	31	26	73	00	0	10	19	6		S	37	34	30	76	12	7
18	10	21	7			36	33	27	70	01	7	10	21	12			33	30	26	76	07	4	10	13	1	12	S	33	33	32	96	08	6
21	10	23	10			34	31	25	70	01	12	10	27	10			33	30	26	76	30	4	10	6	1	8	S	33	32	31	92	10	6
24	10	25	15			32	29	25	75	36	10	10	25	9			32	30	27	82	33	4	10	35	1	8	S	32	32	31	96	07	6

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.07	0.07	0.10	0.10	0.10	0.10	0.10	0.14	0.15	0.16	0.17	0.19
ENDED: DATE	03	03	03	01	01	01	01	01	02	02	02	02
ENDED: TIME	0148	0148	0255	2257	2257	2257	2257	2357	0022	0022	0112	0112

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

NOV 1992 14922
MINNEAPOLIS-ST PAUL, MN

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISI-BILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISI-BILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISI-BILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
	NOV 19th											NOV 20th											NOV 21st										
03	10	19	3		S	33	32	31	92	06	5	10	7	5		RSF	34	34	33	96	10	8	10	11	12			36	34	31	82	33	13
06	10	110	8			32	31	29	89	06	6	10	7	5		RSF	35	34	33	92	04	5	10	13	15			34	32	30	85	32	12
09	10	60	7			32	31	28	85	08	8	10	6	4		RLF	37	36	35	93	04	7	10	17	15			34	32	28	79	31	12
12	10	70	8			35	32	28	76	09	12	10	4	2	8	LF	38	38	37	96	36	8	10	18	15			35	30	22	59	31	10
15	10	70	8			38	34	29	70	09	13	10	1	1		F	37	37	37	100	34	10	10	20	15			35	32	27	73	30	10
18	10	33	5		IPS	35	33	31	85	07	10	10	3	2	8	F	36	34	32	85	35	8	10	17	15			33	30	26	76	30	8
21	10	12	7		S	35	34	32	89	09	13	10	5	5		F	36	35	34	93	01	8	10	16	15			32	29	25	75	34	5
24	10	9	4		RL	34	33	32	92	11	10	10	7	7			36	35	33	89	35	12	10	19	15			32	29	24	72	00	0
	NOV 22nd											NOV 23rd											NOV 24th										
03	10	20	15			32	29	24	72	05	4	10	19	15			31	29	24	75	06	7	10	19	10			31	30	28	89	18	3
06	10	20	15			32	29	24	72	06	8	10	17	15			30	28	24	78	14	5	10	19	10		S	31	29	26	82	33	5
09	10	17	15			32	29	25	75	07	10	10	17	15			31	29	24	75	06	4	10	20	10			31	29	26	82	18	4
12	10	15	15			33	30	25	73	07	10	10	15	12		S	31	29	25	79	11	5	10	33	10			34	31	25	70	17	3
15	10	18	15			34	31	26	73	06	10	10	17	15		S	32	29	25	75	00	0	10	37	10			35	31	25	67	36	6
18	10	19	10			33	30	26	76	05	9	10	17	10			31	29	24	75	00	0	10	22	7			35	31	25	67	35	4
21	10	23	15			33	30	25	73	04	7	10	19	12			32	29	24	72	08	3	10	33	7			34	31	25	70	35	6
24	10	19	15			31	29	24	75	04	8	10	17	10			31	30	27	85	05	4	10	33	7			33	30	26	76	36	6
	NOV 25th											NOV 26th											NOV 27th										
03	10	8	10			33	32	30	89	01	6	10	15	10		S	26	24	20	78	01	11	0	UNL	15			20	19	16	84	30	3
06	10	29	15			32	30	26	79	01	13	10	17	15			25	23	18	75	35	8	0	UNL	15			18	17	15	88	29	5
09	10	23	10			33	30	25	73	05	12	10	17	15			25	23	18	75	32	11	0	UNL	8			21	20	18	88	26	3
12	10	29	12			34	30	23	64	05	13	3	UNL	15			30	26	19	64	33	9	0	UNL	10			31	27	20	64	24	6
15	10	17	12			33	30	26	76	01	15	7	UNL	15			33	29	20	59	30	7	0	UNL	10			35	30	21	57	22	4
18	10	20	10			31	28	23	72	36	16	8	110	15			29	26	21	72	29	7	0	UNL	12			30	27	22	72	27	5
21	10	24	20			29	26	21	72	36	12	0	UNL	15			26	24	21	81	30	8	0	UNL	12			26	24	21	81	28	4
24	10	20	15		SW	27	25	20	75	35	13	0	UNL	15			22	21	18	85	29	5	0	UNL	10			23	22	20	88	25	3
	NOV 28th											NOV 29th											NOV 30th										
03	0	UNL	6		F	20	19	18	92	20	5	0	UNL	5		F	23	22	21	92	19	7	10	11	7			28	26	23	82	34	7
06	0	UNL	6		F	19	18	17	92	21	4	0	UNL	4		F	21	20	18	88	20	5	10	19	7			27	24	19	72	35	7
09	2	UNL	7			23	22	20	88	23	3	9	15	4		F	25	24	23	92	26	7	10	20	7		S	27	25	20	75	04	7
12	0	UNL	7			35	31	24	64	18	4	10	8	4		F	27	26	24	89	31	11	10	17	10			29	26	21	72	31	5
15	0	UNL	10			41	35	26	55	15	7	10	7	3		S	28	27	26	92	31	7	9	20	10			29	26	20	69	24	7
18	0	UNL	10			31	29	24	75	18	8	10	20	12		S	29	27	24	82	30	7	7	14	10			23	21	18	81	22	8
21	0	UNL	10			29	28	25	85	19	3	10	14	7		ZLS	30	28	25	82	31	7	0	UNL	12			21	20	18	88	16	10
24	0	UNL	7			27	26	25	92	21	10	10	15	10			29	28	25	85	34	6	0	UNL	12			20	19	18	92	16	6

SUMMARY BY HOURS

HOUR L.S.T.	AVERAGES							RESULTANT WIND	
	SKY COVER (TENTHS)	STATION PRESSURE (INCHES)	TEMPERATURE			REL HUMIDITY %	WIND SPEED (MPH)		
			AIR TEMP °F	WET BULB °F	DEW POINT °F			DIRECTION	SPEED (MPH)
03	8	29.130	30	28	25	83	8.2	35	1.9
06	8	29.130	29	28	25	84	8.8	35	3.0
09	9	29.150	31	29	25	80	9.4	36	2.2
12	8	29.140	34	30	25	71	10.7	34	2.2
15	8	29.110	34	31	25	71	10.1	33	3.2
18	9	29.130	32	29	25	76	9.0	33	2.5
21	8	29.130	31	29	25	78	9.1	36	2.0
24	8	29.120	30	28	25	82	8.6	34	2.1

WEATHER CODES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXP RESSED IN KNOTS (MPH=KNOTS X 1.15).

NATIONAL CLIMATIC DATA CENTER
FEDERAL BUILDING
37 BATTERY PARK AVE
ASHEVILLE, NORTH CAROLINA   28801-2733

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

FIRST CLASS
POSTAGE AND FEES PAID
NOAA
PERMIT G-19

LCD-21-14922-PD-93D9

45740
JHK & ASSOCIATES
ATTN: M SCOTT MACCALDEN JR
PO BOX 193727
SAN FRANCISCO CA   94119

NOV 1992   14922
MINNEAPOLIS-ST.PAUL, MN
USCOMM - NOAA - ASHEVILLE, NC   675

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

DATE	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												DATE
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
01	T	T		T	0.01	0.01	0.02	0.03	T	0.01	0.03	0.02	0.02	0.04	0.04	0.06	0.03	0.03	0.02	0.03	0.02	0.03	0.07	0.05	01
02	0.05	0.03	T	0.03	0.02	0.02	T	T	0.02	0.03	0.07	0.03	0.02	0.01	0.01	0.07	0.02	0.05	0.03	0.02	0.01	0.02	0.05	0.02	02
03	0.06	0.06	0.03	0.02	0.01	0.02	0.01	0.01	T											T	T	T	T	T	03
04	0.02	T	0.01	T	0.01	T	T	T	T	T									T	T	T	T	T		04
05								T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	05
06	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T						06
07		T	T		T	T	T	T	T	T	T	T	T	T	T	T	T	T							07
08												T	T	T	T	T	T								08
09																						0.02	T	T	09
10		T	T	T																					10
11																									11
12					T	0.02	T																		12
13					T	T	T	T	T	T	T		T	T	T	T	T								13
14				T	T	T									T			T	T	T	T	T	T		14
15																									15
16																									16
17											T														17
18												T	T	T	T	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	18
19	T	0.01	T	T	T												0.01	0.06	0.03	0.02	T	0.01	0.02	0.01	19
20	T	0.03	0.03	0.02	0.02	0.03	T	0.02	T	T	T	T	T	T											20
21																									21
22																									22
23												T	T		T	T	T								23
24						T	T																		24
25					T	T					T			T	T	T	T							T	25
26	T	T	T	T																					26
27																									27
28																									28
29													T	T	T	T	T	T	T	T	T	T	0.01	T	29
30	T	T			T				T	T	0.01	T													30

DEC 1992
MINNEAPOLIS-ST.PAUL, MN
NAT'L WEA SER FCST OFC
FEDERAL AVIATION BUILDING

INTERNATIONAL AIRPORT

ISSN 0198-2745

LOCAL
CLIMATOLOGICAL DATA
Monthly Summary

DEC 1992
MINNEAPOLIS-ST.PAUL, MN

LATITUDE 44° 53'N LONGITUDE 93° 13'W ELEVATION (GROUND) 834 FEET TIME ZONE CENTRAL 14922

DATE	TEMPERATURE °F					DEGREE DAYS BASE 65°F		WEATHER TYPES 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	SNOW ICE PELLETS OR ICE ON GROUND AT 0600	PRECIPITATION		AVERAGE STATION PRESSURE IN INCHES ELEV. 838 FEET ABOVE M.S.L.	WIND (M.P.H.)			PEAK GUST		FASTEST 1-MIN		SUNSHINE		SKY COVER (TENTHS)	
	MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	HEATING (SEASON BEGINS WITH JUL)	COOLING (SEASON BEGINS WITH JAN)		INCHES	WATER EQUIVALENT (INCHES)	SNOW, ICE PELLETS (INCHES)		RESULTANT DIR.	RESULTANT SPEED	AVERAGE SPEED	SPEED	DIRECTION	SPEED	DIRECTION	MINUTES	PERCENT OF TOTAL POSSIBLE	SUNRISE TO SUNSET	MIDNIGHT TO MIDNIGHT
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
01	42*	19	31	6	25	34	0		0	0.02	0.2	28.700	26	8.5	13.0	26	NW	21	30	0	0	10	10
02	33	27	30	5	19	35	0		T	T	T	29.065	31	13.4	14.2	38	NW	20	32	0	0	10	10
03	30	24	27	2	24	38	0		0	0.13	1.3	29.170	22	4.8	7.5	20	NW	14	31	0	0	10	10
04	26	9	18	-6	9	47	0		1	T	T	29.310	31	12.8	13.1			17	31	296	55	8	6
05	21	2	12	-12	6	53	0		1	0.00	0.0	29.390	22	8.3	9.3			16	22	537	100	0	1
06	28	17	23	0	20	42	0		1	0.02	0.2	29.090	23	7.1	8.8			13	22	0	0	10	10
07	28	21	25	2	19	40	0	1	1	T	T	29.230	25	4.6	6.8			12	23	0	0	10	10
08	29	20	25	3	21	40	0	1	1	T	T	29.200	15	9.8	10.6	24	SE	20	15	0	0	10	10
09	35	29	32	10	31	33	0	1	1	0.01	0.0	28.860	16	11.6	11.8	26	SE	17	16	0	0	10	10
10	36	25	31	9	27	34	0	1 6	T	T	T	28.945	30	7.0	9.3	24	NW	17	32	67	13	10	10
11	28	24	26	5	23	39	0	1 8	T	T	T	29.210	13	5.1	9.6			15	13	0	0	10	10
12	37	26	32	11	26	33	0	1 8	T	0.00	0.0	29.205	12	12.4	12.5	29	SE	20	12	85	16	10	9
13	35	33	34	14	30	31	0	1 4	0	0.27	1.1	29.310	12	11.6	12.0	22	E	17	12	0	0	10	10
14	35	33	34*	14	32	31	0	1 4	T	0.07	T	29.130	15	5.8	6.5	16	SE	14	14	0	0	10	10
15	36	30	33	14	32	32	0	1	0	0.06	0.5	28.720	25	3.3	6.9	14	NW	9	30	0	0	10	10
16	30	25	28	9	21	37	0	1	1	0.02	0.2	29.020	31	8.2	8.9	17	NW	13	33	0	0	10	10
17	28	16	22	3	15	43	0		1	T	T	29.210	28	4.8	7.1	16	W	10	30	329	62	7	6
18	26	15	21	3	20	44	0	1	1	0.12	1.2	29.070	14	8.5	9.1	24	S	15	16	53	10	10	10
19	27	1	14	-4	6	51	0	1	2	T	T	29.070	27	10.8	11.3	25	W	18	26	460	87	2	4
20	23	-4	10	-8	4	55	0		2	0.00	0.0	29.200	16	5.0	6.6	20	SE	12	13	490	93	3	4
21	33	11	22	5	18	43	0		2	0.00	0.0	28.930	24	11.3	14.4	30	S	21	21	418	79	2	5
22	36	10	23	6	15	42	0		1	0.00	0.0	28.985	24	3.2	10.2	30	NW	20	31	246	47	8	8
23	18	-8	5	-11	-4	60	0		1	0.02	0.3	29.470	30	13.7	14.5	30	NW	22	30	433	82	4	4
24	30	-11	10	-6	2	55	0		2	0.01	0.3	29.180	19	13.0	16.0	35	S	29	29	5	1	10	7
25	30	-2	14	-2	-3	51	0	9	2	T	T	29.230	29	19.1	19.6	44	W	32	29	458	87	2	3
26	17	-2	8	-7	-2	57	0		2	0.00	0.0	29.340	11	10.2	12.9	28	E	23	11	349	66	10	9
27	37	14	26	11	18	39	0		2	0.00	0.0	29.150	08	1.1	5.5	16	SE	12	11	380	72	10	8
28	21	15	18	4	14	47	0		1	0.12	2.2	29.410	36	9.6	9.8	25	N	14	36	21	4	10	8
29	28	19	24	10	21	41	0	1 6	5	0.16	1.7	29.255	30	4.4	5.5	14	NW	9	35	0	0	10	10
30	20	2	11	-3	12	54	0	1 6	5	0.02	T	29.200	29	7.1	7.6	22	NW	15	29	45	8	10	10
31	2	-12*	-5*	-18	-11	70	0	6	4	T	T	29.570	29	12.1	12.3	23	NW	16	30	492	93	7	3
	SUM	SUM	—	—	—	TOTAL	TOTAL	NUMBER OF DAYS		TOTAL	TOTAL	FOR THE MONTH:								TOTAL	%	SUM	SUM
	885	428	—	—	—	1351	0			1.05	9.2	29.155	25	3.0	10.4			32	29	5164	FOR	253	245
	AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION		DEP.	—	—	—	—	—	DATE:		DATE: 25		POSSIBLE	MONTH	AVG.	AVG.
	28.5	13.8	21.2	2.0	15.6	-69	0	≥ .01 INCH.	14	0.18	—	—	—	—	—					16447	31	8.2	7.9

NUMBER OF DAYS				SEASON TO DATE		NUMBER OF DAYS	
MAXIMUM TEMP.		MINIMUM TEMP.		TOTAL	TOTAL	SNOW, ICE PELLETS ≥ 1.0 INCH	5
≥ 90°	≤ 32°	≤ 32°	≤ 0°	3162	337	THUNDERSTORMS	0
				DEP.	DEP.	HEAVY FOG	0
0	20	29	6	112	-325	CLEAR 5 PARTLY CLOUDY 3 CLOUDY 23	

GREATEST IN 24 HOURS AND DATES				GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE	
PRECIPITATION		SNOW, ICE PELLETS			
0.30	13-14	3.9	28-29	5	30+

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS. COLS 16 & 17: PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED. ONE OF TWO WIND SPEEDS IS GIVEN UNDER COLS 18 & 19: FASTEST MILE - HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTION IN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES). ERRORS WILL BE CORRECTED IN SUBSEQUENT PUBLICATIONS.

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER

Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

noaa
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE
NATIONAL CLIMATIC DATA CENTER ASHEVILLE NORTH CAROLINA

OBSERVATIONS AT 3-HOUR INTERVALS

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
	DEC 1st											DEC 2nd											DEC 3rd										
03	10	120	10			23	22	20	88	14	5	10	25	7			30	27	22	72	31	14	10	22	15			26	23	18	72	24	3
06	10	120	15			29	26	21	72	20	10	10	29	7		SW	29	26	19	66	32	15	10	95	15			26	24	20	78	15	6
09	10	60	15			32	29	23	69	20	15	10	29	15			28	25	18	66	35	16	10	65	10			27	25	21	78	19	7
12	10	250	15			38	34	28	67	25	11	10	30	15			30	26	18	61	32	11	10	44	2	4	S	29	28	26	89	18	6
15	10	42	15			41	36	28	60	29	15	10	31	15			29	25	17	61	32	15	10	10	1		S	29	28	27	92	20	8
18	10	40	12			38	34	27	65	26	13	10	29	15			28	25	17	63	32	10	10	65	2		S	28	28	27	96	22	5
21	10	17	4		S	34	32	30	85	31	17	10	26	15			29	26	19	66	33	8	10	65	3		S	28	27	26	92	26	7
24	10	20	3		S	32	31	28	85	32	15	10	24	15			27	24	18	69	23	5	10	12	8		S	26	25	22	85	31	12
	DEC 4th											DEC 5th											DEC 6th										
03	8	60	12		S	15	14	12	88	31	14	0	UNL	20			6	5	1	80	28	6	8	200	20			19	18	14	81	20	7
06	8	19	15			12	11	8	84	30	8	0	UNL	15			2	2	-1	87	24	5	9	200	20			22	21	18	85	20	7
09	10	UNL	10			15	13	8	74	33	12	0	UNL	12			4	3	0	83	21	5	10	25	1	8	S	25	24	23	92	20	9
12	4	UNL	15			19	17	11	71	32	13	0	UNL	15			17	14	5	59	22	8	10	13	6		S	27	25	22	81	22	11
15	10	20	10			20	18	12	71	29	12	0	UNL	20			21	18	8	57	19	10	10	15	8		S	27	25	22	81	23	8
18	10	40	20			16	14	9	74	30	12	0	UNL	20			16	15	11	81	20	8	10	15	8			27	25	22	81	27	6
21	0	UNL	20			12	11	6	77	30	9	6	UNL	20			17	16	12	81	21	9	10	15	10			27	26	23	85	24	6
24	0	UNL	20			9	8	3	76	31	12	6	UNL	20			19	17	13	77	20	11	10	19	12			28	26	22	78	31	6
	DEC 7th											DEC 8th											DEC 9th										
03	10	17	12			27	25	21	78	31	6	10	7	6		SF	21	20	18	88	23	6	10	60	8			33	31	27	79	16	11
06	10	19	12			26	24	19	75	33	5	10	2	3		SF	20	20	20	100	16	7	10	21	8			35	32	28	76	17	15
09	9	17	7			25	23	18	75	30	5	10	3	1	8	SF	21	21	20	96	15	6	10	11	6		F	35	33	31	85	16	12
12	10	17	6		SF	23	21	18	81	23	8	10	5	3		F	24	23	22	92	17	9	10	6	3		LF	35	33	31	85	17	13
15	10	15	7			21	20	16	81	24	8	10	9	6		F	27	26	24	89	15	11	10	5	1	4	LF	34	33	31	89	15	8
18	10	11	7			21	20	18	88	21	4	10	12	6		F	27	26	23	85	13	13	10	5	1	4	LF	33	33	32	96	14	8
21	10	11	7		S	21	20	18	88	18	3	10	250	5		F	25	24	22	88	15	17	10	5	1	4	LF	33	32	31	92	13	8
24	10	11	6		SF	22	21	19	88	15	4	10	65	6		F	29	28	25	85	13	11	10	3	1	4	LF	32	32	32	100	14	6
	DEC 10th											DEC 11th											DEC 12th										
03	10	5	1	8	ZLSF	32	32	31	96	14	3	10	11	7		S	25	24	21	85	31	5	10	10	4		F	28	27	25	89	12	8
06	10	5	2		LF	33	32	31	92	00	0	10	10	10			24	23	20	85	03	6	3	UNL	6		F	27	26	24	89	12	6
09	10	4	1	8	F	33	33	32	96	24	4	10	9	6		SF	24	23	21	88	13	6	10	200	5		F	29	28	26	89	12	7
12	10	12	4		F	34	32	30	85	28	10	10	8	6		FH	26	25	23	88	15	7	10	200	8			34	31	26	73	11	12
15	10	19	12			33	30	26	76	29	13	10	7	3		SF	26	25	24	92	13	9	10	200	9			36	32	26	67	12	13
18	10	15	7			29	27	22	75	32	15	10	5	3		F	26	25	24	92	13	13	10	250	8			34	31	27	76	12	12
21	10	14	7			26	24	20	78	33	11	10	7	6		F	27	26	25	92	12	9	10	250	10			33	31	28	82	12	17
24	10	14	7			26	24	21	81	33	7	10	8	7			28	27	25	89	12	9	10	16	8			34	32	28	79	13	9
	DEC 13th											DEC 14th											DEC 15th										
03	10	18	7		RW	34	32	28	79	11	13	10	9	3		LF	33	32	31	92	18	5	10	7	5		F	34	34	33	96	14	6
06	10	45	7			34	32	29	82	11	10	10	7	4		RF	33	32	31	92	19	6	10	2	2		LF	35	35	34	96	17	6
09	10	16	9		RIP	34	32	30	85	11	13	10	6	6		F	34	33	31	89	21	5	10	7	6		F	35	35	34	96	22	7
12	10	15	8			34	32	30	85	12	14	10	3	1	8	F	34	33	32	92	16	6	10	9	8			36	35	33	89	24	7
15	10	14	7			34	33	31	89	14	7	10	7	6		LF	34	33	32	92	14	6	10	12	9			35	33	31	85	27	6
18	10	12	8			34	33	31	89	11	9	10	4	3		F	34	33	32	92	12	4	10	11	8			33	32	30	89	31	6
21	10	7	2		IPS	34	33	31	89	13	7	10	3	3		LF	33	33	32	96	11	6	10	9	6		F	32	31	30	92	28	5
24	10	9	3		SF	33	33	32	96	17	6	10	4	2	8	LF	33	33	32	96	12	5	10	9	1	12	SF	30	29	28	92	31	6
	DEC 16th											DEC 17th											DEC 18th										
03	10	11	5		SF	25	24	21	85	31	10	3	UNL	15			21	20	16	81	29	8	10	95	6		F	15	14	12	88	13	6
06	10	12	10			26	24	21	81	31	7	7	16	15			18	17	15	88	28	7	10	21	6		F	18	17	15	88	14	6
09	10	15	12			27	25	21	78	33	7	4	UNL	10			17	16	13	84	30	7	10	10	6		SF	22	21	19	88	13	12
12	10	14	12			28	25	20	72	32	6	10	UNL	12			20	18	13	74	30	8	10	13	6		SF	25	24	21	85	16	13
15	10	17	12			27	25	21	78	32	8	1	UNL	15			22	19	13	68	23	6	10	11	6		S	26	25	23	88	16	7
18	10	23	7			28	25	20	72	36	8	4	UNL	10			19	18	14	81	25	3	10	47	1		SF	25	24	23	92	12	7
21	10	23	7			28	26	21	75	25	5	9	UNL	12			18	17	15	88	12	3	10	16	5		F	25	24	23	92	14	8
24	10	25	7		SW	28	26	21	75	29	8	6	UNL	10			17	16	14	88	11	5	10	65	4		SWF	25	24	23	92	21	4

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.02	0.03	0.04	0.06	0.08	0.12	0.13	0.15	0.17	0.17	0.20	0.22
ENDED: DATE	29	29	13	13	13	13	13	13	13	13	13	13
ENDED: TIME	0020	0029	2210	2204	2210	2210	2210	2234	2210	2325	2309	2325

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

DEC 1992 14922
MINNEAPOLIS-ST.PAUL, MN

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					DEC 19th						
03	10	33	4		SWF	27	26	24	89	24	6
06	10	12	7		SW	22	21	18	85	28	9
09	6	23	7		S	16	14	10	77	27	14
12	0	UNL	15			13	11	4	67	27	11
15	0	UNL	15			11	8	-3	53	27	9
18	0	UNL	20			6	4	-4	63	27	13
21	0	UNL	25			3	2	-6	66	29	9
24	0	UNL	25			1	0	-7	69	26	5
					DEC 20th						
03	0	UNL	15			0	-1	-5	79	22	4
06	0	UNL	15			-1	-2	-5	83	21	4
09	0	UNL	10			1	1	-2	87	20	4
12	2	UNL	10			15	12	4	62	00	0
15	5	UNL	10			19	16	8	62	13	6
18	8	UNL	7			16	14	10	77	12	6
21	10	250	10			20	19	15	81	13	10
24	10	250	7			23	22	19	85	16	8
					DEC 21st						
03	10	95	12			32	29	22	67	19	15
06	10	250	12			29	27	23	78	20	13
09	3	UNL	12			28	26	22	78	22	12
12	0	UNL	12			32	29	22	67	26	14
15	0	UNL	12			30	27	20	66	26	15
18	10	25	12			24	22	17	75	27	12
21	1	UNL	12			16	14	8	71	30	8
24	0	UNL	12			11	10	5	77	29	8
					DEC 22nd						
03	10	250	10			11	9	4	73	00	0
06	10	250	10			13	12	8	80	13	6
09	10	70	9			19	17	13	77	13	7
12	10	50	10			29	27	23	78	15	11
15	4	UNL	15			35	31	25	67	23	13
18	4	UNL	15			29	27	22	75	30	15
21	8	120	10			18	16	11	74	32	9
24	10	12	10			17	16	13	84	29	7
					DEC 23rd						
03	7	55	7			12	10	5	73	32	12
06	10	55	2	8	SW	10	9	4	77	35	11
09	10	60	15			8	6	-1	66	31	17
12	1	UNL	20			6	4	-7	55	30	18
15	0	UNL	20			3	1	-9	57	30	18
18	0	UNL	20			-1	-2	-11	62	29	11
21	0	UNL	20			-6	-7	-14	68	28	10
24	0	UNL	20			-8	-9	-15	71	24	6
					DEC 24th						
03	0	UNL	10			-10	-11	-15	78	19	6
06	1	UNL	10			-9	-10	-13	82	13	6
09	10	250	20			0	-1	-8	69	16	14
12	10	55	15			11	8	-2	55	17	14
15	10	95	15			19	16	8	62	16	20
18	9	250	15			25	22	15	66	19	17
21	10	49	15			28	25	18	66	21	18
24	10	11	1		S	30	29	28	92	29	25
					DEC 25th						
03	6	27	6		BS	9	7	-2	61	29	24
06	9	27	6		BS	6	4	-4	63	29	20
09	10	20	2		SW	6	5	0	76	27	21
12	0	UNL	25			8	6	-5	55	31	23
15	0	UNL	25			7	5	-6	55	30	16
18	0	UNL	20			3	2	-7	63	27	14
21	0	UNL	20			1	0	-7	69	28	10
24	3	UNL	20			-1	-2	-9	68	30	7
					DEC 26th						
03	10	75	20			-1	-2	-9	68	28	7
06	10	60	20			0	-1	-9	65	00	0
09	10	50	15			1	0	-7	69	10	9
12	10	120	15			7	5	-2	66	12	11
15	10	250	15			10	8	-2	58	10	16
18	10	250	12			11	9	0	61	12	14
21	8	250	10			14	12	3	61	11	18
24	8	250	10			17	15	8	68	11	10
					DEC 27th						
03	2	UNL	15			18	16	12	77	13	5
06	6	UNL	15			19	18	16	88	26	3
09	10	140	12			21	20	18	88	19	4
12	10	200	15			30	27	21	69	20	3
15	9	UNL	12			34	30	23	64	10	5
18	10	250	7			30	28	23	75	04	6
21	8	250	7			24	23	20	85	35	6
24	5	UNL	7			20	19	17	88	33	7
					DEC 28th						
03	0	UNL	7			17	16	13	84	36	6
06	10	9	10			15	14	10	81	35	10
09	10	12	7			18	17	13	81	34	7
12	10	23	6		S	18	17	13	81	34	10
15	10	17	8			20	19	15	81	02	9
18	10	14	10			20	19	15	81	36	10
21	10	14	12			21	20	16	81	01	11
24	10	7	0	12	S	21	20	19	92	01	6
					DEC 29th						
03	10	16	6		S	22	21	20	92	33	5
06	10	15	4		F	26	25	24	92	04	4
09	10	4	1	8	ZLSF	27	27	26	96	30	6
12	10	5	2		ZLF	25	25	24	96	29	5
15	10	5	2		ZLF	23	23	22	96	28	5
18	10	6	3		ZLF	21	20	19	92	26	6
21	10	6	4		SF	20	19	18	92	27	5
24	10	5	3		ZLSF	19	19	18	96	23	4
					DEC 30th						
03	10	3	1	4	ZLF	18	18	17	96	26	3
06	10	2	0	12	F	18	18	17	96	00	0
09	10	3	1		ZLSF	19	19	18	96	26	4
12	10	9	0	12	ZLF	19	18	17	92	30	7
15	10	8	1	8	SF	17	16	15	92	31	9
18	10	11	4		S	9	8	6	88	29	9
21	10	17	12		S	5	4	0	80	30	12
24	10	19	10		S	2	1	-4	76	29	13
					DEC 31st						
03	4	UNL	20			-1	-2	-9	68	30	14
06	0	UNL	20			-5	-6	-12	71	30	13
09	3	UNL	15			-6	-7	-13	71	30	11
12	8	UNL	15			-3	-4	-11	68	29	10
15	8	250	9			-3	-4	-11	68	28	12
18	0	UNL	15			-6	-7	-14	68	30	12
21	0	UNL	15			-9	-10	-16	71	28	7
24	0	UNL	15			-12	-13	-18	74	30	7

SUMMARY BY HOURS

HOUR L.S.T.	AVERAGES							RESULTANT WIND	
	SKY COVER (TENTHS)	STATION PRESSURE (INCHES)	TEMPERATURE			REL HUMIDITY %	WIND SPEED (MPH)	DIRECTION	SPEED (MPH)
			AIR TEMP °F	WET BULB °F	DEW POINT °F				
03	8	29.150	19	18	14	81	9.0	26	3.2
06	8	29.150	19	18	14	82	8.6	25	2.1
09	8	29.180	20	18	15	82	10.4	23	3.2
12	8	29.160	23	21	16	75	11.5	23	4.2
15	8	29.140	24	22	17	74	12.0	24	3.9
18	8	29.160	22	20	16	78	11.2	26	2.9
21	8	29.160	21	19	15	81	10.7	25	1.9
24	8	29.170	20	19	15	83	9.4	26	3.1

WEATHER CODES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS. INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXP RESSED IN KNOTS (MPH=KNOTS X 1.15).

NATIONAL CLIMATIC DATA CENTER
FEDERAL BUILDING
37 BATTERY PARK AVE
ASHEVILLE, NORTH CAROLINA 28801-2733

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

FIRST CLASS
~~POSTAGE~~ AND FEES PAID
NOAA
PERMIT G-19

LCD-21-14922-PD-9309
45740
JHK & ASSOCIATES
ATTN: M SCOTT MACCALDEN JR
PO BOX 193727
SAN FRANCISCO CA 94119

DEC 1992 14922
MINNEAPOLIS-ST.PAUL, MN
USCOMM - NOAA - ASHEVILLE, NC 675

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

DATE	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												DATE
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
01																			T	T	0.01	0.01	T	T	01
02	T	T	T		T	T	T	T	T		T	T													02
03										T	0.01	0.01	0.02	0.02	0.02	0.01	0.01	T	0.01	T	0.01	0.01	T	T	03
04	T		T	T	T	T	T	T	T			T				T	T	T							04
05																									05
06								T	T	0.01	0.01	T	T	T	T	T					T				06
07												T	T	T	T				T	T	T	T	T	T	07
08	T	T	T	T	T	T	T	T	T	T	T	T													08
09							T	T				T	T	T	T	T	T	0.01	T	T	T	T	T	T	09
10	T	T	T	T		T	T																		10
11	T	T	T	T	T		T	T	T	T				T	T	T									11
12																									12
13			T				T	T	T	T	T	0.02				T				0.01	0.05	0.11	0.05	0.03	13
14	T	T	0.01	0.01	0.01	T	T	T						T	0.01	0.01	T	T	T	T	T	T	0.01	0.01	14
15	T	T	T	T	T	0.01	T	T														0.02	0.02	0.01	15
16	0.01	T	0.01	T							T	T												T	16
17	T																								17
18							T	T	T	T	T	T	0.01	0.04	0.02	0.01	0.01	0.01	0.01	T		0.01	T	T	18
19	T	T	T	T	T	T	T	T	T	T															19
20																									20
21																									21
22																									22
23						T	T	0.02	T																23
24													T									T	T	0.01	24
25	T								T	T															25
26																									26
27																									27
28										T	T	T	T									T	0.05	0.07	28
29	0.06	0.03	0.01	0.01	T	0.01	0.01	0.01	T	0.01	T	T	T	T	T	0.01	T	T	T	T	T	T	T	T	29
30	T	T	T	T			T	T	T	T	T	T	T	T	T	T	0.01	0.01	T	T	T	T	T	T	30
31	T	T	T																						31

JAN 1993 MINNEAPOLIS–ST.PAUL, MN

JAN 1993
MINNEAPOLIS-ST.PAUL, MN
NAT'L WEA SER FCST OFC
FEDERAL AVIATION BUILDING

ISSN 0198-2745

LOCAL CLIMATOLOGICAL DATA
Monthly Summary

INTERNATIONAL AIRPORT

LATITUDE 44° 53'N LONGITUDE 93° 13'W ELEVATION (GROUND) 834 FEET TIME ZONE CENTRAL 14922

DATE 1	TEMPERATURE °F MAXIMUM 2	MINIMUM 3	AVERAGE 4	DEPARTURE FROM NORMAL 5	AVERAGE DEW POINT 6	DEGREE DAYS BASE 65°F HEATING (SEASON BEGINS WITH JUL) 7A	COOLING (SEASON BEGINS WITH JAN) 7B	WEATHER TYPES 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW 8	SNOW ICE PELLETS OR ICE ON GROUND AT 0600 INCHES 9	PRECIPITATION WATER EQUIVALENT (INCHES) 10	SNOW, ICE PELLETS (INCHES) 11	AVERAGE STATION PRESSURE IN INCHES ELEV. 838 FEET ABOVE M.S.L. 12	WIND (M.P.H.) RESULTANT DIR. 13	RESULTANT SPEED 14	AVERAGE SPEED 15	PEAK GUST SPEED 16	DIRECTION 17	FASTEST 1-MIN SPEED 18	DIRECTION 19	SUNSHINE MINUTES 20	PERCENT OF TOTAL POSSIBLE 21	SKY COVER (TENTHS) SUNRISE TO SUNSET 22	MIDNIGHT TO MIDNIGHT 23
01	4	-16*	-6*	-19	-12	71	0		4	T	T	29.710	12	2.6	4.9	14	E	12	10	464	87	0	2
02	29	4	17	5	16	48	0	1 4 6	4	0.02	T	29.180	14	11.5	12.0	24	SE	17	15	0	0	10	10
03	33	15	24	12	26	41	0	1 6	4	0.02	T	28.940	27	2.7	6.5	24	NW	15	31	126	24	10	10
04	15	2	9	-3	1	56	0	6	4	0.00	0.0	29.200	31	10.4	10.5	22	NW	17	31	476	89	4	5
05	16	2	9	-3	4	56	0	6	4	T	0.1	29.385	30	2.8	4.2	10	N	7	34	336	63	10	8
06	9	-7	1	-11	-4	64	0	6	4	0.00	0.0	29.330	22	7.2	7.6	15	S	13	22	485	90	2	2
07	11	-5	3	-9	-2	62	0	1	4	T	T	29.260	22	3.8	4.2	9	SE	8	26	426	79	5	3
08	14	-9	3	-9	-1	62	0	1	4	0.00	0.0	29.460	02	3.3	5.3	15	N	12	03	412	76	5	5
09	16	8	12	0	2	53	0		4	0.00	0.0	29.690	03	11.7	12.1	22	NE	17	05	372	69	10	10
10	18	7	13	2	3	52	0		4	0.00	0.0	29.680	05	7.9	8.1	15	NE	12	06	444	82	6	6
11	22	7	15	4	10	50	0		4	0.05	0.8	29.490	10	10.6	11.1	21	E	16	09	331	61	10	10
12	28	20	24	13	21	41	0		6	0.63	6.2	29.170	06	13.0	13.3	23	NE	18	04	201	37	10	10
13	27	19	23	12	20	42	0		10	0.13	1.6	29.210	35	10.0	10.4	28	N	15	34	302	55	10	10
14	24	-1	12	1	11	53	0		11	0.02	0.6	29.350	25	5.2	6.6	16	SW	12	24	409	74	9	7
15	16	-6	5	-6	0	60	0	1 8	11	T	T	29.220	18	4.6	5.9	14	S	9	18	501	91	0	4
16	27	11	19	8	14	46	0	1 8	11	T	T	28.945	25	10.9	15.4	24	NW	20	31	482	87	5	5
17	14	-6	4	-7	-2	61	0		11	0.00	0.0	29.330	29	8.5	10.3	21	W	16	31	555	100	1	0
18	20	-9	6	-5	1	59	0		10	0.00	0.0	29.520	16	7.3	8.5	22	S	16	20	307	55	10	9
19	25	11	18	7	9	47	0		10	0.00	0.0	29.610	17	7.8	8.8	18	S	15	19	366	65	6	5
20	32	9	21	10	14	44	0	1 6	10	0.17	0.0	29.325	11	9.6	9.8	18	SE	15	10	229	41	10	9
21	32	27	30	18	29	35	0	1 6	10	0.07	0.9	28.980	22	4.8	6.1	20	SW	14	24	102	18	10	10
22	32	19	26	14	22	39	0	1 6	10	0.00	0.0	28.980	20	4.7	8.6	24	E	12	08	477	84	2	5
23	36	18	27	15	23	38	0	6	10	0.07	0.7	28.860	35	8.4	15.6	38	NW	25	33	28	5	10	7
24	20	0	10	-2	5	55	0		10	0.00	0.0	29.320	27	7.3	8.2	20	NW	15	31	555	97	3	2
25	22	-7	8	-4	3	57	0	1	10	0.00	0.0	29.420	16	6.6	8.0	23	S	18	16	457	80	2	3
26	39	17	28	16	23	37	0	1	10	0.01	0.1	29.010	27	11.8	16.6	39	W	23	26	231	40	7	5
27	24	8	16	4	11	49	0		9	0.06	1.0	29.170	11	2.1	6.5	14	E	14	10	30	5	10	8
28	28	-2	13	0	8	52	0	1	9	0.00	0.0	29.250	30	13.9	14.5	35	NW	26	31	505	87	5	5
29	14	-10	2	-11	-3	63	0		9	0.00	0.0	29.580	22	9.8	10.4	20	SW	15	22	582	100	0	0
30	39	12	26	13	20	39	0		9	0.00	0.0	29.145	23	14.0	14.3	24	SW	20	22	509	87	5	5
31	45*	34	40*	27	30	25	0		8	0.00	0.0	29.050	29	11.1	11.5	25	W	16	28	488	83	7	5
	SUM	SUM				TOTAL	TOTAL	NUMBER OF DAYS		TOTAL	TOTAL	FOR THE MONTH:								TOTAL	%	SUM	SUM
	731	172				1557	0			1.25	12.0	29.280	25	1.6	9.6	39	W	26	31	11188	FOR	194	185
	AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION		DEP.						DATE:26		DATE: 28		POSSIBLE	MONTH	AVG.	AVG.
	23.6	5.5	14.6	2.8	9.5	-92	0	≥ .01 INCH.	11	0.30										17220	65	6.3	6.0

NUMBER OF DAYS				SEASON TO DATE		SNOW, ICE PELLETS ≥ 1.0 INCH	3	GREATEST IN 24 HOURS AND DATES				GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE	
				TOTAL	TOTAL								
MAXIMUM TEMP.		MINIMUM TEMP.		4719	0	THUNDERSTORMS	0	PRECIPITATION		SNOW, ICE PELLETS			
≥ 90°	≤ 32°	≤ 32°	≤ 0°	DEP.	DEP.	HEAVY FOG	0	0.64	11-12	6.2	12	11	17+
0	26	30	12	-46	0	CLEAR 8	PARTLY CLOUDY 10	CLOUDY 13					

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
\+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS. COLS 16 & 17: PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED. ONE OF TWO WIND SPEEDS IS GIVEN UNDER COLS 18 & 19: FASTEST MILE - HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTION IN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES). ERRORS WILL BE CORRECTED IN SUBSEQUENT PUBLICATIONS.

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER

Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

noaa
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE
NATIONAL CLIMATIC DATA CENTER ASHEVILLE NORTH CAROLINA

OBSERVATIONS AT 3-HOUR INTERVALS

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISI-BILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISI-BILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISI-BILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
	JAN 1st											JAN 2nd											JAN 3rd										
03	0	UNL	15			-13	-14	-19	74	30	4	10	65	20			8	7	2	76	12	10	10	7	3		ZLSF	30	29	28	92	16	6
06	0	UNL	12			-13	-14	-19	74	28	3	10	65	20			14	12	7	74	12	11	10	14	4		F	30	29	28	92	15	5
09	0	UNL	10			-13	-14	-19	74	00	0	10	39	10			19	17	11	71	13	12	10	11	4		ZLF	31	30	29	92	00	0
12	0	UNL	10			-3	-4	-13	62	00	0	10	8	2	8	ZLF	22	21	20	92	13	11	10	27	2	4	LF	32	32	31	96	00	0
15	0	UNL	7			1	0	-9	62	11	4	10	5	2	8	ZLF	25	24	23	92	15	14	10	5	2	4	SF	32	31	30	92	27	6
18	2	UNL	15			-2	-3	-8	75	11	5	10	7	2	8	ZLF	26	25	24	92	15	11	10	32	4		F	29	28	27	92	30	5
21	6	UNL	15			-1	-2	-7	75	11	8	10	6	1	8	ZLSF	27	27	27	100	15	8	10	15	7		S	21	20	17	85	29	9
24	10	95	15			4	3	-2	76	11	9	10	5	1	8	ZLSF	29	28	27	92	17	8	10	130	12			15	14	9	77	31	13
	JAN 4th											JAN 5th											JAN 6th										
03	10	120	12			11	10	5	77	29	10	9	130	15			3	3	0	87	33	5	1	UNL	10			1	0	-3	83	28	5
06	10	130	12			8	7	2	76	31	9	10	110	12			5	4	1	83	01	5	0	UNL	10			-4	-5	-8	83	22	4
09	9	110	7			3	2	-2	79	31	10	10	75	9			7	6	2	80	32	3	10	UNL	8			-6	-7	-10	82	22	9
12	6	UNL	7			7	6	-1	69	30	10	10	55	8			12	10	5	73	27	4	0	UNL	9			5	4	-4	66	22	6
15	0	UNL	10			9	7	1	70	29	7	10	UNL	9		S	15	13	8	74	22	5	2	UNL	15			8	6	-4	58	22	11
18	0	UNL	12			4	3	-2	76	31	7	10	UNL	6		S	12	11	8	84	30	3	0	UNL	15			2	1	-5	72	19	9
21	7	15	15			6	5	1	80	33	9	2	UNL	7			7	7	5	91	24	4	0	UNL	15			0	-1	-5	79	20	10
24	7	150	15			4	3	0	83	30	5	4	UNL	7			6	5	3	87	26	4	6	UNL	10			0	-1	-4	83	20	4
	JAN 7th											JAN 8th											JAN 9th										
03	2	UNL	5		IC	-3	-4	-7	83	14	4	0	UNL	6		F	-4	-4	-7	87	25	3	10	110	10			10	9	3	73	04	8
06	2	UNL	1	8	IC	-3	-3	-6	87	22	4	0	UNL	6		F	-4	-5	-8	83	00	0	10	110	10			9	8	3	76	02	10
09	8	UNL	6		F	-1	-1	-4	87	00	0	2	UNL	5		F	0	-1	-3	87	01	3	10	110	15			8	7	3	80	01	10
12	6	UNL	7			7	6	0	73	20	5	3	UNL	6		F	7	6	1	76	14	4	10	200	15			13	11	2	61	05	13
15	3	UNL	12			11	9	1	64	19	6	10	UNL	10			13	10	1	58	06	5	10	UNL	15			15	12	0	51	06	12
18	2	UNL	15			7	6	-1	69	23	7	10	250	12			10	8	2	70	01	6	9	120	10			13	11	3	64	01	11
21	0	UNL	10			3	2	-2	79	25	5	10	250	15			11	9	2	67	01	9	10	95	10			10	8	1	67	03	13
24	0	UNL	8			-1	-1	-4	87	22	4	10	110	15			10	9	3	73	03	10	10	42	10			9	8	2	73	03	6
	JAN 10th											JAN 11th											JAN 12th										
03	10	UNL	15			8	7	1	73	04	8	10	150	10			7	6	2	80	11	7	10	4	0	6	S	21	20	18	88	07	9
06	10	95	15			7	6	1	76	03	7	9	150	10			9	8	4	80	11	8	10	7	1		S	21	20	19	92	06	11
09	10	110	15			8	7	1	73	04	6	10	150	12			11	10	5	77	11	11	10	18	0	12	S	22	21	20	92	06	10
12	7	100	15			12	10	3	67	04	7	10	120	15			18	16	10	71	10	10	10	13	4		S	26	25	22	85	07	13
15	0	UNL	20			18	15	6	59	07	9	10	75	12			21	19	14	74	11	9	10	17	7		S	27	26	23	85	05	12
18	2	UNL	15			13	11	4	67	05	8	10	41	7		S	21	19	14	74	08	12	10	29	1	8	S	26	25	24	92	05	14
21	3	UNL	15			11	9	2	67	06	8	10	65	10		S	21	19	15	78	08	11	10	13	10		S	26	25	22	85	04	16
24	6	250	15			9	8	2	73	06	6	10	9	1	12	S	21	20	18	88	07	10	10	33	6		S	25	24	22	88	02	13
	JAN 13th											JAN 14th											JAN 15th										
03	10	13	2	8	S	23	22	20	88	01	11	10	40	6		S	20	19	18	92	32	4	7	6	2		ICF	-2	-3	-6	83	22	4
06	10	33	2		S	22	21	20	92	36	7	10	43	6		S	19	18	16	88	28	4	8	9	4		SF	-4	-5	-8	83	24	3
09	10	UNL	5		S	24	23	21	88	36	11	10	90	6		S	18	17	15	88	30	6	1	UNL	7			-2	-2	-4	91	23	3
12	10	30	7		S	26	24	20	78	35	12	8	100	9		S	22	20	15	74	31	8	0	UNL	8			9	8	2	73	19	4
15	10	30	7		S	25	23	19	78	34	12	9	17	12			20	18	13	74	23	10	0	UNL	10			13	11	5	70	14	6
18	10	55	8		S	24	23	20	85	33	9	0	UNL	10			9	8	4	80	22	7	0	UNL	10			6	5	2	83	14	7
21	9	60	8		S	22	21	18	85	34	7	2	UNL	10			3	3	0	87	21	4	10	21	8		S	10	9	6	84	12	5
24	10	41	12		S	20	19	18	92	35	6	2	UNL	7		IC	1	0	-3	83	22	5	10	14	6		SF	16	15	12	84	18	8
	JAN 16th											JAN 17th											JAN 18th										
03	10	9	4		SF	18	17	15	88	19	12	0	UNL	20			8	7	2	76	31	13	7	90	15			-5	-6	-9	83	12	6
06	10	8	4		SF	19	18	17	92	20	12	0	UNL	20			6	5	-1	73	29	9	10	100	15			1	0	-5	76	15	3
09	10	9	3		F	21	20	18	88	20	12	3	UNL	20			4	3	-4	69	30	10	10	85	15			7	5	-2	66	17	5
12	7	UNL	5		H	25	23	18	75	24	14	0	UNL	20			10	8	-3	55	32	10	10	80	15			17	13	1	49	20	14
15	0	UNL	8			25	22	16	69	25	12	0	UNL	20			13	10	-3	48	26	8	9	85	15			19	15	3	50	18	12
18	0	UNL	10			20	18	12	71	29	15	0	UNL	20			8	6	-5	55	25	5	10	45	15			18	15	7	62	15	10
21	0	UNL	15			15	13	6	67	31	17	0	UNL	20			-4	-5	-10	75	20	6	10	50	20			17	15	9	71	14	6
24	0	UNL	15			11	10	5	77	31	14	0	UNL	20			-5	-6	-9	83	21	4	10	49	20			18	16	9	68	15	6

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.02	0.03	0.03	0.05	0.06	0.08	0.10	0.12	0.13	0.14	0.16	0.18
ENDED: DATE	12	12	12	12	12	12	12	12	12	12	12	12
ENDED: TIME	1006	1014	1014	0310	1030	0310	0310	1038	0328	1038	1038	1038

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

JAN 1993 14922
MINNEAPOLIS-ST.PAUL, MN

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
JAN 19th											
03	10	31	20			20	17	8	60	18	4
06	10	35	20			19	17	11	71	16	6
09	10	29	12			20	17	10	65	18	7
12	10	29	15			23	19	10	57	19	11
15	0	UNL	20			24	20	9	53	17	10
18	0	UNL	10			16	15	10	77	13	7
21	0	UNL	10			13	12	9	84	15	5
24	0	UNL	10			12	11	6	77	11	6
JAN 20th											
03	8	250	10			10	9	3	73	10	7
06	10	UNL	10			10	8	2	70	11	6
09	10	250	10			12	10	4	70	12	6
12	10	250	10			20	17	10	65	12	9
15	10	20	6		ZR	26	24	19	75	08	10
18	10	12	5		ZLF	29	28	27	92	12	11
21	10	5	4		F	31	30	29	92	11	8
24	10	3	1		ZLF	31	31	31	100	14	4
JAN 21st											
03	10	1	0	12	ZLSF	31	31	31	100	00	0
06	10	14	1		SF	31	31	31	100	26	3
09	10	26	2		F	31	31	30	96	00	0
12	10	29	2		F	31	30	29	92	13	4
15	10	8	5		F	32	31	30	92	22	6
18	10	17	6		SF	31	30	28	89	21	10
21	10	7	1	12	S	28	27	25	89	21	9
24	10	110	3		F	28	27	25	89	21	7
JAN 22nd											
03	2	UNL	7			29	27	24	82	26	8
06	0	UNL	10			27	25	22	81	26	7
09	0	UNL	15			22	21	17	81	23	10
12	0	UNL	20			29	26	20	69	22	6
15	5	UNL	20			31	28	22	69	21	7
18	10	110	20			30	28	23	75	14	6
21	10	95	20			29	27	22	75	11	7
24	10	110	20			30	27	22	72	08	10
JAN 23rd											
03	10	55	15			33	29	23	67	11	12
06	10	30	15			35	32	26	70	10	11
09	10	19	8		S	34	31	26	73	36	8
12	10	11	2	8	S	34	32	30	85	34	14
15	10	15	2		S	34	31	27	76	34	21
18	0	UNL	20			33	30	24	70	32	14
21	0	UNL	25			26	23	16	66	30	13
24	0	UNL	25			18	16	9	68	31	13
JAN 24th											
03	0	UNL	20			12	11	7	80	30	10
06	0	UNL	20			9	8	5	84	28	7
09	4	UNL	12			8	7	3	80	26	6
12	4	UNL	15			17	15	7	65	23	8
15	6	65	15			20	17	7	57	26	8
18	0	UNL	15			12	10	5	73	23	8
21	4	UNL	15			11	10	6	80	27	6
24	4	UNL	15			2	1	-2	83	22	5
JAN 25th											
03	2	UNL	10			3	3	0	87	29	4
06	0	UNL	10			-5	-5	-8	87	20	5
09	0	UNL	7			-1	-1	-4	87	22	4
12	5	UNL	8			10	9	5	80	16	7
15	0	UNL	12			14	12	4	64	15	8
18	1	UNL	15			14	12	6	70	13	11
21	10	250	15			14	13	8	77	15	11
24	10	250	15			22	20	16	78	16	16
JAN 26th											
03	10	45	6		SW	29	27	22	75	19	17
06	0	UNL	7			31	29	25	79	24	15
09	2	UNL	15			36	33	28	73	28	17
12	10	41	20			39	35	28	65	28	19
15	10	55	15			35	32	26	70	31	18
18	1	UNL	15			28	26	21	75	31	10
21	1	UNL	15			22	20	15	74	30	10
24	0	UNL	15			17	15	11	77	32	9
JAN 27th											
03	0	UNL	15			12	11	6	77	31	7
06	8	UNL	15			9	8	5	84	31	5
09	10	110	10			13	11	6	73	05	5
12	10	90	10			16	14	8	71	15	5
15	10	27	1	8	S	17	16	13	84	10	7
18	10	31	1	8	S	18	17	15	88	10	9
21	10	25	7			20	19	18	92	12	7
24	10	14	8			24	23	21	88	13	4
JAN 28th											
03	10	7	7			26	25	22	85	24	7
06	10	9	6		F	27	26	24	89	30	12
09	9	16	15			27	25	20	75	31	20
12	9	50	10			15	13	7	70	30	21
15	4	UNL	15			12	10	2	64	31	15
18	0	UNL	20			6	4	-5	60	30	13
21	0	UNL	20			2	1	-8	62	30	11
24	0	UNL	20			-2	-3	-10	68	30	8
JAN 29th											
03	0	UNL	20			-4	-5	-10	75	25	6
06	0	UNL	20			-9	-9	-13	82	21	6
09	0	UNL	12			-6	-7	-11	79	24	7
12	0	UNL	12			6	4	-5	60	20	8
15	0	UNL	12			13	10	1	58	21	10
18	3	UNL	15			12	10	5	73	22	8
21	0	UNL	20			11	9	2	67	22	13
24	0	UNL	20			12	10	4	70	23	11
JAN 30th											
03	5	UNL	15			14	13	8	77	24	8
06	5	UNL	15			16	15	11	81	23	11
09	3	UNL	15			21	19	15	78	21	10
12	0	UNL	15			28	25	20	72	22	17
15	6	UNL	15			35	31	25	67	23	13
18	4	UNL	15			36	33	28	73	24	15
21	6	UNL	15			36	33	27	70	24	12
24	8	UNL	15			39	35	28	65	26	11
JAN 31st											
03	5	UNL	15			39	35	30	70	28	10
06	3	UNL	15			39	35	30	70	28	8
09	8	250	15			40	36	31	70	30	10
12	8	UNL	15			44	38	30	58	30	14
15	4	UNL	15			45	39	30	56	29	13
18	4	UNL	25			41	37	30	65	30	9
21	8	49	25			36	33	29	76	31	8
24	2	UNL	25			34	31	27	76	30	8

SUMMARY BY HOURS

HOUR L.S.T.	AVERAGES							RESULTANT WIND	
	SKY COVER (TENTHS)	STATION PRESSURE (INCHES)	TEMPERATURE			REL HUMIDITY %	WIND SPEED (MPH)	DIRECTION	SPEED (MPH)
			AIR TEMP °F	WET BULB °F	DEW POINT °F				
03	6	29.285	13	12	8	80	8.5	25	1.3
06	6	29.280	12	11	8	81	8.0	25	1.7
09	7	29.290	13	12	8	79	8.6	28	2.3
12	7	29.290	19	17	11	71	10.7	25	2.6
15	6	29.260	21	18	12	68	11.4	24	2.2
18	5	29.280	18	16	11	76	10.5	24	1.0
21	6	29.285	16	14	10	78	10.2	28	0.9
24	6	29.280	15	13	10	80	9.2	28	1.1

WEATHER CODES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXP RESSED IN KNOTS (MPH=KNOTS X 1.15).

NATIONAL CLIMATIC DATA CENTER
FEDERAL BUILDING
37 BATTERY PARK AVE
ASHEVILLE, NORTH CAROLINA 28801-2733

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JAN 1993 14922
MINNEAPOLIS-ST.PAUL, MN
USCOMM - NOAA - ASHEVILLE, NC 675

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

DATE	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												DATE
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
01					T	T																			01
02									T	T	T	T	T	0.01	T	T	T	T	T	0.01	T	T	T	T	02
03	T	T	T	T	T	T	T	T	T	T	0.01	T	T	T	T	T	0.01	T	T	T	T	T			03
04																									04
05													T	T	T	T	T	T	T	T			T	T	05
06																									06
07		T	T	T	T	T	T	T																	07
08																									08
09																									09
10																									10
11																	T	T	T	T	0.01	0.01	0.01	0.02	11
12	0.04	0.02	0.08	0.04	0.03	0.05	0.04	0.03	0.04	0.08	0.05	0.01	T	T	T	0.01	0.01	0.02	0.01	0.02	T	0.03	0.01	0.01	12
13	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	T	T	T	0.01	T	T	T	0.01	T	T	T	T	T	T	0.01	T	13
14	T	T	T	T	0.01	T	T	T	0.01	T	T	T	T	T								T	T	T	14
15	T	T	T	T	T	T	T	T													T	T	T	T	15
16	T	T	T	T	T	T	T	T	T																16
17																									17
18																									18
19																									19
20														T	0.01	0.04	0.06	0.04	0.01	T		T	T	0.01	20
21	T	T	T	T	0.01	T	0.01	T	T									T	T	0.01	0.03	0.01	T		21
22																									22
23				T	0.02				T	0.01	T	0.01	T	0.02	0.01	T	T								23
24																									24
25																									25
26		0.01	T	T	T	T																			26
27													T	T	0.01	0.02	T-	0.02	T	0.01	T				27
28																									28
29																									29
30																									30
31																									31

FEB 1993
MINNEAPOLIS-ST.PAUL, MN
NAT'L WEA SER FCST OFC
FEDERAL AVIATION BUILDING

INQUIRIES/COMMENTS CALL
(704) 271-4800

INTERNATIONAL AIRPORT

ISSN 0198-2745

DEPARTMENT OF COMMERCE · UNITED STATES OF AMERICA

LOCAL CLIMATOLOGICAL DATA
Monthly Summary

FEB 1993
MINNEAPOLIS–ST.PAUL, MN

LATITUDE 44° 53'N LONGITUDE 93° 13'W ELEVATION (GROUND) 834 FEET TIME ZONE CENTRAL 14922

DATE 1	TEMPERATURE °F MAXIMUM 2	MINIMUM 3	AVERAGE 4	DEPARTURE FROM NORMAL 5	AVERAGE DEW POINT 6	DEGREE DAYS BASE 65°F HEATING (SEASON BEGINS WITH JUL) 7A	COOLING (SEASON BEGINS WITH JAN) 7B	WEATHER TYPES 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW 8	SNOW ICE PELLETS OR ICE ON GROUND AT 0600 INCHES 9	PRECIPITATION WATER EQUIVALENT (INCHES) 10	SNOW, ICE PELLETS (INCHES) 11	AVERAGE STATION PRESSURE IN INCHES ELEV. 838 FEET ABOVE M.S.L. 12	WIND (M.P.H.) RESULTANT DIR. 13	RESULTANT SPEED 14	AVERAGE SPEED 15	PEAK GUST SPEED 16	PEAK GUST DIRECTION 17	FASTEST 1-MIN SPEED 18	FASTEST 1-MIN DIRECTION 19	SUNSHINE MINUTES 20	PERCENT OF TOTAL POSSIBLE 21	SKY COVER (TENTHS) SUNRISE TO SUNSET 22	MIDNIGHT TO MIDNIGHT 23
01	42*	24	33*	20	25	32	0		7	0.00	0.0	29.400	22	3.7	5.8	13	SW	10	21	588	100	0	0
02	38	22	30	16	26	35	0	1	6	0.00	0.0	29.340	18	7.0	8.0	18	S	16	21	495	84	8	5
03	38	20	29	15	25	36	0	2 8	6	0.00	0.0	29.455	28	2.3	4.7	15	SW	8	28	324	55	7	6
04	28	21	25	11	24	40	0	2	5	0.00	0.0	29.570	23	6.3	6.7	15	SW	13	23	205	34	10	10
05	32	28	30	15	29	35	0	2 6	5	T	0.0	29.380	27	2.2	5.9	12	N	8	21	0	0	10	10
06	31	25	28	13	26	37	0	1 6	5	0.01	T	29.285	12	5.8	9.4	23	S	17	19	0	0	10	10
07	33	25	29	14	26	36	0	1 6	5	T	0.0	29.100	29	5.8	10.8	24	N	17	21	0	0	10	10
08	26	21	24	9	18	41	0	1 6	5	T	T	29.310	07	4.3	6.9	14	N	10	01	134	22	10	10
09	33	26	30	14	28	35	0	1 6	5	0.03	0.2	29.140	18	3.2	7.2	14	SW	10	21	6	1	10	10
10	31	23	27	11	24	38	0	1 6	5	0.04	0.5	29.335	03	10.2	10.9	21	NE	16	04	0	0	10	10
11	24	18	21	5	13	44	0		5	T	0.1	29.410	06	13.5	13.7	23	NE	17	06	58	9	10	10
12	29	18	24	7	16	41	0		5	0.07	0.7	29.170	01	5.4	7.0	15	N	10	05	375	61	10	10
13	27	11	19	2	16	46	0	1	6	0.03	0.5	29.090	29	7.9	8.2	18	W	15	30	490	79	8	6
14	19	1	10	-8	2	55	0		6	0.00	0.0	29.230	28	6.2	7.2	16	NW	14	30	558	89	7	4
15	14	-1	7	-11	-2	58	0		6	0.00	0.0	29.390	30	6.4	7.1	20	NW	14	31	526	84	5	5
16	8	-4	2	-16	-7	63	0		6	0.00	0.0	29.450	31	8.1	8.5	21	NW	14	30	488	77	5	5
17	0	-12*	-6*	-25	-14	71	0		6	0.00	0.0	29.495	26	10.1	10.9	23	W	17	25	633	100	0	0
18	12	-9	2	-17	-5	63	0		6	0.00	0.0	29.270	24	6.8	7.5	17	SW	13	30	635	100	2	1
19	20	-6	7	-12	0	58	0		6	0.00	0.0	29.110	24	2.9	3.9	13	SW	12	23	532	83	9	7
20	22	12	17	-3	8	48	0		6	T	T	28.990	08	5.3	5.6			10	09	198	31	9	10
21	26	20	23	3	18	42	0	1	6	0.14	2.4	28.780	02	9.2	9.9	25	N	16	01	346	54	10	10
22	22	2	12	-9	9	53	0	1	8	0.07	0.9	29.050	31	9.8	10.5	20	NW	15	30	436	67	10	10
23	6	-8	-1	-22	-9	66	0		9	T	T	29.330	29	9.9	10.6	21	W	15	27	603	92	0	2
24	14	-11	2	-19	-6	63	0		9	0.00	0.0	29.420	22	4.4	4.9	13	SW	10	21	618	94	0	2
25	22	0	11	-11	0	54	0		8	0.00	0.0	29.420	07	2.0	4.7	13	N	8	36	528	80	6	6
26	27	-1	13	-9	4	52	0	1 8	8	0.00	0.0	29.520	22	3.2	3.5	12	SW	9	22	661	100	0	1
27	26	9	18	-5	9	47	0		8	T	T	29.370	18	5.8	6.9	15	SE	10	20	568	86	2	4
28	33	4	19	-4	13	46	0	1	8	0.00	0.0	29.140	19	6.1	7.2	15	SW	14	20	561	84	5	4
	SUM	SUM				TOTAL	TOTAL	NUMBER OF DAYS		TOTAL	TOTAL	FOR THE MONTH:								TOTAL	% FOR MONTH	SUM	SUM
	683	278				1335	0			0.39	5.3	29.280	29	1.7	7.6	25	N	17	25	10566		183	178
	AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION		DEP.						DATE:21		DATE: 17+		POSSIBLE		AVG.	AVG.
	24.4	9.9	17.2	-0.7	11.0	16	0	≥ .01 INCH.	7	-0.49										17560	60	6.5	6.4

NUMBER OF DAYS				SEASON TO DATE				GREATEST IN 24 HOURS AND DATES				GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE	
				TOTAL	TOTAL	SNOW, ICE PELLETS ≥ 1.0 INCH	1						
MAXIMUM TEMP.		MINIMUM TEMP.		6054	0	THUNDERSTORMS	0	PRECIPITATION		SNOW, ICE PELLETS			
≥ 90°	≤ 32°	≤ 32°	≤ 0°	DEP.	DEP.	HEAVY FOG	3	0.19	21-22	2.7	21-22	9	24+
0	22	28	9	-30	0	CLEAR 7	PARTLY CLOUDY 6	CLOUDY 15					

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS. COLS 16 & 17: PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED. ONE OF TWO WIND SPEEDS IS GIVEN UNDER COLS 18 & 19: FASTEST MILE - HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION [DIRECTION IN COMPASS POINTS]. FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED [DIRECTION IN TENS OF DEGREES]. ERRORS WILL BE CORRECTED IN SUBSEQUENT PUBLICATIONS.

ERRATA - JAN 1993 - CORRECT HEATING DEGREE DAYS DEPARTURES TO READ - MTH: -111 SEASON: 1

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER

Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

noaa
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE
NATIONAL CLIMATIC DATA CENTER ASHEVILLE NORTH CAROLINA

OBSERVATIONS AT 3-HOUR INTERVALS

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
FEB 1st											
03	0	UNL	25			30	29	26	85	36	5
06	0	UNL	25			25	24	22	88	22	3
09	0	UNL	10			28	27	25	89	00	0
12	0	UNL	10			38	33	26	62	23	3
15	0	UNL	10			40	35	27	60	23	7
18	0	UNL	10			32	30	27	82	19	8
21	0	UNL	15			29	27	24	82	18	7
24	0	UNL	10			26	25	23	88	20	8
FEB 2nd											
03	0	UNL	7			25	24	23	92	17	4
06	0	UNL	4		F	23	22	21	92	13	6
09	10	UNL	3		F	25	24	23	92	13	5
12	10	UNL	8			35	32	28	76	19	11
15	8	UNL	8			37	34	30	76	22	7
18	3	UNL	8			32	31	28	85	19	6
21	7	UNL	8			30	29	27	89	20	6
24	10	UNL	7			29	28	25	85	24	3
FEB 3rd											
03	10	UNL	5		F	26	25	24	92	23	3
06	3	UNL	4		F	22	22	21	96	00	0
09	10	1	0	4	F	25	25	24	96	33	5
12	10	5	1	4	F	30	29	27	89	33	5
15	2	UNL	3		H	36	33	29	76	34	7
18	0	UNL	3		F	31	30	28	89	28	4
21	0	UNL	4		F	25	25	24	96	00	0
24	10	2	0	2	F	21	21	20	96	24	4
FEB 4th											
03	10	4	0	3	F	23	23	22	96	23	5
06	10	1	0	1	F	21	21	20	96	20	3
09	10	2	0	2	F	21	21	20	96	18	5
12	10	3	1	2	F	24	24	24	100	23	6
15	10	3	1	4	F	27	27	26	96	23	6
18	10	1	0	5	F	28	28	27	96	24	7
21	10	1	0	5	F	27	27	27	100	25	7
24	10	1	0	5	F	28	28	28	100	23	5
FEB 5th											
03	10	1	0	8	F	29	29	29	100	23	7
06	10	1	0	12	F	29	29	28	96	24	5
09	10	1	0	4	F	29	29	28	96	23	5
12	10	2	0	8	F	30	30	29	96	28	4
15	10	4	2		F	31	31	30	96	28	4
18	10	6	2		F	32	31	30	92	01	5
21	10	14	6		F	32	31	29	89	03	5
24	10	17	6		F	31	30	28	89	06	6
FEB 6th											
03	10	23	6		F	29	28	26	89	04	8
06	10	7	6		F	26	25	24	92	05	6
09	10	5	3		SF	26	25	24	92	09	6
12	10	4	2	8	ZLSF	25	24	23	92	09	8
15	10	5	2		ZLSF	26	26	25	96	13	7
18	10	3	1	12	F	27	27	26	96	13	6
21	10	7	3		F	30	30	29	96	18	9
24	10	5	6		F	30	30	29	96	20	13
FEB 7th											
03	10	4	4		ZLF	30	29	28	92	23	13
06	10	5	6		F	30	29	27	89	24	9
09	10	7	5		F	29	28	27	92	26	8
12	10	9	6		F	31	30	27	85	31	7
15	10	10	6		F	32	31	28	85	31	10
18	10	13	7			33	31	28	82	33	8
21	10	17	12			26	24	21	81	01	13
24	10	23	15			25	23	18	75	01	8
FEB 8th											
03	10	20	10			23	21	16	75	36	8
06	10	20	15			23	21	15	71	03	6
09	10	20	12		SW	21	19	15	78	05	6
12	10	20	12		S	24	21	15	69	11	4
15	10	20	12			25	23	18	75	12	6
18	10	15	7			24	22	19	81	11	5
21	10	9	7			25	24	21	85	13	5
24	10	5	2	8	ZLF	26	26	25	96	13	6
FEB 9th											
03	10	3	1	8	ZLF	26	26	25	96	12	6
06	10	4	1		SF	27	27	27	100	12	5
09	10	5	2		SF	29	28	27	92	12	6
12	10	7	2		F	32	31	30	92	16	6
15	10	14	12			33	31	28	82	20	8
18	10	11	9			32	31	28	85	29	5
21	10	11	8			32	31	28	85	24	6
24	10	9	7			31	30	28	89	31	5
FEB 10th											
03	10	9	6		F	31	30	28	89	32	6
06	10	7	7		ZL	30	29	27	89	01	9
09	10	11	9			30	29	26	85	04	8
12	10	13	10			30	28	25	82	04	9
15	10	17	12			30	28	24	78	03	12
18	10	18	1	8	S	27	26	23	85	03	13
21	10	27	2		S	23	22	19	85	04	11
24	10	50	10			23	21	15	71	04	10
FEB 11th											
03	10	70	4		SW	20	18	14	78	05	15
06	10	55	6		SW	18	17	13	81	06	12
09	10	47	7		S	18	17	13	81	05	13
12	10	45	6		S	20	19	15	81	06	13
15	10	60	15			23	20	14	68	06	11
18	10	48	12			23	19	10	57	05	12
21	10	37	10			22	19	12	65	08	9
24	10	25	6		S	20	19	15	81	05	9
FEB 12th											
03	10	12	2	8	S	19	18	16	88	05	9
06	10	55	8		S	19	18	15	84	03	6
09	10	65	10			19	18	14	81	05	8
12	10	UNL	15			25	22	14	63	00	0
15	10	UNL	15			26	23	16	66	35	6
18	10	65	12			26	23	17	69	35	5
21	10	65	8		S	24	23	21	88	31	4
24	10	47	7		S	23	22	20	88	30	6
FEB 13th											
03	10	50	4		S	22	21	20	92	29	7
06	10	38	7			21	20	18	88	28	6
09	9	UNL	7			20	19	16	84	29	7
12	7	UNL	10			26	23	18	72	29	10
15	10	20	7		S	25	23	17	72	30	13
18	0	UNL	7			22	20	15	74	28	6
21	0	UNL	10			16	14	10	77	29	7
24	2	UNL	7			11	10	6	80	27	6
FEB 14th											
03	3	UNL	12			7	6	3	84	28	5
06	4	UNL	9			5	4	1	83	28	5
09	8	UNL	10			7	6	2	80	27	5
12	6	UNL	10			15	12	3	59	30	7
15	9	UNL	10			18	14	2	49	30	12
18	2	UNL	20			15	12	3	59	30	7
21	0	UNL	20			9	8	2	73	24	6
24	10	UNL	20			6	5	2	83	21	5
FEB 15th											
03	2	UNL	10			-1	-1	-4	87	23	3
06	7	UNL	8			2	1	-2	83	30	4
09	3	UNL	7			3	3	0	87	29	3
12	8	UNL	12			11	9	0	61	31	6
15	0	UNL	15			13	10	-2	51	30	9
18	2	UNL	15			9	7	-5	53	28	6
21	5	UNL	15			3	2	-6	66	30	9
24	10	250	15			2	1	-6	69	31	8
FEB 16th											
03	9	85	12			2	1	-7	66	32	6
06	10	75	15			2	1	-8	62	34	7
09	7	200	12			2	1	-8	62	33	6
12	10	UNL	15			6	4	-8	52	32	12
15	2	UNL	15			8	6	-7	50	31	11
18	0	UNL	15			5	3	-8	54	31	9
21	0	UNL	15			1	0	-8	65	27	4
24	0	UNL	10			-4	-5	-12	68	30	7
FEB 17th											
03	0	UNL	20			-7	-8	-16	64	30	8
06	0	UNL	20			-10	-11	-19	64	30	7
09	0	UNL	15			-9	-10	-19	61	27	8
12	0	UNL	15			-4	-5	-15	58	24	10
15	1	UNL	15			0	-2	-13	54	28	13
18	0	UNL	15			-2	-3	-12	62	25	10
21	0	UNL	15			-4	-5	-11	71	26	9
24	0	UNL	20			-4	-5	-11	71	25	8
FEB 18th											
03	0	UNL	20			-7	-8	-13	75	23	6
06	0	UNL	15			-5	-6	-11	75	24	6
09	0	UNL	20			2	1	-8	62	26	8
12	2	UNL	20			10	7	-5	50	27	7
15	1	UNL	15			12	9	-1	56	22	10
18	0	UNL	15			9	7	-2	61	23	6
21	0	UNL	15			4	3	-2	76	21	5
24	0	UNL	15			1	0	-4	79	20	5

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.05
ENDED: DATE	22	22	22	21	21	22	21	22	22	22	22	22
ENDED: TIME	0733	0733	0733	2309	2309	0505	2135	0505	0638	0201	0733	0638

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

FEB 19th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	0	UNL	15			1	0	-4	79	00	0
06	0	UNL	10			-4	-4	-7	87	20	5
09	6	UNL	10			1	0	-4	79	20	5
12	10	250	12			14	11	0	53	26	5
15	10	UNL	15			20	16	4	50	22	6
18	8	UNL	15			19	15	4	52	29	5
21	10	250	15			14	12	5	67	31	4
24	10	85	15			15	13	7	70	00	0

FEB 20th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	10	85	10			15	14	9	77	00	0
06	10	80	10			14	13	9	80	00	0
09	10	110	8			17	14	5	59	10	5
12	7	60	15			20	16	6	54	10	8
15	10	50	12			21	18	8	57	10	6
18	10	47	12			22	18	8	55	09	8
21	10	50	12		S	22	18	9	57	06	8
24	10	39	5		S	21	19	14	74	07	6

FEB 21st

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	10	40	2	12	S	20	19	16	84	04	8
06	10	31	6		S	20	19	16	84	04	8
09	10	22	3		S	21	20	16	81	03	7
12	10	17	4		S	24	22	18	78	01	10
15	10	49	7		S	25	23	18	75	01	12
18	10	23	1	8	S	24	22	19	81	36	8
21	10	55	2		S	23	22	20	88	36	6
24	10	30	2		SF	22	21	19	88	36	6

FEB 22nd

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	10	32	2	8	S	21	20	18	88	34	10
06	10	44	2	8	S	20	19	17	88	34	8
09	10	45	4		S	18	17	13	81	35	8
12	10	32	3		S	17	15	11	77	30	7
15	10	29	3		S	12	10	5	73	30	13
18	10	15	7		S	10	9	3	73	29	9
21	10	38	6		S	7	6	2	80	30	12
24	10	27	15		S	2	1	-5	72	30	10

FEB 23rd

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	9	41	7		S	-2	-3	-9	72	32	11
06	0	UNL	10			-6	-7	-11	79	31	8
09	0	UNL	15			-3	-4	-11	68	30	11
12	0	UNL	15			2	0	-10	57	30	12
15	0	UNL	20			6	4	-11	45	29	13
18	0	UNL	20			2	0	-10	57	26	7
21	0	UNL	20			-1	-2	-10	65	27	5
24	0	UNL	20			-8	-9	-12	82	20	4

FEB 24th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	0	UNL	15			-4	-5	-10	75	27	5
06	0	UNL	15			-7	-8	-11	82	00	0
09	0	UNL	10			-5	-6	-11	75	22	5
12	0	UNL	10			8	6	-4	58	19	4
15	0	UNL	10			12	9	-1	56	21	6
18	2	UNL	15			7	5	-3	63	22	6
21	10	200	15			3	2	-4	72	20	4
24	10	200	15			1	0	-3	83	07	3

FEB 25th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	10	200	7			2	1	-3	79	11	4
06	10	100	7			1	0	-4	79	12	4
09	5	UNL	7			4	3	-3	72	03	5
12	10	UNL	10			15	12	0	51	16	5
15	4	UNL	10			20	15	0	41	02	4
18	2	UNL	12			17	13	1	49	36	7
21	1	UNL	15			13	11	2	61	28	4
24	0	UNL	15			10	8	0	64	29	3

FEB 26th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	0	UNL	15			8	7	2	76	00	0
06	0	UNL	15			1	1	-1	91	00	0
09	0	UNL	6		F	8	7	5	87	00	0
12	0	UNL	8			23	19	7	50	19	5
15	0	UNL	12			27	21	5	39	21	4
18	0	UNL	10			20	16	5	52	22	8
21	4	UNL	12			14	12	7	74	20	4
24	10	75	10			15	13	6	67	22	5

FEB 27th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	10	250	7			13	11	6	73	19	6
06	4	UNL	10			10	9	6	84	14	6
09	0	UNL	7			15	13	5	64	12	5
12	0	UNL	7			23	20	11	60	20	7
15	0	UNL	7			25	22	14	63	18	7
18	8	UNL	7			20	18	12	71	20	9
21	5	UNL	7			15	14	9	77	20	8
24	3	UNL	7			10	9	6	84	20	8

FEB 28th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	7	130	6		F	8	7	4	84	16	5
06	1	UNL	7			5	4	1	83	12	5
09	10	UNL	7			15	13	8	74	17	3
12	1	UNL	7			25	22	15	66	20	12
15	5	UNL	7			32	28	19	59	20	7
18	3	UNL	7			29	26	21	72	20	6
21	0	UNL	8			27	25	22	81	22	6
24	0	UNL	8			24	23	20	85	23	4

WEATHER CODES

*	TORNADO
T	THUNDERSTORM
Q	SQUALL
R	RAIN
RW	RAIN SHOWERS
ZR	FREEZING RAIN
L	DRIZZLE
ZL	FREEZING DRIZZLE
S	SNOW
SW	SNOW SHOWERS
SG	SNOW GRAINS
SP	SNOW PELLETS
IC	ICE CRYSTALS
IP	ICE PELLETS
IPW	ICE PELLET SHOWERS
A	HAIL
F	FOG
IF	ICE FOG
GF	GROUND FOG
BD	BLOWING DUST
BN	BLOWING SAND
BS	BLOWING SNOW
BY	BLOWING SPRAY
K	SMOKE
H	HAZE
D	DUST

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXP RESSED IN KNOTS (MPH=KNOTS X 1.15).

SUMMARY BY HOURS

HOUR L.S.T.	AVERAGES SKY COVER (TENTHS)	AVERAGES STATION PRESSURE (INCHES)	AVERAGES TEMPERATURE AIR TEMP °F	AVERAGES TEMPERATURE WET BULB °F	AVERAGES TEMPERATURE DEW POINT °F	AVERAGES REL HUMIDITY %	AVERAGES WIND SPEED (MPH)	RESULTANT WIND DIRECTION	RESULTANT WIND SPEED (MPH)
03	7	29.285	15	14	10	83	7.1	32	1.8
06	6	29.290	13	12	9	85	6.1	35	1.1
09	7	29.300	15	14	10	80	6.8	35	1.2
12	7	29.300	21	18	12	69	8.3	27	2.1
15	6	29.265	23	20	13	66	9.7	29	3.8
18	5	29.270	21	18	12	71	8.3	28	2.6
21	6	29.280	18	16	12	78	7.5	27	2.1
24	7	29.280	16	14	11	81	7.0	26	1.9

NATIONAL CLIMATIC DATA CENTER
FEDERAL BUILDING
37 BATTERY PARK AVE
ASHEVILLE, NORTH CAROLINA 28801-2733

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

FIRST CLASS
POSTAGE AND FEES PAID
NOAA
PERMIT G-19

LCD-21-14922-PD-9309

45740
JHK & ASSOCIATES
ATTN: M SCOTT MACCALDEN JR
PO BOX 193727
SAN FRANCISCO CA 94119

FEB 1993 14922
MINNEAPOLIS-ST.PAUL, MN
USCOMM - NOAA - ASHEVILLE, NC 675

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

DATE	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												DATE
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
01																									01
02																									02
03																									03
04																									04
05																				T	T				05
06								T	T	T	0.01	T	T	T	T	T	T	T							06
07	T	T	T	T	T																				07
08									T	T	T	T	T										T	T	08
09	T	T	T	0.01	T	T	0.01	0.01	T	T															09
10						T	T	T			T	T					T	0.01	T	0.01	0.01	0.01	T	T	10
11	T	T	T	T	T	T	T	T	T	T	T	T	T									T	T	T	11
12	T	0.01	0.02	0.02	T	T	T	T											T	T	0.01	0.01	T	T	12
13	T	0.02	0.01	T	T	T	T	T	T				T	T	T	T	T								13
14																									14
15																									15
16																									16
17																									17
18																									18
19																									19
20																					T	T	T	T	20
21	0.01	T	T	0.01	T	T	T	T	0.01	0.02	T	T	T	0.01	T	T	T	0.01	T	0.01	0.02	0.01	0.01	0.02	21
22	0.01	T	0.01	0.02	0.01	0.01	0.01	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	22
23	T	T	T	T	T																				23
24																									24
25																									25
26																									26
27			T	T																					27
28																									28

MAR 1993
MINNEAPOLIS-ST.PAUL, MN
NAT'L WEA SER FCST OFC
FEDERAL AVIATION BUILDING

INQUIRIES/COMMENTS CALL
(704) 271-4800

INTERNATIONAL AIRPORT

ISSN 0198-2745

LOCAL CLIMATOLOGICAL DATA

Monthly Summary

MAR 1993
MINNEAPOLIS-ST.PAUL, MN

LATITUDE 44° 53'N LONGITUDE 93° 13'W ELEVATION (GROUND) 834 FEET TIME ZONE CENTRAL 14922

	TEMPERATURE °F					DEGREE DAYS BASE 65°F		WEATHER TYPES 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	SNOW ICE PELLETS OR ICE ON GROUND AT 0600 INCHES	PRECIPITATION		AVERAGE STATION PRESSURE IN INCHES ELEV. 838 FEET ABOVE M.S.L.	WIND (M.P.H.)							SUNSHINE		SKY COVER (TENTHS)	
																PEAK GUST		FASTEST 1-MIN					
DATE	MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	HEATING (SEASON BEGINS WITH JUL)	COOLING (SEASON BEGINS WITH JAN)			WATER EQUIVALENT (INCHES)	SNOW, ICE PELLETS (INCHES)		RESULTANT DIR.	RESULTANT SPEED	AVERAGE SPEED	SPEED	DIRECTION	SPEED	DIRECTION	MINUTES	PERCENT OF TOTAL POSSIBLE	SUNRISE TO SUNSET	MIDNIGHT TO MIDNIGHT
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
01	42	17	30	6	22	35	0		8	0.00	0.0	29.020	21	6.4	6.6	14	SW	12	21	671	100	1	0
02	43	18	31	7	24	34	0	2 8	7	0.00	0.0	28.970	09	2.4	5.9	15	NE	12	06	542	81	4	4
03	44	30	37	12	26	28	0		5	0.00	0.0	29.100	05	7.9	8.6	18	NE	13	07	666	99	2	2
04	44	26	35	10	26	30	0		4	0.00	0.0	29.220	35	7.2	7.6	23	N	13	35	615	91	2	2
05	42	23	33	7	27	32	0	1	3	0.00	0.0	29.125	21	5.4	6.0	31	S	10	20	643	94	1	0
06	40	22	31	5	27	34	0	1	2	0.00	0.0	29.000	23	5.7	6.6	20	SW	16	24	560	82	5	5
07	46	28	37	11	30	28	0	1	1	0.00	0.0	28.820	28	8.6	9.8	25	W	14	31	544	79	5	7
08	38	32	35	8	27	30	0		1	T	T	29.070	31	9.6	9.8	24	NW	14	30	130	19	10	10
09	32	29	31	4	26	34	0	6	1	0.33	3.2	29.090	15	4.1	6.6	15	SE	10	12	178	26	10	10
10	34	13	24	-4	23	41	0		3	0.10	1.2	29.130	32	13.8	15.1	26	NW	21	31	472	68	10	10
11	24	4	14	-14	1	51	0		3	0.00	0.0	29.440	31	8.5	9.8	24	NW	16	31	643	92	1	1
12	22	2	12	-17	3	53	0		3	T	0.1	29.430	31	9.1	10.8	31	NW	22	31	528	75	8	6
13	15	-3	6*	-23	-7	59	0		3	0.00	0.0	29.400	32	9.0	9.5	21	N	15	30	706	100	0	0
14	18	-3*	8	-22	-3	57	0		3	0.00	0.0	29.260	24	5.4	8.1	17	SW	13	23	704	99	0	1
15	36	8	22	-8	15	43	0		3	0.00	0.0	28.910	14	9.8	10.3	25	SE	15	15	562	79	8	8
16	39	7	23	-8	12	42	0		2	0.04	0.5	29.170	31	15.5	18.1	41	NW	29	32	586	82	3	3
17	19	0	10	-21	-6	55	0		3	0.00	0.0	29.740	31	4.6	6.5	18	NW	14	32	719	100	0	0
18	27	0	14	-18	5	51	0		2	0.01	0.2	29.510	14	9.9	10.1	24	SE	17	14	574	80	3	4
19	34	26	30	-2	26	35	0	1 8	2	0.02	0.2	29.280	18	6.6	7.3	17	S	14	16	341	47	10	10
20	35	30	33	0	24	32	0	1	2	0.00	0.0	29.390	30	5.4	6.1	20	NW	12	29	463	64	10	10
21	35	25	30	-3	19	35	0		2	0.00	0.0	29.410	07	2.5	3.9	13	E	8	06	497	68	9	10
22	37	27	32	-2	22	33	0		1	0.01	0.2	29.410	06	7.3	7.4	17	E	13	06	401	55	10	10
23	49	27	38	3	25	27	0		1	0.00	0.0	29.250	01	6.6	7.0	16	N	14	01	708	96	3	4
24	46	28	37	2	29	28	0	1 8	T	0.00	0.0	29.290	16	3.9	5.1	12	SW	10	22	614	83	8	7
25	42	32	37	1	32	28	0	1 8	T	0.00	0.0	29.350	17	4.8	5.2	16	S	10	19	270	36	10	10
26	53	32	43	7	35	22	0	1 8	T	0.00	0.0	29.290	17	6.4	7.1	20	S	14	20	675	90	0	1
27	49	27	38	1	34	27	0	2 8	0	0.00	0.0	29.215	13	3.8	4.0	13	SE	8	11	536	71	6	5
28	60	30	45	8	34	20	0	2	0	0.00	0.0	29.150	11	3.8	4.4	14	E	7	15	651	86	1	1
29	62*	28	45	7	31	20	0	1 8	0	0.00	0.0	29.070	13	3.1	3.7	15	E	10	12	667	88	3	3
30	50	39	45*	7	40	20	0	1 3	0	0.49	0.0	28.960	04	6.6	9.2	22	N	16	36	0	0	10	10
31	39	26	33	-6	29	32	0	1 4	0	0.25	1.3	28.975	02	18.0	18.0	39	N	24	01	132	17	10	10
	SUM	SUM	—	—	—	TOTAL	TOTAL	NUMBER OF DAYS		TOTAL	TOTAL	FOR THE MONTH:								TOTAL	%	SUM	SUM
	1196	630	—	—	—	1096	0			1.25	6.9	29.210	32	1.3	8.2	41	NW	29	32	15998	FOR	163	164
	AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION		DEP.	—	—	—	—	—	DATE:16		DATE: 16		POSSIBLE	MONTH	AVG.	AVG.
	38.6	20.3	29.5	-1.5	21.1	-14	0	≥ .01 INCH.	8	-0.69	—	—	—	—	—					22194	72	5.3	5.3

NUMBER OF DAYS			
MAXIMUM TEMP.		MINIMUM TEMP.	
≥ 90°	≤ 32°	≤ 32°	≤ 0°
0	7	30	4

SEASON TO DATE	
TOTAL	TOTAL
7150	0
DEP.	DEP.
-8	0

SNOW, ICE PELLETS ≥ 1.0 INCH	3
THUNDERSTORMS	1
HEAVY FOG	3

CLEAR 14 PARTLY CLOUDY 4 CLOUDY 13

GREATEST IN 24 HOURS AND DATES			
PRECIPITATION		SNOW, ICE PELLETS	
0.50	30-31	4.0	09-10

GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE	
8	01

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS. COLS 16 & 17: PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED. ONE OF TWO WIND SPEEDS IS GIVEN UNDER COLS 18 & 19: FASTEST MILE - HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTION IN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES). ERRORS WILL BE CORRECTED IN SUBSEQUENT PUBLICATIONS.

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER

Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

noaa
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE
NATIONAL CLIMATIC DATA CENTER ASHEVILLE NORTH CAROLINA

OBSERVATIONS AT 3-HOUR INTERVALS

MAR 1993 14922
MINNEAPOLIS-ST.PAUL, MN

MAR 1st

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	0	UNL	10			22	21	18	85	23	5
06	0	UNL	15			19	18	16	88	23	3
09	1	UNL	8			25	23	18	75	21	6
12	1	UNL	10			35	31	24	64	21	10
15	0	UNL	10			39	34	27	62	20	8
18	0	UNL	10			38	33	26	62	21	8
21	0	UNL	9			31	29	25	79	21	6
24	0	UNL	7			27	26	23	85	19	5

MAR 2nd

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	0	UNL	4		F	25	24	23	92	20	4
06	0	UNL	3		F	19	19	18	96	12	5
09	10	1	0	4	F	22	21	20	92	16	4
12	0	UNL	2		H	33	30	25	73	05	3
15	3	UNL	5		H	41	35	27	58	06	10
18	5	UNL	7			41	35	27	58	05	6
21	6	250	8			37	34	28	70	36	5
24	8	UNL	12			32	30	27	82	36	4

MAR 3rd

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	1	UNL	10			34	31	27	76	03	7
06	0	UNL	15			32	30	27	82	06	7
09	2	UNL	15			36	33	27	70	07	7
12	0	UNL	15			41	35	26	55	05	9
15	3	UNL	15			44	37	26	49	07	9
18	3	UNL	15			41	35	25	53	04	9
21	2	UNL	10			37	33	26	65	02	4
24	3	UNL	10			32	27	18	56	01	7

MAR 4th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	0	UNL	12			27	26	24	89	36	5
06	7	130	10			27	26	24	89	36	4
09	4	UNL	7			32	29	25	75	01	6
12	2	UNL	12			39	34	27	62	34	9
15	1	UNL	15			43	37	27	53	36	11
18	0	UNL	12			39	35	28	65	33	8
21	0	UNL	15			34	32	28	79	32	4
24	0	UNL	15			31	30	27	85	00	0

MAR 5th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	0	UNL	6		F	27	26	25	92	30	4
06	0	UNL	6		F	26	26	25	96	23	5
09	0	UNL	2		F	30	29	27	89	20	6
12	0	UNL	7			39	35	30	70	19	6
15	2	UNL	15			42	37	30	63	22	9
18	0	UNL	12			36	33	28	73	20	9
21	0	UNL	10			30	29	27	89	20	5
24	0	UNL	10			28	27	25	89	17	3

MAR 6th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	0	UNL	6		F	25	25	24	96	20	5
06	0	UNL	4		F	22	22	21	96	12	3
09	8	5	1		F	26	25	24	92	24	4
12	2	UNL	4		F	34	31	27	76	19	5
15	2	UNL	7			38	35	30	73	24	9
18	10	9	5		F	32	31	30	92	24	8
21	10	7	4		F	32	31	30	92	25	9
24	10	7	4		F	31	30	27	85	26	9

MAR 7th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	10	7	5		F	33	32	30	89	23	5
06	5	UNL	6		F	30	29	28	92	20	4
09	1	UNL	7			35	33	30	82	25	7
12	3	UNL	15			44	39	31	60	29	11
15	7	70	20			46	39	30	54	30	12
18	10	70	15			39	36	31	73	28	12
21	10	65	20			37	34	30	76	29	11
24	10	75	20			36	34	30	79	30	8

MAR 8th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	10	33	10			35	33	29	79	31	8
06	10	65	10			34	32	28	79	31	8
09	10	22	8			35	32	28	76	30	8
12	10	24	12			35	32	27	73	32	12
15	10	34	15			36	32	25	64	31	9
18	10	31	20			35	31	24	64	30	7
21	10	30	20			33	30	24	70	30	5
24	10	27	20			32	29	23	69	28	6

MAR 9th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	10	23	20			31	28	21	67	28	5
06	10	21	15			30	27	22	72	23	5
09	10	20	12			31	28	23	72	15	6
12	10	12	1		S	31	30	28	89	17	5
15	10	8	0	8	S	31	31	30	96	13	5
18	10	10	0	8	ZLS	31	30	29	92	12	9
21	10	8	0	8	S	31	31	30	96	12	9
24	10	9	2	8	S	32	31	29	89	08	6

MAR 10th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	10	7	2	8	S	31	30	29	92	01	10
06	10	7	2	8	S	30	29	28	92	34	16
09	10	13	3		S	32	30	27	82	34	17
12	10	17	12			30	28	25	82	31	14
15	10	19	5		S	28	26	22	78	30	15
18	10	45	2	8	S	24	22	18	78	30	15
21	10	80	10		S	22	20	16	78	30	10
24	3	UNL	15			13	12	7	77	31	14

MAR 11th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	1	UNL	20			10	9	4	77	32	11
06	4	UNL	20			9	7	1	70	34	11
09	1	UNL	20			12	9	-1	56	34	10
12	0	UNL	20			21	17	4	48	34	7
15	0	UNL	20			22	18	4	46	29	8
18	0	UNL	15			18	14	1	47	30	9
21	0	UNL	10			14	10	-4	44	26	4
24	7	UNL	10			5	4	-2	73	22	5

MAR 12th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	8	85	12			4	3	-1	80	18	4
06	10	55	12			7	6	2	80	14	3
09	10	33	1		SW	13	12	9	84	31	7
12	5	UNL	10			20	17	10	65	32	14
15	9	37	20			19	16	6	57	31	16
18	5	UNL	25			17	14	4	56	30	12
21	0	UNL	25			8	6	-3	60	31	12
24	0	UNL	25			5	3	-6	60	32	12

MAR 13th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	0	UNL	20			2	1	-8	62	33	10
06	0	UNL	20			-2	-3	-10	68	35	8
09	0	UNL	20			2	0	-9	60	31	7
12	0	UNL	20			12	9	-8	40	31	8
15	0	UNL	20			14	10	-6	40	32	7
18	0	UNL	15			10	7	-7	46	30	13
21	0	UNL	10			5	3	-8	54	30	5
24	0	UNL	10			3	2	-7	63	28	4

MAR 14th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	0	UNL	15			0	-1	-9	65	29	6
06	0	UNL	15			-3	-4	-10	72	30	6
09	0	UNL	15			5	4	-4	66	30	5
12	1	UNL	20			17	13	-1	45	22	4
15	0	UNL	20			16	13	1	51	22	9
18	0	UNL	20			13	10	-1	53	22	9
21	5	UNL	15			10	8	2	70	19	7
24	9	250	15			8	6	-2	63	14	6

MAR 15th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	10	60	15			8	6	-3	60	14	7
06	10	60	12			13	11	2	61	12	10
09	6	UNL	15			20	17	9	62	12	10
12	7	UNL	15			28	25	18	66	14	12
15	10	UNL	12			34	30	22	62	14	10
18	9	85	9			34	31	26	73	14	8
21	10	90	9			34	32	28	79	14	6
24	3	UNL	12			36	34	31	82	20	8

MAR 16th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	7	UNL	10			38	36	32	79	22	11
06	10	17	10			37	35	31	79	30	9
09	7	24	15			31	29	24	75	32	17
12	0	UNL	20			29	24	12	49	34	23
15	0	UNL	25			22	19	4	46	33	18
18	0	UNL	20			16	12	-2	45	30	20
21	0	UNL	20			11	8	-3	53	30	15
24	0	UNL	20			7	5	-4	60	31	10

MAR 17th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	0	UNL	15			4	2	-7	60	32	9
06	0	UNL	15			1	0	-8	65	31	6
09	0	UNL	15			6	4	-9	50	36	6
12	0	UNL	15			15	11	-12	29	35	5
15	0	UNL	15			19	14	-8	29	01	3
18	0	UNL	15			13	10	-5	44	24	5
21	0	UNL	15			8	6	-7	50	23	3
24	0	UNL	15			6	4	-6	57	16	5

MAR 18th

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
03	0	UNL	15			2	1	-7	66	15	4
06	0	UNL	15			0	-1	-8	69	12	3
09	0	UNL	15			10	8	-3	55	16	9
12	0	UNL	15			21	17	7	55	15	10
15	8	65	15			25	21	10	53	14	11
18	10	49	12			26	22	13	58	15	11
21	10	40	12			27	23	15	61	14	8
24	10	33	3		S	27	25	22	81	14	7

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.02	0.03	0.03	0.04	0.04	0.06	0.08	0.09	0.11	0.12	0.14	0.17
ENDED: DATE	30	30	30	30	30	30	30	30	30	30	30	30
ENDED: TIME	1356	1404	1404	1122	1421	1158	1158	1228	1228	1243	1326	1404

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

MAR 1993 14922
MINNEAPOLIS-ST.PAUL, MN

OBSERVATIONS AT 3-HOUR INTERVALS

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
	MAR 19th											MAR 20th											MAR 21st										
03	10	32	5		S	26	25	23	88	16	4	10	5	2	8	F	33	32	30	89	30	3	10	31	8			29	26	19	66	25	3
06	10	20	7		S	27	26	23	85	15	6	10	22	5		F	32	31	28	85	30	6	10	31	10			27	24	18	69	00	0
09	10	15	6		FH	29	27	24	82	17	9	10	14	7			31	29	25	79	30	8	8	100	9			31	28	23	72	36	3
12	10	17	8			32	29	25	75	18	10	10	18	8			32	29	24	72	30	5	10	110	12			32	27	18	56	11	6
15	10	18	8			34	31	27	76	18	6	10	27	9			33	29	22	64	29	10	10	110	12			34	29	18	52	05	5
18	10	28	6		S	34	32	28	79	20	6	10	29	12			31	28	21	67	34	6	10	130	10			33	28	18	54	06	7
21	10	11	6		SF	33	32	29	85	21	4	10	30	10			31	27	20	64	25	3	10	130	10			32	28	19	59	05	3
24	10	8	3		F	33	32	30	89	28	4	10	31	10			30	27	20	66	23	3	10	UNL	10			30	26	18	61	04	4
	MAR 22nd											MAR 23rd											MAR 24th										
03	10	250	7			27	24	17	66	05	4	10	33	10			32	29	23	69	05	4	0	UNL	10			31	29	25	79	00	0
06	10	180	10			27	24	17	66	06	6	2	UNL	12			27	25	21	78	36	5	2	UNL	7			29	28	25	85	00	0
09	10	20	2	8	S	28	26	23	82	06	9	4	UNL	12			33	29	21	61	01	8	8	42	5		H	39	35	29	67	10	6
12	10	20	8		S	33	30	25	73	08	8	2	UNL	12			44	38	28	54	04	9	10	16	8			45	39	32	61	13	6
15	10	47	10			36	32	25	64	07	7	3	UNL	15			48	39	27	44	01	8	10	29	6		H	45	39	30	56	20	6
18	10	55	10			35	31	24	64	05	7	0	UNL	15			46	38	26	46	36	8	10	15	6		H	43	37	28	56	14	6
21	10	80	10			34	30	24	67	08	4	1	UNL	15			41	35	24	51	00	0	10	17	7			40	36	30	68	17	6
24	10	32	10			33	30	24	70	03	3	0	UNL	15			37	33	25	62	00	0	10	1	0	4	F	34	33	32	92	21	7
	MAR 25th											MAR 26th											MAR 27th										
03	10	1	0	8	F	33	33	32	96	22	4	5	UNL	5		F	35	34	32	89	14	4	10	2	0	2	F	31	31	31	100	00	0
06	10	3	1		F	33	33	33	100	14	3	0	UNL	3		F	34	33	32	92	14	3	10	2	0	2	F	31	31	31	100	14	4
09	10	15	3		F	37	35	33	86	18	3	0	UNL	4		F	43	40	35	74	16	6	10	2	0	6	F	33	32	32	96	00	0
12	10	15	6		H	39	37	33	79	18	6	0	UNL	5		F	50	44	38	64	20	10	10	6	2	8	F	38	37	34	86	13	5
15	10	21	8			42	38	33	71	18	6	0	UNL	6		H	53	46	38	57	19	8	0	UNL	6		H	45	41	37	74	13	6
18	10	20	7			40	37	32	73	18	4	0	UNL	5		H	43	40	37	80	13	7	0	UNL	9			46	42	38	74	14	5
21	10	17	6		FH	39	36	32	76	20	4	0	UNL	6		FH	36	35	33	89	16	3	0	UNL	6		F	39	38	36	89	12	3
24	10	18	6		FH	38	35	31	76	14	3	0	UNL	6		F	32	31	30	92	11	4	0	UNL	4		F	35	34	33	92	11	4
	MAR 28th											MAR 29th											MAR 30th										
03	1	UNL	3		F	32	32	31	96	06	3	0	UNL	10			33	32	31	92	00	0	10	60	10			47	41	34	61	33	5
06	1	UNL	2		F	31	31	31	100	12	3	0	UNL	4		F	29	29	28	96	00	0	10	50	7			45	43	40	83	12	6
09	0	UNL	2	8	F	39	37	35	86	11	4	2	UNL	5		FH	49	43	36	61	00	0	10	28	5		F	45	43	41	86	09	8
12	0	UNL	7			52	45	36	55	12	6	3	UNL	10			58	46	32	38	13	4	10	30	2	8	RF	45	44	43	93	09	7
15	0	UNL	12			59	48	35	41	10	5	3	UNL	10			62	47	30	30	17	8	10	40	3		RF	45	44	42	89	06	9
18	0	UNL	12			55	46	35	47	15	6	9	95	15			58	44	25	28	12	9	10	40	3		RF	45	45	44	96	36	6
21	2	UNL	12			45	40	34	66	11	4	5	UNL	15			50	42	31	48	09	4	10	27	3		RF	45	45	44	96	36	14
24	2	UNL	12			38	36	33	82	00	0	5	UNL	15			48	40	30	50	06	5	10	22	6		LF	39	38	37	93	02	12
	MAR 31st																																
03	10	9	6		RF	38	37	36	93	02	14																						
06	10	12	7		R	37	36	34	89	02	11																						
09	10	13	7		RIP	35	34	33	92	01	14																						
12	10	11	1		S	33	32	30	89	02	16																						
15	10	13	0	12	S	31	30	28	89	02	18																						
18	10	13	1		S	29	28	26	89	01	21																						
21	10	47	5		S	27	25	22	81	02	18																						
24	10	55	12		S	27	24	19	72	02	14																						

SUMMARY BY HOURS

HOUR L.S.T.	AVERAGES							RESULTANT WIND	
	SKY COVER (TENTHS)	STATION PRESSURE (INCHES)	TEMPERATURE			REL HUMIDITY %	WIND SPEED (MPH)	DIRECTION	SPEED (MPH)
			AIR TEMP °F	WET BULB °F	DEW POINT °F				
03	5	29.190	25	24	20	80	6.2	31	1.9
06	5	29.200	24	23	19	83	6.3	36	1.3
09	5	29.220	29	27	22	75	7.9	35	1.6
12	5	29.230	35	31	23	64	9.9	34	0.7
15	5	29.190	36	31	23	60	10.3	32	1.3
18	6	29.200	34	30	22	64	10.2	30	1.8
21	6	29.200	30	27	22	72	7.4	29	1.1
24	5	29.220	27	25	20	75	6.8	30	1.4

WEATHER CODES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXP RESSED IN KNOTS (MPH=KNOTS X 1.15).

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MAR 1993 14922
MINNEAPOLIS-ST.PAUL, MN
USCOMM - NOAA - ASHEVILLE, NC 675

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

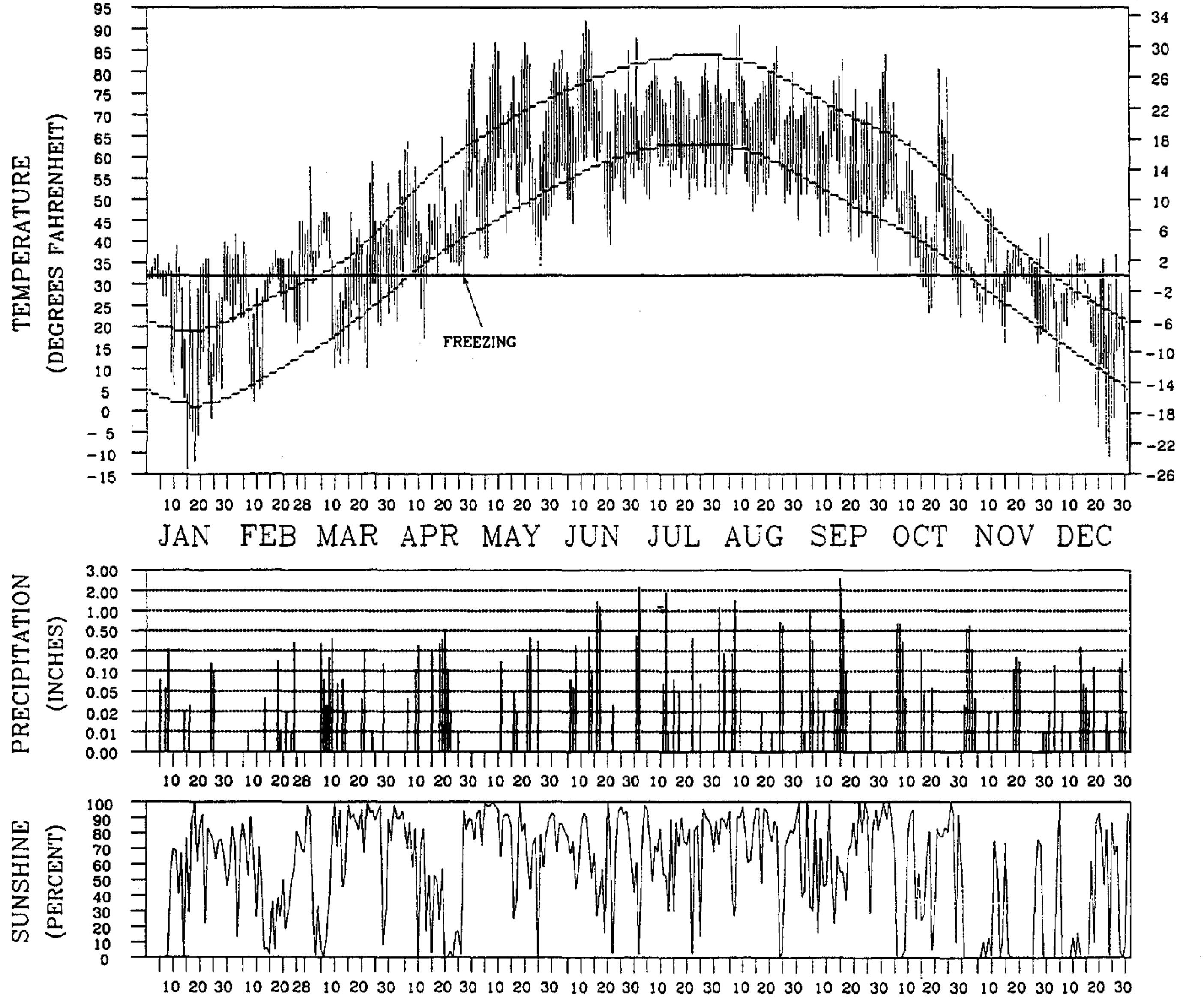
DATE	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												DATE
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
01																									01
02																									02
03																									03
04																									04
05																									05
06																									06
07																									07
08								T	T	T	T														08
09											T	0.02	0.02	0.02	0.04	0.05	0.02	0.01	0.01	0.02	0.05	0.04	0.01	0.02	09
10	0.01	0.01	T	0.01	0.01	0.01	0.02	T	T	T	T	T	T	T	T	T	0.01	0.01	T	0.01	T	T	T	T	10
11																									11
12								T	T	T	T	T													12
13																									13
14																									14
15																									15
16						T	0.02	0.02																	16
17																									17
18																						T	T	0.01	18
19	T	0.01	0.01	T	T	T	T	T										T	T		T	T	T	T	19
20																									20
21																									21
22									T	0.01	T	T	T												22
23																									23
24																									24
25																									25
26																									26
27																									27
28																									28
29																									29
30				0.04	0.03		0.03	0.04	0.01	0.03	0.05	0.07	0.05	0.04	0.02	0.02	0.02	T	T	0.02	T	0.01	0.01	T	30
31	T	T	0.01	T	0.02	0.01	0.01	0.02	0.01	0.02	0.04	0.01	0.02	0.02	0.02	0.01	0.01	T	0.01	0.01	T	T	T	T	31

ISSN 0198-2737

1992 LOCAL CLIMATOLOGICAL DATA
ANNUAL SUMMARY WITH COMPARATIVE DATA
MINNEAPOLIS – ST. PAUL, MINNESOTA

DEPARTMENT OF COMMERCE · UNITED STATES OF AMERICA

Daily Data



TEMPERATURE DEPICTS NORMAL MAXIMUM, NORMAL MINIMUM AND ACTUAL DAILY HIGH AND LOW VALUES (FAHRENHEIT)
PRECIPITATION IS MEASURED IN INCHES. SCALE IS NON-LINEAR
SUNSHINE IS PERCENT OF THE POSSIBLE SUNSHINE

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Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

noaa
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NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE
NATIONAL CLIMATIC DATA CENTER ASHEVILLE NORTH CAROLINA

METEOROLOGICAL DATA FOR 1992

MINNEAPOLIS - ST. PAUL, MINNESOTA

LATITUDE: 44°53' N LONGITUDE: 93°13' W ELEVATION: FT. GRND 834 BARO 860 TIME ZONE: CENTRAL WBAN: 14922

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F:													
Averages													
-Daily Maximum	29.4	33.9	41.0	52.2	72.3	76.3	74.7	75.7	69.8	57.0	35.9	28.5	53.9
-Daily Minimum	14.4	22.1	25.2	35.0	48.6	54.8	56.8	56.1	49.3	37.7	26.8	13.8	36.7
-Monthly	21.9	28.0	33.1	43.6	60.5	65.6	65.8	65.9	59.6	47.4	31.4	21.2	45.3
-Monthly Dewpt.	16.7	21.4	23.1	31.7	41.7	50.6	56.0	54.9	49.4	35.9	25.0	15.6	35.2
Extremes													
-Highest	40	45	59	82	87	92	88	91	83	84	48	42	92
-Date	29	27	24	30	20	12	1	9	16	2	10	1	JUN 12
-Lowest	-14	2	10	17	34	39	50	45	33	22	16	-12	-14
-Date	15	9	22	12	26	21	21	31	29	30	27	31	JAN 15
DEGREE DAYS BASE 65 °F:													
Heating	1333	1067	981	636	190	72	32	52	182	542	1003	1351	7441
Cooling	0	0	0	3	56	96	64	88	28	2	0	0	337
% OF POSSIBLE SUNSHINE	48	50	66	51	78	68	68	75	65	57	15	31	59
AVG. SKY COVER (tenths)													
Sunrise - Sunset	6.9	8.0	6.3	7.5	5.1	6.7	7.2	5.4	5.8	5.5	8.5	8.2	6.8
Midnight - Midnight	6.8	7.7	6.0	7.1	4.6	6.4	6.5	4.8	5.5	5.0	8.3	7.9	6.4
NUMBER OF DAYS:													
Sunrise to Sunset													
-Clear	5	3	10	5	11	2	3	10	9	12	3	5	78
-Partly Cloudy	7	5	4	7	13	16	12	11	9	6	3	3	96
-Cloudy	19	21	17	18	7	12	16	10	12	13	24	23	192
Precipitation .01 inches or more	7	7	12	10	6	8	9	9	12	8	11	14	113
Snow, Ice pellets, hail 1.0 inches or more	2	2	4	0	0	0	0	0	0	0	4	5	17
Thunderstorms	0	0	0	1	3	6	6	5	8	1	0	0	30
Heavy Fog, visibility 1/4 mile or less	1	2	4	0	0	0	0	1	0	0	0	0	8
Temperature °F													
-Maximum													
90° and above	0	0	0	0	0	2	0	1	0	0	0	0	3
32° and below	13	11	5	0	0	0	0	0	0	0	8	20	57
-Minimum													
32° and below	30	27	23	11	0	0	0	0	0	11	25	29	156
0° and below	6	0	0	0	0	0	0	0	0	0	0	6	12
AVG. STATION PRESS. (mb)	985.4	987.0	986.1	984.8	987.5	982.7	984.1	988.2	985.1	986.8	986.5	987.3	985.9
RELATIVE HUMIDITY (%)													
Hour 00 (Local Time)	82	80	74	71	59	70	82	80	77	71	82	83	76
Hour 06 (Local Time)	83	81	80	79	72	79	88	87	84	83	84	82	82
Hour 12 (Local Time)	74	70	59	58	41	48	61	56	60	56	71	75	61
Hour 18 (Local Time)	78	72	61	58	41	50	60	58	61	58	76	78	63
PRECIPITATION (inches):													
Water Equivalent													
-Total	0.66	0.57	1.56	1.99	1.15	3.68	5.21	4.54	5.20	2.11	1.95	1.05	29.67
-Greatest (24 hrs)	0.26	0.34	0.56	0.63	0.58	2.61	2.56	1.67	3.39	0.95	0.74	0.30	3.39
-Date	7- 8	23-24	8- 9	18-19	21-22	16-17	1- 2	6- 7	15-16	6- 7	1- 2	13-14	SEP 15-16
Snow, Ice pellets, hail													
-Total	5.0	5.9	10.8	0.6	0.0	0.0	0.0	T	T	1.3	12.2	9.2	45.0
-Greatest (24 hrs)	3.6	3.4	3.9	0.6	0.0	0.0	0.0	T	T	0.8	6.5	3.9	6.5
-Date	24-25	23-24	8- 9	9-10				1	4	15-16	1- 2	28-29	NOV 1- 2
WIND:													
Resultant													
-Direction (!!!)	265	305	004	026	194	073	284	218	194	337	341	248	268
-Speed (mph)	1.6	2.0	2.7	1.5	2.7	0.8	1.9	1.7	4.8	1.5	2.4	3.0	0.9
Average Speed (mph)	9.8	9.9	9.7	11.4	11.2	9.8	9.3	9.2	11.6	9.8	9.4	10.4	10.1
Fastest Obs. 1 Min.													
-Direction (!!!)	31	32	33	15	17	22	26	26	32	29	31	29	22
-Speed (mph)	31	29	23	28	30	35	24	29	29	23	28	32	35
-Date	23	6	31	30	10	17	3	1	27	12	12	25	JUN 17
Peak Gust													
-Direction (!!!)	NW	NW	N	SE	W	S	W	SW	NW	S	NW		
-Speed (mph)	41	38	32	38	49	51	33	39	40	32	41		
-Date	23	7	24	5	2	17	3	1	27	22	12		

(!!!) See Reference Notes on Page 6B

NORMALS, MEANS, AND EXTREMES

MINNEAPOLIS - ST. PAUL, MINNESOTA

LATITUDE: 44°53'N LONGITUDE: 93°13' W ELEVATION: FT. GRND 834 BARO - 860 TIME ZONE: CENTRAL WBAN: 14922

	(a)	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F:														
Normals														
-Daily Maximum		19.9	26.4	37.5	56.0	69.4	78.5	83.4	80.9	71.0	59.7	41.1	26.7	54.2
-Daily Minimum		2.4	8.5	20.8	36.0	47.6	57.7	62.7	60.3	50.2	39.4	25.3	11.7	35.2
-Monthly		11.2	17.5	29.2	46.0	58.5	68.1	73.1	70.6	60.6	49.6	33.2	19.2	44.7
Extremes														
-Record Highest	54	58	60	83	95	96	102	105	102	98	89	75	63	105
-Year		1944	1981	1986	1980	1978	1985	1988	1947	1976	1953	1944	1982	JUL 1988
-Record Lowest	54	-34	-28	-32	2	18	34	43	39	26	15	-17	-29	-34
-Year		1970	1965	1962	1962	1967	1945	1972	1967	1974	1972	1964	1983	JAN 1970
NORMAL DEGREE DAYS:														
Heating (base 65°F)		1668	1330	1110	570	238	41	12	16	160	488	954	1420	8007
Cooling (base 65°F)		0	0	0	0	36	134	263	190	28	11	0	0	662
% OF POSSIBLE SUNSHINE	54	53	59	57	58	61	66	72	69	62	55	39	42	58
MEAN SKY COVER (tenths)														
Sunrise - Sunset	54	6.3	6.3	6.7	6.5	6.4	6.1	5.3	5.3	5.6	5.8	7.1	7.0	6.2
MEAN NUMBER OF DAYS:														
Sunrise to Sunset														
-Clear	54	8.3	7.7	6.9	7.0	7.1	7.3	10.0	10.3	9.9	9.9	5.6	6.4	96.4
-Partly Cloudy	54	7.4	6.9	7.4	7.7	9.1	10.4	11.9	11.1	8.6	7.6	6.5	6.4	100.9
-Cloudy	54	15.4	13.6	16.6	15.2	14.8	12.3	9.2	9.6	11.6	13.5	17.9	18.2	167.9
Precipitation														
.01 inches or more	54	8.6	7.4	10.3	10.2	11.3	11.6	9.7	9.9	9.6	8.0	8.5	9.3	114.5
Snow,Ice pellets,hail														
1.0 inches or more	54	3.2	2.7	3.0	0.8	0.1	0.0	0.0	0.0	0.*	0.1	2.2	3.1	15.2
Thunderstorms	54	0.*	0.2	1.0	2.7	5.2	7.5	7.6	6.5	4.3	1.8	0.6	0.1	37.5
Heavy Fog Visibility														
1/4 mile or less	54	1.2	1.4	1.3	0.4	0.5	0.5	0.3	0.6	0.9	1.0	1.2	1.4	10.6
Temperature °F														
-Maximum														
90° and above	33	0.0	0.0	0.0	0.1	0.8	2.8	6.3	3.7	0.8	0.0	0.0	0.0	14.6
32° and below	33	23.4	17.7	8.7	0.3	0.0	0.0	0.0	0.0	0.0	0.1	7.0	21.4	78.5
-Minimum														
32° and below	33	30.8	27.3	25.0	11.0	1.1	0.0	0.0	0.0	0.5	7.7	22.9	29.8	156.2
0° and below	33	13.6	8.1	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	8.0	32.3
AVG. STATION PRESS.(mb)	20	987.3	988.2	985.0	984.2	983.6	983.0	984.8	985.7	986.0	986.3	985.9	987.5	985.6
RELATIVE HUMIDITY (%)														
Hour 00	33	72	73	72	67	67	72	75	77	79	74	77	76	73
Hour 06 (Local Time)	33	74	75	76	75	76	79	81	84	85	81	80	78	79
Hour 12	33	67	65	61	52	52	54	54	56	59	58	66	70	60
Hour 18	33	68	66	61	51	50	52	53	56	61	60	69	72	60
PRECIPITATION (inches):														
Water Equivalent														
-Normal		0.82	0.85	1.71	2.05	3.20	4.07	3.51	3.64	2.50	1.85	1.29	0.87	26.36
-Maximum Monthly	54	3.63	2.14	4.75	5.88	8.03	9.82	17.90	9.31	7.53	5.68	5.29	4.27	17.90
-Year		1967	1981	1965	1986	1962	1990	1987	1977	1942	1971	1991	1982	JUL 1987
-Minimum Monthly	54	0.10	0.06	0.32	0.16	0.61	0.22	0.58	0.43	0.41	0.01	0.02	T	T
-Year		1990	1964	1958	1987	1967	1988	1975	1946	1940	1952	1939	1943	DEC 1943
-Maximum in 24 hrs	54	1.21	1.10	1.66	2.23	3.03	3.00	10.00	7.36	3.55	2.95	2.91	2.47	10.00
-Year		1967	1966	1965	1975	1965	1986	1987	1977	1942	1966	1940	1982	JUL 1987
Snow,Ice pellets,hail														
-Maximum Monthly	54	46.4	26.5	40.0	21.8	3.0	T	0.0	T	1.7	8.2	46.9	33.2	46.9
-Year		1982	1962	1951	1983	1946	1989		1992	1942	1991	1991	1969	NOV 1991
-Maximum in 24 hrs	54	18.5	9.3	14.7	13.6	3.0	T	0.0	T	1.7	8.2	21.0	16.5	21.0
-Year		1982	1939	1985	1983	1946	1989		1992	1942	1991	1991	1982	NOV 1991
WIND:														
Mean Speed (mph)	54	10.5	10.4	11.4	12.2	11.2	10.5	9.4	9.3	10.0	10.5	10.9	10.4	10.6
Prevailing Direction through 1963		NW	NW	NW	NW	SE	SE	S	SE	S	SE	NW	NW	NW
Fastest Obs. 1 Min.														
-Direction (!!)	13	32	34	08	19	23	01	35	20	18	33	25	34	32
-Speed (MPH)	13	51	37	33	41	35	46	43	44	36	33	41	35	51
-Year		1986	1987	1985	1984	1986	1980	1980	1983	1988	1981	1986	1989	JAN 1986
Peak Gust														
-Direction (!!)	9	NW	NW	W	SW	N	S	NW	W	N	NW	W	NW	W
-Speed (mph)	9	67	55	60	61	67	51	51	71	52	53	66	48	71
-Date		1986	1987	1988	1984	1985	1992	1984	1988	1989	1987	1986	1989	AUG 1988

(!!) See Reference Notes on Page 68.

PRECIPITATION (inches)

MINNEAPOLIS – ST. PAUL, MINNESOTA

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1963	0.46	0.41	1.18	2.07	5.06	1.91	1.53	1.55	3.47	0.81	0.52	0.60	19.57
1964	0.47	0.06	1.35	2.98	3.44	2.18	2.02	5.42	5.21	0.57	1.19	1.08	25.97
1965	0.47	1.59	4.75	3.52	7.86	4.01	4.69	4.04	4.90	0.90	1.98	1.23	39.94
1966	0.95	1.55	2.48	0.89	1.46	3.51	2.47	4.40	1.69	3.53	0.39	1.02	24.34
1967	3.63	1.59	0.96	4.07	0.61	7.53	1.36	2.79	0.63	1.73	0.09	0.45	25.44
1968	0.71	0.13	1.89	2.94	3.74	6.78	6.46	0.75	6.15	5.62	0.54	2.21	37.93
1969	2.05	0.31	0.90	1.55	1.98	2.93	2.95	0.99	0.49	2.53	0.65	2.06	19.39
1970	0.47	0.16	2.05	3.55	4.77	1.27	3.66	2.19	3.19	4.97	3.82	0.43	30.53
1971	1.22	1.74	1.21	1.11	3.14	3.52	3.94	1.78	2.73	5.68	2.67	0.70	29.44
1972	0.84	0.49	1.25	1.69	2.18	3.31	5.12	2.48	1.96	1.77	1.11	1.57	23.77
1973	0.92	0.84	1.12	2.32	2.48	1.06	2.90	3.05	2.08	1.29	1.97	1.10	21.13
1974	0.17	1.06	1.00	2.42	2.08	5.21	1.14	2.75	0.58	1.69	0.66	0.35	19.11
1975	2.82	0.79	1.67	5.40	3.81	7.99	0.58	4.92	1.31	0.27	4.80	0.79	35.15
1976	0.87	0.59	2.83	0.80	1.13	3.86	2.45	1.39	1.42	0.49	0.16	0.51	16.50
1977	0.65	0.93	2.66	1.84	2.86	3.57	3.72	9.31	4.43	2.34	1.42	1.15	34.88
1978	0.38	0.24	0.79	3.63	3.79	7.09	3.19	5.77	2.47	0.19	1.84	0.88	30.26
1979	1.09	1.39	2.55	0.66	4.55	4.78	2.34	7.04	2.20	3.16	0.98	0.33	31.07
1980	0.94	0.67	1.12	0.83	2.29	5.52	2.30	3.26	3.68	0.66	0.26	0.24	21.77
1981	0.30	2.14	0.71	2.17	2.18	4.42	4.09	4.73	1.46	2.69	2.16	0.92	27.97
1982	2.45	0.43	2.09	1.62	4.99	1.44	0.92	3.80	1.50	3.45	3.27	4.27	30.23
1983	0.67	1.19	3.22	3.97	6.20	5.22	3.07	3.12	3.34	2.61	4.93	1.53	39.07
1984	0.88	1.64	1.47	3.86	2.29	7.95	3.03	5.15	2.65	5.48	0.31	2.24	36.95
1985	0.87	0.50	4.48	1.81	3.65	2.18	2.20	5.02	4.37	3.66	1.72	1.20	31.66
1986	0.90	0.84	2.03	5.88	3.48	5.34	4.11	4.44	6.90	1.77	0.62	0.31	36.62
1987	0.63	0.13	0.64	0.16	1.88	1.95	17.90	3.67	1.28	0.60	2.07	1.25	32.16
1988	1.37	0.30	1.33	1.58	1.70	0.22	1.17	4.29	2.79	0.80	2.86	0.67	19.08
1989	0.52	1.04	2.19	2.66	3.38	3.50	3.50	2.92	1.28	0.53	1.38	0.42	23.32
1990	0.10	0.77	3.66	3.80	3.36	9.82	5.06	1.71	1.88	1.23	0.65	1.01	33.05
1991	0.49	1.03	2.29	3.58	6.35	2.57	2.95	3.14	5.43	2.52	5.29	1.05	36.69
1992	0.66	0.57	1.56	1.99	1.15	3.68	5.21	4.54	5.20	2.11	1.95	1.05	29.67
Record Mean	0.83	0.86	1.61	2.17	3.38	4.14	3.53	3.37	2.90	2.02	1.45	0.95	27.21

See Reference Notes on Page 6B.
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AVERAGE TEMPERATURE (deg. F)

MINNEAPOLIS – ST. PAUL, MINNESOTA

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1963	2.9	12.1	34.2	47.3	55.4	69.8	73.5	68.9	62.2	58.1	38.3	10.0	44.4
1964	20.0	23.9	25.8	46.8	61.5	68.7	76.0	68.5	58.9	48.2	35.0	14.8	45.7
1965	10.0	11.8	19.5	41.8	58.7	66.5	70.5	68.6	52.8	50.7	33.1	28.0	42.7
1966	3.3	16.3	35.8	42.2	53.6	68.4	76.8	68.2	60.3	47.5	30.1	18.1	43.4
1967	14.6	8.7	29.8	44.7	52.3	66.9	68.8	66.2	60.3	46.3	30.7	21.8	42.6
1968	14.3	15.2	38.8	48.5	53.4	67.2	71.1	70.7	61.1	50.7	34.0	16.9	45.2
1969	9.4	19.3	24.1	49.3	60.6	61.8	73.6	74.4	63.0	46.5	33.6	20.3	44.7
1970	5.6	15.4	26.0	46.1	58.5	71.2	75.2	71.9	61.2	49.6	32.7	18.2	44.3
1971	6.5	17.0	28.0	47.0	55.4	71.5	68.8	69.6	62.8	51.4	32.7	18.4	44.1
1972	5.5	10.5	26.5	41.9	61.3	66.0	68.5	69.8	57.9	43.7	32.2	11.3	41.3
1973	17.4	21.6	40.2	44.4	55.2	69.5	73.8	73.4	60.1	53.8	34.3	16.7	46.7
1974	11.9	16.9	29.5	47.1	54.4	65.5	76.6	67.3	55.3	49.8	33.7	24.4	44.4
1975	14.5	15.5	22.1	38.9	60.9	68.8	76.3	71.7	57.7	52.8	37.5	21.3	44.8
1976	11.6	27.8	31.4	51.8	58.9	71.7	76.1	73.3	61.8	44.6	28.3	13.6	45.9
1977	0.3	22.7	37.5	53.0	66.9	68.4	74.8	66.1	60.5	47.1	30.8	14.4	45.2
1978	5.5	11.6	30.0	45.2	61.8	67.8	71.1	72.2	67.3	49.8	32.5	15.2	44.2
1979	3.2	10.0	28.9	44.0	55.5	67.3	73.6	69.9	63.4	46.6	31.7	26.0	43.3
1980	15.3	15.3	27.3	49.2	61.5	67.6	75.2	70.7	59.5	45.1	36.6	19.8	45.2
1981	18.0	23.4	37.7	49.1	57.1	67.0	70.9	69.3	60.0	46.7	38.0	17.5	46.2
1982	2.3	15.8	29.0	43.8	62.5	63.7	75.6	71.8	60.9	50.3	31.5	25.7	44.4
1983	19.6	26.9	34.2	42.3	54.6	68.0	77.2	76.8	62.6	48.4	34.0	3.7	45.7
1984	12.0	27.5	24.8	47.1	56.0	69.7	72.2	73.5	57.2	50.7	33.3	17.9	45.2
1985	10.1	16.5	35.6	52.1	62.2	63.9	73.9	67.6	59.9	47.5	24.8	7.7	43.5
1986	17.5	15.7	33.9	49.6	59.4	68.6	73.9	67.1	59.8	49.2	28.2	24.7	45.6
1987	21.2	31.6	38.7	53.5	63.5	72.8	76.0	69.0	62.5	44.6	37.9	25.0	49.7
1988	10.4	13.9	33.8	47.4	65.4	74.4	78.1	73.9	62.4	44.0	32.7	20.5	46.4
1989	21.2	8.6	26.6	45.3	57.5	68.4	76.4	70.8	60.9	49.9	28.0	10.6	43.7
1990	26.3	23.7	35.7	46.8	56.3	69.5	71.3	70.6	64.4	48.1	37.4	16.9	47.3
1991	12.5	24.4	34.3	49.1	61.9	72.9	72.3	71.1	59.0	47.2	24.5	21.2	45.9
1992	21.9	28.0	33.1	43.6	60.5	65.6	65.8	65.9	59.6	47.4	31.4	21.2	45.3
Record Mean	13.2	17.3	30.1	46.0	58.3	68.0	73.2	70.7	61.5	49.6	32.8	19.2	45.0
Max	21.8	25.9	38.4	55.8	68.5	77.9	83.2	80.6	71.3	59.0	40.4	26.7	54.1
Min	4.6	8.6	21.8	36.3	48.0	58.0	63.1	60.7	51.6	40.2	25.2	11.6	35.8

See Reference Notes on Page 6B.
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HEATING DEGREE DAYS Base 65 deg. F MINNEAPOLIS - ST. PAUL, MINNESOTA

SEASON	JULY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	TOTAL
1963-64	1	32	129	216	793	1703	1390	1186	1209	543	154	49	7405
1964-65	0	63	224	515	894	1551	1702	1486	1405	690	211	19	8760
1965-66	7	40	368	447	950	1140	1909	1358	899	678	357	41	8194
1966-67	0	40	185	536	1042	1446	1556	1572	1086	600	404	30	8497
1967-68	36	65	166	577	1024	1335	1567	1440	808	491	358	62	7929
1968-69	10	28	143	451	922	1486	1723	1274	1261	461	204	136	8099
1969-70	5	0	131	580	933	1379	1842	1382	1204	577	249	20	8302
1970-71	3	5	190	476	959	1443	1811	1341	1139	537	297	18	8219
1971-72	16	22	164	413	962	1438	1844	1576	1188	687	204	73	8587
1972-73	34	52	218	651	974	1664	1474	1208	761	611	299	13	7959
1973-74	1	3	185	350	915	1493	1642	1344	1092	535	338	72	7970
1974-75	0	48	289	467	933	1252	1561	1379	1324	775	188	39	8255
1975-76	15	7	231	387	818	1346	1650	1074	1031	405	195	11	7170
1976-77	0	4	162	632	1092	1590	2005	1180	844	365	75	17	7966
1977-78	0	35	145	548	1016	1565	1842	1488	1080	584	162	46	8511
1978-79	5	7	89	464	968	1538	1914	1537	1112	623	307	38	8602
1979-80	0	24	105	566	992	1203	1536	1436	1165	484	184	34	7729
1980-81	0	12	194	611	845	1396	1453	1160	838	472	249	28	7258
1981-82	11	11	172	564	803	1466	1945	1374	1111	629	117	71	8274
1982-83	0	14	168	448	997	1212	1400	1061	947	673	313	49	7282
1983-84	2	0	161	514	923	1901	1641	1082	1240	531	284	7	8286
1984-85	5	12	251	435	943	1453	1694	1355	904	403	123	104	7682
1985-86	0	28	240	537	1201	1774	1466	1377	957	454	212	30	8276
1986-87	0	43	177	480	1096	1243	1352	929	809	347	134	13	6623
1987-88	2	29	106	623	804	1236	1688	1479	962	523	76	4	7532
1988-89	1	16	116	646	963	1373	1353	1576	1184	583	251	44	8106
1989-90	0	6	159	470	1105	1683	1194	1151	899	569	274	37	7547
1990-91	2	5	136	516	820	1484	1624	1130	945	481	197	3	7343
1991-92	7	8	228	548	1206	1354	1333	1067	981	636	190	72	7630
1992-93	32	52	182	542	1003	1351							

See Reference Notes on Page 6B.
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COOLING DEGREE DAYS Base 65 deg. F MINNEAPOLIS - ST. PAUL, MINNESOTA

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	TOTAL
1969	0	0	0	0	76	49	276	298	77	12	0	0	788
1970	0	0	0	17	54	213	323	225	83	5	0	0	920
1971	0	0	0	2	5	218	141	168	106	3	0	0	643
1972	0	0	0	0	94	109	148	208	13	0	0	0	572
1973	0	0	0	1	4	158	280	271	47	8	0	0	769
1974	0	0	0	5	18	93	369	127	6	1	0	0	619
1975	0	0	0	0	66	159	371	220	18	16	0	0	850
1976	0	0	0	14	14	223	351	269	72	7	0	0	950
1977	0	0	0	12	145	129	310	76	19	0	0	0	691
1978	0	0	0	0	72	138	201	236	164	0	0	0	811
1979	0	0	0	0	17	113	275	181	65	0	0	0	651
1980	0	0	0	16	82	121	322	194	38	1	0	0	774
1981	0	0	0	0	10	96	200	151	28	0	0	0	485
1982	0	0	0	0	46	40	338	232	53	0	0	0	709
1983	0	0	0	0	0	145	389	368	98	8	0	0	1008
1984	0	0	0	0	13	155	237	280	24	0	0	0	709
1985	0	0	0	22	43	77	284	118	93	0	0	0	637
1986	0	0	0	1	45	148	286	115	32	0	0	0	627
1987	0	0	0	11	95	253	348	159	37	0	0	0	903
1988	0	0	0	1	96	296	412	302	45	0	0	0	1152
1989	0	0	0	0	26	153	359	192	41	8	0	0	779
1990	0	0	0	28	11	178	206	191	125	1	0	0	740
1991	0	0	0	8	109	246	238	205	51	0	0	0	857
1992	0	0	0	3	56	96	64	88	28	2	0	0	337

See Reference Notes on Page 6B.
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SNOWFALL (inches)

MINNEAPOLIS - ST. PAUL, MINNESOTA

SEASON	JULY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	TOTAL
1963-64	0.0	0.0	0.0	0.0	T	7.6	5.0	1.0	9.7	5.6	0.0	0.0	28.9
1964-65	0.0	0.0	0.0	T	4.3	8.1	10.5	11.7	37.1	2.0	T	0.0	73.7
1965-66	0.0	0.0	0.0	0.0	1.6	1.2	11.9	6.8	14.2	0.4	T	0.0	36.1
1966-67	0.0	0.0	0.0	0.2	3.4	12.7	35.3	23.7	2.6	0.2	0.3	0.0	78.4
1967-68	0.0	0.0	0.0	0.3	0.8	2.4	10.6	2.2	0.8	0.4	0.0	0.0	17.5
1968-69	0.0	0.0	0.0	T	4.9	28.7	21.6	5.3	7.3	0.3	0.0	0.0	68.1
1969-70	0.0	0.0	0.0	2.4	3.8	33.2	9.8	4.3	8.6	1.3	T	0.0	63.4
1970-71	0.0	0.0	0.0	T	6.3	5.5	19.9	13.9	7.0	1.9	0.2	0.0	54.7
1971-72	0.0	0.0	0.0	0.0	13.2	12.8	12.2	7.6	10.4	8.0	0.0	0.0	64.2
1972-73	0.0	0.0	T	T	1.1	15.3	11.6	11.3	0.4	2.0	0.0	0.0	41.7
1973-74	0.0	0.0	0.0	0.0	0.1	17.9	2.5	15.7	7.7	7.3	0.0	0.0	51.2
1974-75	0.0	0.0	0.0	0.0	1.2	6.1	27.4	9.0	18.3	2.2	0.0	0.0	64.2
1975-76	0.0	0.0	0.0	0.0	16.2	5.6	12.8	5.1	13.6	0.0	1.2	0.0	54.5
1976-77	0.0	0.0	0.0	2.3	1.4	8.3	13.4	1.8	14.6	1.8	0.0	0.0	43.6
1977-78	0.0	0.0	0.0	3.0	11.7	14.2	6.8	4.6	8.5	1.9	0.0	0.0	50.7
1978-79	0.0	0.0	0.0	0.0	16.5	15.1	14.2	13.5	8.4	0.7	0.0	0.0	68.4
1979-80	0.0	0.0	0.0	T	7.7	1.7	12.9	8.8	13.7	8.5	0.0	0.0	53.3
1980-81	0.0	0.0	0.0	T	0.9	2.8	4.6	11.0	0.1	1.7	0.0	0.0	21.1
1981-82	0.0	0.0	0.0	0.9	14.0	10.6	46.4	7.4	10.9	4.8	0.0	0.0	95.0
1982-83	0.0	0.0	0.0	1.4	3.6	19.3	3.2	10.8	14.3	21.8	0.0	0.0	74.4
1983-84	0.0	0.0	0.0	T	30.4	21.0	10.6	9.3	17.3	9.8	0.0	0.0	98.4
1984-85	0.0	0.0	0.0	0.3	2.0	16.3	13.1	4.2	36.8	T	0.0	0.0	72.7
1985-86	0.0	0.0	0.4	T	23.9	13.5	10.3	12.3	8.7	0.4	0.0	0.0	69.5
1986-87	0.0	0.0	0.0	T	4.4	4.2	5.5	1.2	2.1	T	0.0	0.0	17.4
1987-88	0.0	0.0	0.0	0.3	4.5	7.5	19.5	4.5	3.7	2.4	0.0	0.0	42.4
1988-89	0.0	0.0	0.0	0.2	15.8	7.2	6.0	17.3	22.7	0.8	0.1	T	70.1
1989-90	0.0	0.0	0.0	0.0	11.3	7.0	1.1	10.7	3.2	2.2	0.0	0.0	35.5
1990-91	0.0	0.0	0.0	T	5.0	11.7	6.5	14.2	4.4	1.5	0.3	0.0	43.6
1991-92	0.0	T	0.0	8.2	46.9	6.7	5.0	5.9	10.8	0.6	0.0	0.0	84.1
1992-93	0.0	T	T	1.3	12.2	9.2							
Record Mean	0.0	T	T	0.5	7.9	9.4	9.7	8.5	10.8	2.9	0.1	T	49.9

See Reference Notes on Page 6B.

REFERENCE NOTES

MINNEAPOLIS - ST. PAUL, MINNESOTA

GENERAL
T - TRACE AMOUNT.
BLANK ENTRIES DENOTE MISSING/UNREPORTED DATA.
# INDICATES A STATION OR INSTRUMENT RELOCATION.
SEE STATION LOCATION TABLE ON PAGE 8.

SPECIFIC
PAGE 2
PM - INCLUDES LAST DAY OF PREVIOUS MONTH
ASOS - AUTOMATED SURFACE OBSERVING SYSTEM IN
OPERATION DURING THESE MONTHS.

PAGE 3
(a) - LENGTH OF RECORD IN YEARS, ALTHOUGH
INDIVIDUAL MONTHS MAY BE MISSING.
0.* OR * - THE VALUE IS BETWEEN 0.0 AND 0.05
NORMALS - BASED ON THE 1951-1980 RECORD PERIOD.
EXTREMES - DATES ARE THE MOST RECENT OCCURRENCE
WIND DIR.- NUMERALS SHOW TENS OF DEGRESS CLOCKWISE
FROM TRUE NORTH. "00" INDICATES CALM.
RESULTANT DIRECTIONS ARE GIVEN TO WHOLE DEGREES.
BOLD VALUES INDICATE EXTREME VALUES WHICH OCCURRED
AFTER THE ASOS SYSTEM WAS COMMISSIONED.

PAGE 4B
RECORD = PERIOD OF RECORD
RECORD MEAN PRECIPITATION IS THE MEAN OF ALL DAILY
PRECIPITATION AMOUNTS DURING THE PERIOD OF RECORD.
RECORD MAX(MIN) TEMPERATURE IS THE MEAN OF ALL DAILY
MAX(MIN) TEMPERATURES DURING THE PERIOD OF RECORD.
RECORD MEAN TEMPERATURE IS THE SUM OF THE RECORD
MAX AND RECORD MIN DIVIDED BY 2.
AVERAGE TEMPERATURE IS THE SUM OF THE MEAN DAILY
MAX AND MIN TEMPERATURE DIVIDED BY 2.

EXCEPTIONS

PAGES 4A, 4B, 6A
RECORD MEANS ARE THROUGH THE CURRENT YEAR,
BEGINNING IN 1891 FOR TEMPERATURE
1891 FOR PRECIPITATION
1939 FOR SNOWFALL

MINNEAPOLIS – ST. PAUL, MINNESOTA

The Twin Cities of Minneapolis and St. Paul are located at the confluence of the Mississippi and Minnesota Rivers over the heart of an artesian water basin. Its flat or gently rolling terrain varies little in elevation from that of the official observation station at International Airport. Numerous lakes dot the surrounding area. Minneapolis alone boasts of 22 lakes within the city park system. The largest body of water, nearly 15,000 acres, is Lake Minnetonka, located about 15 miles west of the airport. Most bodies of water are relatively small and shallow and are ice covered during winter.

The climate of the Minneapolis-St. Paul area is predominantly continental. Seasonal temperature variations are quite large. Temperatures range from less than –30 degrees to over 100 degrees. The growing season is 166 days. Because of this favorable growing season, all crops generally mature before the autumn freeze occurs.

The Twin Cities lie near the northern edge of the influx of moisture from the Gulf of Mexico. Severe storms such as blizzards, freezing rain (glaze), tornadoes, wind and hail storms do occur. The total annual precipitation is important. Even more significant is its proper distribution during the growing season. During the five month growing season, May through September, the major crops produced are corn, soybeans, small grains, and hay. During this period, the normal rainfall is over 16 inches, approximately 65 percent of the annual precipitation. Winter snowfall is nearly 48 inches. Winter recreational weather is excellent because of the dry snow. These conditions exist from about Christmas into early March. Snow depths average 6 to 8 inches in the city and 8 to 10 inches in the suburbs during this period.

Floods occur along the Mississippi River due to spring snow melt, excessive rainfall, or both. Occasionally an ice jam forms and creates a local flood condition. The flood problem at St. Paul is complicated because the Minnesota River empties into the Mississippi River between the two cities. Consequently, high water or flooding on the Minnesota River creates a greater flood potential at St. Paul. Flood stage at St. Paul can be expected on the average once in every eight years.

STATION LOCATION

MINNEAPOLIS-ST. PAUL, MINNESOTA

LOCATION	OCCUPIED FROM	OCCUPIED TO	AIRLINE DISTANCES AND DIRECTIONS FROM PREVIOUS LOCATION	LATITUDE NORTH	LONGITUDE WEST	ELEVATION ABOVE										AUTOMATIC OBSERVING EQUIPMENT *	REMARKS
						SEA LEVEL	GROUND										
						GROUND TEMPERATURE SITE	WIND INSTRUMENTS	EXTREME THERMOMETERS	PSYCHROMETER	SUNSHINE SWITCH	TIPPING BUCKET RAIN GAGE	WEIGHING RAIN GAGE	8 INCH RAIN GAGE	HYGROTHERMOMETER			
COOPERATIVE																	
Dr. C.L. Anderson Corner Helen & 2nd St.	1/01/56	12/31/59		44°59'	93°18'	839											Surgeon General & Smithsonian Institute to 1870.
Mr. Wm. Cheney, Corner Douglas & Freemonet St.	11/01/64	6/30/01		44°58'	93°20'	850											
Mr. J.H. Aschenbeck 721 6th Avenue North	11/25/87	10/?/95		45°00'	93°19'	850		18					3				
Mr. J.H. Aschenbeck 731 6th Avenue North	10/?/95	9/?/23	2 blocks	45°00'	93°19'	825		4					3				Thermometers 99', RG 95' to 11/1/04; anemometer 192' to 4/96.
Mr. J.H. Aschenbeck 1730 Penn. Avenue N.	9/?/23	10/?/36	1.5 mi. NW	45°01'	93°21'	888		4					3				Precipitation only after 2/23/29. Temperature obs. 7A, 2P and 9P.
CITY																	
U.S. Court House, cor. Marquette Ave. & 3rd St	11/06/90	4/10/38		44°59'	93°18'	839	105	105	104		97		96				
AIRPORT																	
Administration Bldg. Wold-Chamberlain AP	1/27/34	10/16/37		44°53'	93°13'	832	61	32									
Administration Bldg. Minneapolis-St. Paul International Airport Wold-Chamberlain Field	10/16/37	Present	NA	44°53'	93°13'	a834	b21 h33	f43	f42	%50 i42	e41	c4 g41	e41	d5 j5	NA		Several minor moves of instruments but no significant changes in elevations other than given below. St. Paul WBAS was integrated with Minneapolis WBAS 6/1/53. a - Ground elevation 830' to 1/1/60 & 822' to 5/24/63. b - 75' to 9/18/58. c - Installed 11/20/53. Elevation 41' to 10/24/62. d - Commissioned on field site 1/1/60; moved 800' WNW 5/31/63. e - Standby after 10/24/62. f - Standby after 1/1/60. g - Effective 11/15/72. % - Commissioned 9/18/58. h - Raised 10/17/81. i - Effective 11/5/84. j - Type change 12/11/85.

* Type

M = AMOS
T = AUTOB
S = ASOS
W = AWOS

SUBSCRIPTION:
Price and ordering information available through: National Climatic Data Center, Federal Building, Asheville, North Carolina 28801.
INQUIRIES/COMMENTS CALL: (704) 271-4800

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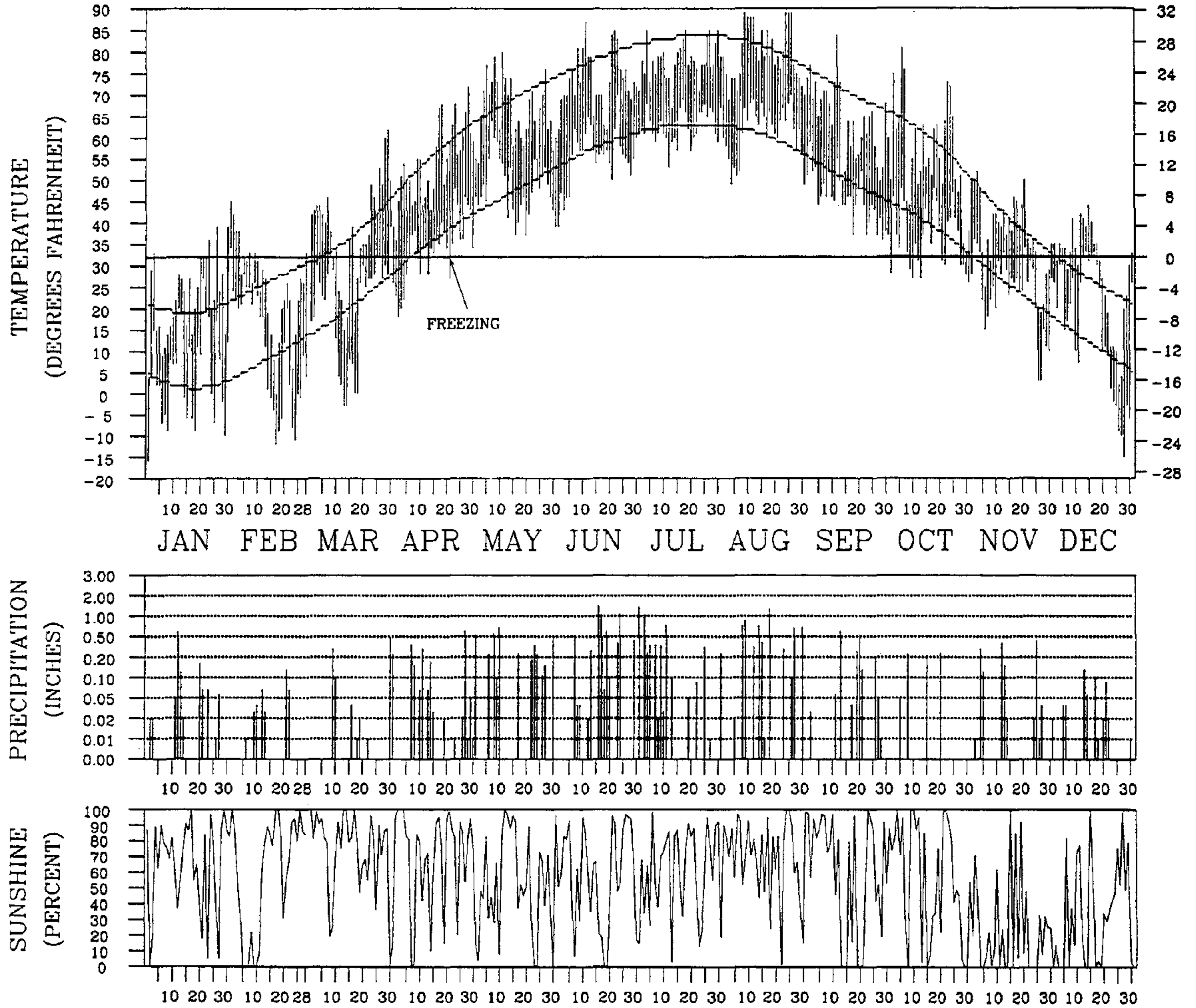
1993 LOCAL CLIMATOLOGICAL DATA
ANNUAL SUMMARY WITH COMPARATIVE DATA
MINNEAPOLIS - ST. PAUL,
MINNESOTA

DEPARTMENT OF COMMERCE UNITED STATES OF AMERICA

Daily Data



TEMPERATURE DEPICTS NORMAL MAXIMUM, NORMAL MINIMUM AND ACTUAL DAILY HIGH AND LOW VALUES (FAHRENHEIT)
PRECIPITATION IS MEASURED IN INCHES, SCALE IS NON-LINEAR
SUNSHINE IS PERCENT OF THE POSSIBLE SUNSHINE

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER, ASHEVILLE, NORTH CAROLINA, 28801

Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

noaa
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ENVIRONMENTAL SATELLITE, DATA
AND INFORMATION SERVICE

NATIONAL
CLIMATIC DATA CENTER
ASHEVILLE NORTH CAROLINA

METEOROLOGICAL DATA FOR 1993

MINNEAPOLIS – ST. PAUL, MINNESOTA

LATITUDE: 44°53′ N LONGITUDE: 93°13′ W ELEVATION: FT. GRND 834 BARO 860 TIME ZONE: CENTRAL WBAN: 14922

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F:													
Averages													
-Daily Maximum	23.6	24.4	38.6	54.5	66.3	73.6	78.1	79.6	64.3	56.6	37.6	28.8	52.2
-Daily Minimum	5.5	9.9	20.3	33.9	48.1	55.4	62.5	61.2	45.6	36.3	23.6	15.5	34.8
-Monthly	14.6	17.2	29.5	44.2	57.2	64.5	70.3	70.4	55.0	46.5	30.6	22.2	43.5
-Monthly Dewpt.	9.5	11.0	21.1	29.4	45.4	54.0	61.0	61.4	45.9	34.6	22.9	16.0	34.4
Extremes													
-Highest	45	42	62	72	80	87	85	89	84	81	52	44	89
-Date	31	1	29	28	11	11	30	26	12	6	3	15	AUG 26
-Lowest	-16	-12	-3	18	37	39	53	49	36	26	3	-15	-16
-Date	1	17	14	2	20	1	12	31	29	31	27	28	JAN 1
DEGREE DAYS BASE 65 °F:													
Heating	1557	1335	1096	617	243	70	3	18	302	566	1025	1322	8154
Cooling	0	0	0	0	12	60	176	195	8	0	0	0	451
% OF POSSIBLE SUNSHINE	65	60	72	70	52	58	60	71	60	57	24	33	58
AVG. SKY COVER (tenths)													
Sunrise - Sunset	6.3	6.5	5.3	6.4	7.6	7.1	7.0	6.5	6.3	5.9	8.3	7.5	6.7
Midnight - Midnight	6.0	6.4	5.3	6.0	7.1	6.4	6.3	5.6	5.9	5.7	7.8	7.9	6.4
NUMBER OF DAYS:													
Sunrise to Sunset													
-Clear	8	7	14	7	3	4	5	5	8	11	3	5	80
-Partly Cloudy	10	6	4	8	9	10	9	14	9	7	5	5	96
-Cloudy	13	15	13	15	19	16	17	12	13	13	22	21	189
Precipitation .01 inches or more	11	7	8	14	12	13	15	12	10	4	10	11	127
Snow,Ice pellets,hail 1.0 inches or more	3	1	3	0	0	0	0	0	0	0	2	1	10
Thunderstorms	0	0	1	0	2	9	9	9	3	1	1	0	35
Heavy Fog, visibility 1/4 mile or less	0	3	3	0	1	0	1	0	0	0	0	0	8
Temperature °F													
-Maximum													
90° and above	0	0	0	0	0	0	0	0	0	0	0	0	0
32° and below	26	22	7	0	0	0	0	0	0	0	7	15	77
-Minimum													
32° and below	30	28	30	9	0	0	0	0	0	11	25	30	163
0° and below	12	9	4	0	0	0	0	0	0	0	0	7	32
AVG. STATION PRESS. (mb)	991.5	991.5	989.2	984.1	983.7	983.1	983.1	985.4	985.4	985.6	986.1	985.6	986.1
RELATIVE HUMIDITY (%)													
Hour 00	80	81	75	66	74	79	82	86	81	72	77	79	78
Hour 06 (Local Time)	81	85	83	79	81	83	86	91	87	79	79	81	83
Hour 12	71	69	64	49	60	61	66	61	60	55	66	72	63
Hour 18	76	71	64	46	57	62	64	62	63	57	71	76	64
PRECIPITATION (inches):													
Water Equivalent													
-Total	1.25	0.39	1.25	1.99	4.02	6.28	5.58	6.50	2.04	0.79	1.57	0.55	32.21
-Greatest (24 hrs)	0.64	0.19	0.50	0.66	0.83	1.94	1.44	1.65	0.84	0.26	0.57	0.20	1.94
-Date	11-12	21-22	30-31	26-27	9-10	16-17	1	8- 9	19-20	20	12-13	13-14	JUN 16-17
Snow,Ice pellets,hail													
-Total	12.0	5.3	6.9	0.5	0.0	0.0	T	0.0	0.0	T	7.7	4.5	36.9
-Greatest (24 hrs)	6.2	2.7	4.0	0.5	0.0	0.0	T	0.0	0.0	T	4.6	1.4	6.2
-Date	12	21-22	9-10	14-15			1			30	24-25	21-22	JAN 12
WIND:													
Resultant													
-Direction (!!)	253	287	321	022	347	153	190	219	255	277	249	266	266
-Speed (mph)	1.6	1.7	1.3	2.7	1.8	1.8	2.5	1.7	2.9	4.7	1.1	2.4	1.2
Average Speed (mph)	9.6	7.6	8.2	10.9	10.3	10.6	9.9	8.9	10.8	11.3	11.8	10.7	10.1
Fastest Obs. 1 Min.													
-Direction (!!)	31	25	32	05	16	32	22	33	18	33	32	31	33
-Speed (mph)	26	17	29	30	26	29	30	38	30	30	31	28	38
-Date	28	17	16	19	8	16	7	18	30	20	19	29	AUG 18
Peak Gust													
-Direction (!!)	W	N	NW	N	S	NW	NW	NW	SW	NW	NW	NW	NW
-Speed (mph)	39	25	41	48	37	43	44	52	44	41	44	40	52
-Date	26	21	16	15	8	16	1	18	9	28	19	29	AUG 18

(!!!) See Reference Notes on Page 6B

NORMALS, MEANS, AND EXTREMES

MINNEAPOLIS – ST. PAUL, MINNESOTA

LATITUDE: 44°53'N LONGITUDE: 93°13' W ELEVATION: FT. GRND 834 BARO 860 TIME ZONE: CENTRAL WBAN: 14922

	(a)	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F:														
Normals														
-Daily Maximum		20.7	26.6	39.2	56.5	69.4	78.8	84.0	80.7	70.7	58.8	41.0	25.5	54.3
-Daily Minimum		2.8	9.2	22.7	36.2	47.6	57.6	63.1	60.3	50.3	38.8	25.2	10.2	35.3
-Monthly		11.8	17.9	31.0	46.4	58.5	68.2	73.6	70.5	60.5	48.8	33.2	17.9	44.9
Extremes														
-Record Highest	55	58	60	83	95	96	102	105	102	98	89	75	63	105
-Year		1944	1981	1986	1980	1978	1985	1988	1947	1976	1953	1944	1982	JUL 1988
-Record Lowest	55	-34	-28	-32	2	18	34	43	39	26	15	-17	-29	-34
-Year		1970	1965	1962	1962	1967	1945	1972	1967	1974	1972	1964	1983	JAN 1970
NORMAL DEGREE DAYS:														
Heating (base 65°F)		1649	1319	1054	558	244	41	11	22	167	502	954	1460	7981
Cooling (base 65°F)		0	0	0	0	43	137	278	192	32	0	0	0	682
% OF POSSIBLE SUNSHINE	55	53	59	57	58	61	65	72	69	62	55	39	42	58
MEAN SKY COVER (tenths)														
Sunrise - Sunset	55	6.3	6.3	6.7	6.5	6.4	6.1	5.3	5.3	5.6	5.8	7.1	7.0	6.2
MEAN NUMBER OF DAYS:														
Sunrise to Sunset														
-Clear	55	8.3	7.7	7.1	7.0	7.1	7.2	9.9	10.2	9.8	9.9	5.5	6.4	96.1
-Partly Cloudy	55	7.4	6.9	7.3	7.7	9.1	10.4	11.8	11.1	8.6	7.6	6.5	6.4	100.8
-Cloudy	55	15.3	13.7	16.6	15.2	14.8	12.3	9.3	9.7	11.6	13.5	18.0	18.2	168.3
Precipitation														
.01 inches or more	55	8.7	7.3	10.3	10.3	11.3	11.7	9.8	10.0	9.6	7.9	8.5	9.4	114.7
Snow, Ice pellets, hail														
1.0 inches or more	55	3.2	2.7	3.0	0.7	0.1	0.0	0.0	0.0	0.*	0.1	2.2	3.1	15.1
Thunderstorms	55	0.*	0.2	1.0	2.6	5.1	7.5	7.6	6.5	4.3	1.8	0.6	0.1	37.4
Heavy Fog Visibility 1/4 mile or less	55	1.1	1.4	1.3	0.4	0.5	0.5	0.3	0.6	0.9	0.9	1.1	1.3	10.5
Temperature °F														
-Maximum														
90° and above	34	0.0	0.0	0.0	0.1	0.8	2.7	6.1	3.6	0.8	0.0	0.0	0.0	14.2
32° and below	34	23.4	17.9	8.7	0.3	0.0	0.0	0.0	0.0	0.0	0.1	7.0	21.2	78.5
-Minimum														
32° and below	34	30.8	27.3	25.2	11.0	1.1	0.0	0.0	0.0	0.5	7.8	23.0	29.9	156.4
0° and below	34	13.5	8.1	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	8.0	32.3
AVG. STATION PRESS. (mb)	21	987.5	988.3	985.2	984.2	983.6	983.0	984.7	985.6	986.0	986.3	985.9	987.4	985.6
RELATIVE HUMIDITY (%)														
Hour 00	34	73	74	72	67	68	72	75	77	79	74	77	76	74
Hour 06 (Local Time)	34	74	76	76	75	76	79	81	84	85	81	80	78	79
Hour 12	34	67	65	61	52	52	54	54	57	59	58	66	70	60
Hour 18	34	68	66	61	51	50	52	53	56	61	60	69	73	60
PRECIPITATION (inches):														
Water Equivalent														
-Normal		0.95	0.88	1.94	2.42	3.39	4.05	3.53	3.62	2.72	2.19	1.55	1.08	28.32
-Maximum Monthly	55	3.63	2.14	4.75	5.88	8.03	9.82	17.90	9.31	7.53	5.68	5.29	4.27	17.90
-Year		1967	1981	1965	1986	1962	1990	1987	1977	1942	1971	1991	1982	JUL 1987
-Minimum Monthly	55	0.10	0.06	0.32	0.16	0.61	0.22	0.58	0.43	0.41	0.01	0.02	T	T
-Year		1990	1964	1958	1987	1967	1988	1975	1946	1940	1952	1939	1943	DEC 1943
-Maximum in 24 hrs	55	1.21	1.10	1.66	2.23	3.03	3.00	10.00	7.36	3.55	2.95	2.91	2.47	10.00
-Year		1967	1966	1965	1975	1965	1986	1987	1977	1942	1966	1940	1982	JUL 1987
Snow, Ice pellets, hail														
-Maximum Monthly	55	46.4	26.5	40.0	21.8	3.0	T	T	T	1.7	8.2	46.9	33.2	46.9
-Year		1982	1962	1951	1983	1946	1989	1993	1992	1942	1991	1991	1969	NOV 1991
-Maximum in 24 hrs	55	18.5	9.3	14.7	13.6	3.0	T	T	T	1.7	8.2	21.0	16.5	21.0
-Year		1982	1939	1985	1983	1946	1989	1993	1992	1942	1991	1991	1982	NOV 1991
WIND:														
Mean Speed (mph)	55	10.5	10.4	11.3	12.2	11.1	10.5	9.4	9.3	10.0	10.5	10.9	10.4	10.5
Prevailing Direction through 1963		NW	NW	NW	NW	SE	SE	S	SE	S	SE	NW	NW	NW
Fastest Obs. 1 Min.														
-Direction (!!!)	14	32	34	08	19	23	01	35	20	18	33	25	34	32
-Speed (MPH)	14	51	37	33	41	35	46	43	44	36	33	41	35	51
-Year		1986	1987	1985	1984	1986	1980	1980	1983	1988	1981	1986	1989	JAN 1986
Peak Gust														
-Direction (!!!)	10	NW	NW	W	SW	N	S	NW	W	N	NW	W	NW	W
-Speed (mph)	10	67	55	60	61	67	51	51	71	52	53	66	48	71
-Date		1986	1987	1988	1984	1985	1992	1984	1988	1989	1987	1986	1989	AUG 1988

(!!!) See Reference Notes on Page 68.

PRECIPITATION (inches)

MINNEAPOLIS - ST. PAUL, MINNESOTA

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1964	0.47	0.06	1.35	2.98	3.44	2.18	2.02	5.42	5.21	0.57	1.19	1.08	25.97
1965	0.47	1.59	4.75	3.52	7.86	4.01	4.69	4.04	4.90	0.90	1.98	1.23	39.94
1966	0.95	1.55	2.48	0.89	1.46	3.51	2.47	4.40	1.69	3.53	0.39	1.02	24.34
1967	3.63	1.59	0.96	4.07	0.61	7.53	1.36	2.79	0.63	1.73	0.09	0.45	25.44
1968	0.71	0.13	1.89	2.94	3.74	6.78	6.46	0.75	6.16	5.62	0.54	2.21	37.93
1969	2.05	0.31	0.90	1.55	1.98	2.93	2.95	0.99	0.49	2.53	0.65	2.06	19.39
1970	0.47	0.16	2.05	3.55	4.77	1.27	3.66	2.19	3.19	4.97	3.82	0.43	30.53
1971	1.22	1.74	1.21	1.11	3.14	3.52	3.94	1.78	2.73	5.68	2.67	0.70	29.44
1972	0.84	0.49	1.25	1.69	2.18	3.31	5.12	2.48	1.96	1.77	1.11	1.57	23.77
1973	0.92	0.84	1.12	2.32	2.48	1.06	2.90	3.05	2.08	1.29	1.97	1.10	21.13
1974	0.17	1.06	1.00	2.42	2.08	5.21	1.14	2.75	0.58	1.69	0.66	0.35	19.11
1975	2.82	0.79	1.67	5.40	3.81	7.99	0.58	4.92	1.31	0.27	4.80	0.79	35.15
1976	0.87	0.59	2.83	0.80	1.13	3.86	2.45	1.39	1.42	0.49	0.16	0.51	16.50
1977	0.65	0.93	2.66	1.84	2.86	3.57	3.72	9.31	4.43	2.34	1.42	1.15	34.88
1978	0.38	0.24	0.79	3.63	3.79	7.09	3.19	5.77	2.47	0.19	1.84	0.88	30.26
1979	1.09	1.39	2.55	0.66	4.55	4.78	2.34	7.04	2.20	3.16	0.98	0.33	31.07
1980	0.94	0.67	1.12	0.83	2.29	5.52	2.30	3.26	3.68	0.66	0.26	0.24	21.77
1981	0.30	2.14	0.71	2.17	2.18	4.42	4.09	4.73	1.46	2.69	2.16	0.92	27.97
1982	2.45	0.43	2.09	1.62	4.99	1.44	0.92	3.80	1.50	3.45	3.27	4.27	30.23
1983	0.67	1.19	3.22	3.97	6.20	5.22	3.07	3.12	3.34	2.61	4.93	1.53	39.07
1984	0.88	1.64	1.47	3.86	2.29	7.95	3.03	5.15	2.65	5.48	0.31	2.24	36.95
1985	0.87	0.50	4.48	1.81	3.65	2.18	2.20	5.02	4.37	3.66	1.72	1.20	31.66
1986	0.90	0.84	2.03	5.88	3.48	5.34	4.11	4.44	6.90	1.77	0.62	0.31	36.62
1987	0.63	0.13	0.64	0.16	1.88	1.95	17.90	3.67	1.28	0.60	2.07	1.25	32.16
1988	1.37	0.30	1.33	1.58	1.70	0.22	1.17	4.29	2.79	0.80	2.86	0.67	19.08
1989	0.52	1.04	2.19	2.66	3.38	3.50	3.50	2.92	1.28	0.53	1.38	0.42	23.32
1990	0.10	0.77	3.66	3.80	3.36	9.82	5.06	1.71	1.88	1.23	0.65	1.01	33.05
1991	0.49	1.03	2.29	3.58	6.35	2.57	2.95	3.14	5.43	2.52	5.29	1.05	36.69
1992	0.66	0.57	1.56	1.99	1.15	3.68	5.21	4.54	5.20	2.11	1.95	1.05	29.67
1993	1.25	0.39	1.25	1.99	4.02	6.28	5.58	6.50	2.04	0.79	1.57	0.55	32.21
Record Mean	0.83	0.85	1.60	2.17	3.38	4.17	3.55	3.40	2.89	2.01	1.45	0.94	27.26

See Reference Notes on Page 6B.

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AVERAGE TEMPERATURE (deg. F)

MINNEAPOLIS - ST. PAUL, MINNESOTA

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1964	20.0	23.9	25.8	46.8	61.5	68.7	76.0	68.5	58.9	48.2	35.0	14.8	45.7
1965	10.0	11.8	19.5	41.8	58.7	66.5	70.5	68.6	52.8	50.7	33.1	28.0	42.7
1966	3.3	16.3	35.8	42.2	53.6	68.4	76.8	68.2	60.3	47.5	30.1	18.1	43.4
1967	14.6	8.7	29.8	44.7	52.3	66.9	68.8	66.2	60.3	46.3	30.7	21.8	42.6
1968	14.3	15.2	38.8	48.5	53.4	67.2	71.1	70.7	61.1	50.7	34.0	16.9	45.2
1969	9.4	19.3	24.1	49.3	60.6	61.8	73.6	74.4	63.0	46.5	33.6	20.3	44.7
1970	5.6	15.4	26.0	46.1	58.5	71.2	75.2	71.9	61.2	49.6	32.7	18.2	44.3
1971	6.5	17.0	28.0	47.0	55.4	71.5	68.8	69.6	62.8	51.4	32.7	18.4	44.1
1972	5.5	10.5	26.5	41.9	61.3	66.0	68.5	69.8	57.9	43.7	32.2	11.3	41.3
1973	17.4	21.6	40.2	44.4	55.2	69.5	73.8	73.4	60.1	53.8	34.3	16.7	46.7
1974	11.9	16.9	29.5	47.1	54.4	65.5	76.6	67.3	55.3	49.8	33.7	24.4	44.4
1975	14.5	15.5	22.1	38.9	60.9	68.8	76.3	71.7	57.7	52.8	37.5	21.3	44.8
1976	11.6	27.8	31.4	51.8	58.9	71.7	76.1	73.3	61.8	44.6	28.3	13.6	45.9
1977	0.3	22.7	37.5	53.0	66.9	68.4	74.8	66.1	60.5	47.1	30.8	14.4	45.2
1978	5.5	11.6	30.0	45.2	61.8	67.8	71.1	72.2	67.3	49.8	32.5	15.2	44.2
1979	3.2	10.0	28.9	44.0	55.5	67.3	73.6	69.9	63.4	46.6	31.7	26.0	43.3
1980	15.3	15.3	27.3	49.2	61.5	67.6	75.2	70.7	59.5	45.1	36.6	19.8	45.2
1981	18.0	23.4	37.7	49.1	57.1	67.0	70.9	69.3	60.0	46.7	38.0	17.5	46.2
1982	2.3	15.8	29.0	43.8	62.5	63.7	75.6	71.8	60.9	50.3	31.5	25.7	44.4
1983	19.6	26.9	34.2	42.3	54.6	68.0	77.2	76.8	62.6	48.4	34.0	3.7	45.7
1984	12.0	27.5	24.8	47.1	56.0	69.7	72.2	73.5	57.2	50.7	33.3	17.9	45.2
1985	10.1	16.5	35.6	52.1	62.2	63.9	73.9	67.6	59.9	47.5	24.8	7.7	43.5
1986	17.5	15.7	33.9	49.6	59.4	68.6	73.9	67.1	59.8	49.2	28.2	24.7	45.6
1987	21.2	31.6	38.7	53.5	63.5	72.8	76.0	69.0	62.5	44.6	37.9	25.0	49.7
1988	10.4	13.9	33.8	47.4	65.4	74.4	78.1	73.9	62.4	44.0	32.7	20.5	46.4
1989	21.2	8.6	26.6	45.3	57.5	68.4	76.4	70.8	60.9	49.9	28.0	10.6	43.7
1990	26.3	23.7	35.7	46.8	56.3	69.5	71.3	70.6	64.4	48.1	37.4	16.9	47.3
1991	12.5	24.4	34.3	49.1	61.9	72.9	72.3	71.1	59.0	47.2	24.5	21.2	45.9
1992	21.9	28.0	33.1	43.6	60.5	65.6	65.8	65.9	59.6	47.4	31.4	21.2	45.3
1993	14.6	17.2	29.5	44.2	57.2	64.5	70.3	70.4	55.0	46.5	30.6	22.2	43.5
Record													
Mean	13.2	17.3	30.1	46.0	58.3	67.9	73.2	70.6	61.4	49.5	32.8	19.2	45.0
Max	21.8	25.9	38.4	55.8	68.5	77.8	83.2	80.5	71.3	59.0	40.4	26.7	54.1
Min	4.6	8.6	21.8	36.3	48.0	58.0	63.1	60.7	51.5	40.1	25.2	11.7	35.8

See Reference Notes on Page 6B.

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HEATING DEGREE DAYS Base 65 deg. F

MINNEAPOLIS - ST. PAUL, MINNESOTA

SEASON	JULY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	TOTAL
1964-65	0	63	224	515	894	1551	1702	1486	1405	690	211	19	8760
1965-66	7	40	368	447	950	1140	1909	1358	899	678	357	41	8194
1966-67	0	40	185	536	1042	1446	1556	1572	1086	600	404	30	8497
1967-68	36	65	166	577	1024	1335	1567	1440	808	491	358	62	7929
1968-69	10	28	143	451	922	1486	1723	1274	1261	461	204	136	8099
1969-70	5	0	131	580	933	1379	1842	1382	1204	577	249	20	8302
1970-71	3	5	190	476	959	1443	1811	1341	1139	537	297	18	8219
1971-72	16	22	164	413	962	1438	1844	1576	1188	687	204	73	8587
1972-73	34	52	218	651	974	1664	1474	1208	761	611	299	13	7959
1973-74	1	3	185	350	915	1493	1642	1344	1092	535	338	72	7970
1974-75	0	48	289	467	933	1252	1561	1379	1324	775	188	39	8255
1975-76	15	7	231	387	818	1346	1650	1074	1031	405	195	11	7170
1976-77	0	4	162	632	1092	1590	2005	1180	844	365	75	17	7966
1977-78	0	35	145	548	1016	1565	1842	1488	1080	584	162	46	8511
1978-79	5	7	89	464	968	1538	1914	1537	1112	623	307	38	8602
1979-80	0	24	105	566	992	1203	1536	1436	1165	484	184	34	7729
1980-81	0	12	194	611	845	1396	1453	1160	838	472	249	28	7258
1981-82	11	11	172	564	803	1466	1945	1374	1111	629	117	71	8274
1982-83	0	14	168	448	997	1212	1400	1061	947	673	313	49	7282
1983-84	2	0	161	514	923	1901	1641	1082	1240	531	284	7	8286
1984-85	5	12	251	435	943	1453	1694	1355	904	403	123	104	7682
1985-86	0	28	240	537	1201	1774	1466	1377	957	454	212	30	8276
1986-87	0	43	177	480	1096	1243	1352	929	809	347	134	13	6623
1987-88	2	29	106	623	804	1236	1688	1479	962	523	76	4	7532
1988-89	1	16	116	646	963	1373	1353	1576	1184	583	251	44	8106
1989-90	0	6	159	470	1105	1683	1194	1151	899	569	274	37	7547
1990-91	2	5	136	516	820	1484	1624	1130	945	481	197	3	7343
1991-92	7	8	228	548	1206	1354	1333	1067	981	636	190	72	7630
1992-93	32	52	182	542	1003	1351	1557	1335	1096	617	243	70	8080
1993-94	3	18	302	566	1025	1322							

See Reference Notes on Page 6B.

Page 5A

COOLING DEGREE DAYS Base 65 deg. F

MINNEAPOLIS - ST. PAUL, MINNESOTA

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	TOTAL
1969	0	0	0	0	76	49	276	298	77	12	0	0	788
1970	0	0	0	17	54	213	323	225	83	5	0	0	920
1971	0	0	0	2	5	218	141	168	106	3	0	0	643
1972	0	0	0	0	94	109	148	208	13	0	0	0	572
1973	0	0	0	1	4	158	280	271	47	8	0	0	769
1974	0	0	0	5	18	93	369	127	6	1	0	0	619
1975	0	0	0	0	66	159	371	220	18	16	0	0	850
1976	0	0	0	14	14	223	351	269	72	7	0	0	950
1977	0	0	0	12	145	129	310	76	19	0	0	0	691
1978	0	0	0	0	72	138	201	236	164	0	0	0	811
1979	0	0	0	0	17	113	275	181	65	0	0	0	651
1980	0	0	0	16	82	121	322	194	38	1	0	0	774
1981	0	0	0	0	10	96	200	151	28	0	0	0	485
1982	0	0	0	0	46	40	338	232	53	0	0	0	709
1983	0	0	0	0	0	145	389	368	98	8	0	0	1008
1984	0	0	0	0	13	155	237	280	24	0	0	0	709
1985	0	0	0	22	43	77	284	118	93	0	0	0	637
1986	0	0	0	1	45	148	286	115	32	0	0	0	627
1987	0	0	0	11	95	253	348	159	37	0	0	0	903
1988	0	0	0	1	96	296	412	302	45	0	0	0	1152
1989	0	0	0	0	26	153	359	192	41	8	0	0	779
1990	0	0	0	28	11	178	206	191	125	1	0	0	740
1991	0	0	0	8	109	246	238	205	51	0	0	0	857
1992	0	0	0	3	56	96	64	88	28	2	0	0	337
1993	0	0	0	0	12	60	176	195	8	0	0	0	451

See Reference Notes on Page 6B.

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SNOWFALL (inches)

MINNEAPOLIS - ST. PAUL, MINNESOTA

SEASON	JULY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	TOTAL
1964-65	0.0	0.0	0.0	T	4.3	8.1	10.5	11.7	37.1	2.0	T	0.0	73.7
1965-66	0.0	0.0	0.0	0.0	1.6	1.2	11.9	6.8	14.2	0.4	T	0.0	36.1
1966-67	0.0	0.0	0.0	0.2	3.4	12.7	35.3	23.7	2.6	0.2	0.3	0.0	78.4
1967-68	0.0	0.0	0.0	0.3	0.8	2.4	10.6	2.2	0.8	0.4	0.0	0.0	17.5
1968-69	0.0	0.0	0.0	T	4.9	28.7	21.6	5.3	7.3	0.3	0.0	0.0	68.1
1969-70	0.0	0.0	0.0	2.4	3.8	33.2	9.8	4.3	8.6	1.3	T	0.0	63.4
1970-71	0.0	0.0	0.0	T	6.3	5.5	19.9	13.9	7.0	1.9	0.2	0.0	54.7
1971-72	0.0	0.0	0.0	0.0	13.2	12.8	12.2	7.6	10.4	8.0	0.0	0.0	64.2
1972-73	0.0	0.0	T	T	1.1	15.3	11.6	11.3	0.4	2.0	0.0	0.0	41.7
1973-74	0.0	0.0	0.0	0.0	0.1	17.9	2.5	15.7	7.7	7.3	0.0	0.0	51.2
1974-75	0.0	0.0	0.0	0.0	1.2	6.1	27.4	9.0	18.3	2.2	0.0	0.0	64.2
1975-76	0.0	0.0	0.0	0.0	16.2	5.6	12.8	5.1	13.6	0.0	1.2	0.0	54.5
1976-77	0.0	0.0	0.0	2.3	1.4	8.3	13.4	1.8	14.6	1.8	0.0	0.0	43.6
1977-78	0.0	0.0	0.0	3.0	11.7	14.2	6.8	4.6	8.5	1.9	0.0	0.0	50.7
1978-79	0.0	0.0	0.0	0.0	16.5	15.1	14.2	13.5	8.4	0.7	0.0	0.0	68.4
1979-80	0.0	0.0	0.0	T	7.7	1.7	12.9	8.8	13.7	8.5	0.0	0.0	53.3
1980-81	0.0	0.0	0.0	T	0.9	2.8	4.6	11.0	0.1	1.7	0.0	0.0	21.1
1981-82	0.0	0.0	0.0	0.9	14.0	10.6	46.4	7.4	10.9	4.8	0.0	0.0	95.0
1982-83	0.0	0.0	0.0	1.4	3.6	19.3	3.2	10.8	14.3	21.8	0.0	0.0	74.4
1983-84	0.0	0.0	0.0	T	30.4	21.0	10.6	9.3	17.3	9.8	0.0	0.0	98.4
1984-85	0.0	0.0	0.0	0.3	2.0	16.3	13.1	4.2	36.8	T	0.0	0.0	72.7
1985-86	0.0	0.0	0.4	T	23.9	13.5	10.3	12.3	8.7	0.4	0.0	0.0	69.5
1986-87	0.0	0.0	0.0	T	4.4	4.2	5.5	1.2	2.1	T	0.0	0.0	17.4
1987-88	0.0	0.0	0.0	0.3	4.5	7.5	19.5	4.5	3.7	2.4	0.0	0.0	42.4
1988-89	0.0	0.0	0.0	0.2	15.8	7.2	6.0	17.3	22.7	0.8	0.1	T	70.1
1989-90	0.0	0.0	0.0	0.0	11.3	7.0	1.1	10.7	3.2	2.2	0.0	0.0	35.5
1990-91	0.0	0.0	0.0	T	5.0	11.7	6.5	14.2	4.4	1.5	0.3	0.0	43.6
1991-92	0.0	T	0.0	8.2	46.9	6.7	5.0	5.9	10.8	0.6	0.0	0.0	84.1
1992-93	0.0	T	T	1.3	12.2	9.2	12.0	5.3	6.9	0.5	0.0	0.0	47.4
1993-94	T	0.0	0.0	T	7.7	4.5							
Record Mean	T	T	T	0.5	7.9	9.3	9.8	8.4	10.7	2.8	0.1	T	49.6

See Reference Notes on Page 6B.

REFERENCE NOTES

MINNEAPOLIS - ST. PAUL, MINNESOTA

GENERAL
T - TRACE AMOUNT.
BLANK ENTRIES DENOTE MISSING/UNREPORTED DATA.
# INDICATES A STATION OR INSTRUMENT RELOCATION.
SEE STATION LOCATION TABLE ON PAGE 8.

SPECIFIC
PAGE 2
PM - INCLUDES LAST DAY OF PREVIOUS MONTH
ASOS - AUTOMATED SURFACE OBSERVING SYSTEM IN OPERATION DURING THESE MONTHS.

PAGE 3
(a) - LENGTH OF RECORD IN YEARS, ALTHOUGH INDIVIDUAL MONTHS MAY BE MISSING.
0.* OR * - THE VALUE IS BETWEEN 0.0 AND 0.05
NORMALS - BASED ON THE 1961-1990 RECORD PERIOD.
EXTREMES - DATES ARE THE MOST RECENT OCCURRENCE
WIND DIR.- NUMERALS SHOW TENS OF DEGRESS CLOCKWISE FROM TRUE NORTH. "00" INDICATES CALM.
RESULTANT DIRECTIONS ARE GIVEN TO WHOLE DEGREES.
BOLD VALUES INDICATE EXTREME VALUES WHICH OCCURRED AFTER THE ASOS SYSTEM WAS COMMISSIONED.

PAGE 4B
RECORD = PERIOD OF RECORD
RECORD MEAN PRECIPITATION IS THE MEAN OF ALL DAILY PRECIPITATION AMOUNTS DURING THE PERIOD OF RECORD.
RECORD MAX(MIN) TEMPERATURE IS THE MEAN OF ALL DAILY MAX(MIN) TEMPERATURES DURING THE PERIOD OF RECORD.
RECORD MEAN TEMPERATURE IS THE SUM OF THE RECORD MAX AND RECORD MIN DIVIDED BY 2.
AVERAGE TEMPERATURE IS THE SUM OF THE MEAN DAILY MAX AND MIN TEMPERATURE DIVIDED BY 2.

EXCEPTIONS

PAGES 4A, 4B, 6A
RECORD MEANS ARE THROUGH THE CURRENT YEAR.
BEGINNING IN 1891 FOR TEMPERATURE
1891 FOR PRECIPITATION
1939 FOR SNOWFALL

MINNEAPOLIS – ST. PAUL, MINNESOTA

The Twin Cities of Minneapolis and St. Paul are located at the confluence of the Mississippi and Minnesota Rivers over the heart of an artesian water basin. Its flat or gently rolling terrain varies little in elevation from that of the official observation station at International Airport. Numerous lakes dot the surrounding area. Minneapolis alone boasts of 22 lakes within the city park system. The largest body of water, nearly 15,000 acres, is Lake Minnetonka, located about 15 miles west of the airport. Most bodies of water are relatively small and shallow and are ice covered during winter.

The climate of the Minneapolis–St. Paul area is predominantly continental. Seasonal temperature variations are quite large. Temperatures range from less than −30 degrees to over 100 degrees The growing season is 166 days. Because of this favorable growing season, all crops generally mature before the autumn freeze occurs.

The Twin Cities lie near the northern edge of the influx of moisture from the Gulf of Mexico. Severe storms such as blizzards, freezing rain (glaze), tornadoes, wind and hail storms do occur. The total annual precipitation is important. Even more significant is its proper distribution during the growing season. During the five month growing season, May through September, the major crops produced are corn, soybeans, small grains, and hay. During this period, the normal rainfall is over 16 inches, approximately 65 percent of the annual precipitation. Winter snowfall is nearly 48 inches. Winter recreational weather is excellent because of the dry snow. These conditions exist from about Christmas into early March. Snow depths average 6 to 8 inches in the city and 8 to 10 inches in the suburbs during this period.

Floods occur along the Mississippi River due to spring snow melt, excessive rainfall, or both. Occasionally an ice jam forms and creates a local flood condition. The flood problem at St. Paul is complicated because the Minnesota River empties into the Mississippi River between the two cities. Consequently, high water or flooding on the Minnesota River creates a greater flood potential at St. Paul. Flood stage at St. Paul can be expected on the average once in every eight years.

Notice of Correction

Any previously received edition of the "Local Climatological Data Annual Summary for 1993" should be discarded. This revised edition contains updates to the "Normals" based upon the 1961-1990 record period as noted in the "Reference Notes" on Page 6B.

STATION LOCATION

MINNEAPOLIS-ST. PAUL, MINNESOTA

* Type
M = AMOS
T = AUTOB
S = ASOS
W = AWOS

LOCATION	OCCUPIED FROM	OCCUPIED TO	AIRLINE DISTANCES AND DIRECTIONS FROM PREVIOUS LOCATION	LATITUDE NORTH	LONGITUDE WEST	ELEVATION ABOVE SEA LEVEL GROUND TEMPERATURE SITE	ELEVATION ABOVE GROUND WIND INSTRUMENTS	EXTREME THERMOMETERS	PSYCHROMETER	SUNSHINE SWITCH	TIPPING BUCKET RAIN GAGE	WEIGHING RAIN GAGE	8 INCH RAIN GAGE	HYGROTHERMOMETER	AUTOMATIC OBSERVING EQUIPMENT *	REMARKS
COOPERATIVE																
Dr. C.L. Anderson Corner Helen & 2nd St.	1/01/56	12/31/59		44°59'	93°18'	839										Surgeon General & Smithsonian Institute to 1870.
Mr. Wm. Cheney, Corner Douglas & Freemonet St.	11/01/64	6/30/01		44°58'	93°20'	850										
Mr. J.H. Aschenbeck 721 6th Avenue North	11/25/87	10/?/95		45°00'	93°19'	850		18					3			
Mr. J.H. Aschenbeck 731 6th Avenue North	10/?/95	9/?/23	2 blocks	45°00'	93°19'	825		4					3			Thermometers 99', RG 95' to 11/1/04; anemometer 192' to 4/96.
Mr. J.H. Aschenbeck 1730 Penn. Avenue N.	9/?/23	10/?/36	1.5 mi. NW	45°01'	93°21'	888		4					3			Precipitation only after 2/23/29. Temperature obs. 7A, 2P and 9P.
CITY																
U.S. Court House, cor. Marquette Ave. & 3rd St	11/06/90	4/10/38		44°59'	93°18'	839	105	105	104		97		96			
AIRPORT																
Administration Bldg. Wold-Chamberlain AP	1/27/34	10/16/37		44°53'	93°13'	832	61	32								
Administration Bldg. Minneapolis-St. Paul International Airport Wold-Chamberlain Field	10/16/37	Present	NA	44°53'	93°13'	a834	b21 h33	f43	f42	%50 i42	e41	c4 g41	e41	d5 j5	NA	Several minor moves of instruments but no significant changes in elevations other than given below. St. Paul WBAS was integrated with Minneapolis WBAS 6/1/53. a - Ground elevation 830' to 1/1/60 & 822' to 5/24/63. b - 75' to 9/18/58. c - Installed 11/20/53. Elevation 41' to 10/24/62. d - Commissioned on field site 1/1/60; moved 800' WNW 5/31/63. e - Standby after 10/24/62. f - Standby after 1/1/60. g - Effective 11/15/72. % - Commissioned 9/18/58. h - Raised 10/17/81. i - Effective 11/5/84. j - Type change 12/11/85.

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APR 1993
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INTERNATIONAL AIRPORT

ISSN 0198-1390

LOCAL CLIMATOLOGICAL DATA

Monthly Summary

APR 1993
ORLANDO, FL

LATITUDE 28° 26'N LONGITUDE 81° 19'W ELEVATION (GROUND) 96 FEET TIME ZONE EASTERN 12815

DATE	TEMPERATURE °F					DEGREE DAYS BASE 65°F		WEATHER TYPES	SNOW ICE PELLETS OR ICE ON GROUND AT 0700	PRECIPITATION		AVERAGE STATION PRESSURE	WIND (M.P.H.)							SUNSHINE		SKY COVER (TENTHS)	
	MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	HEATING (SEASON BEGINS WITH JUL)	COOLING (SEASON BEGINS WITH JAN)	1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	INCHES	WATER EQUIVALENT (INCHES)	SNOW, ICE PELLETS (INCHES)	IN INCHES ELEV. 106 FEET ABOVE M.S.L.	RESULTANT DIR.	RESULTANT SPEED	AVERAGE SPEED	PEAK GUST SPEED	PEAK GUST DIRECTION	FASTEST 1-MIN SPEED	FASTEST 1-MIN DIRECTION	MINUTES	PERCENT OF TOTAL POSSIBLE	SUNRISE TO SUNSET	MIDNIGHT TO MIDNIGHT
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
01	83	64	74	5	63	0	9	3	0	0.63	0.0	29.720	21	14.5	16.5	38	SW	26	21			7	6
02	75	57	66	-3	52	0	1		0	0.00	0.0	29.840	27	13.1	14.3	37	W	25	29			2	1
03	74	50	62	-7	49	3	0		0	0.00	0.0	30.010	02	6.5	8.7	18	N	14	02			6	6
04	82	58	70	1	60	0	5	1	0	0.00	0.0	29.870	10	8.6	10.3	23	E	16	09			10	10
05	83	61	72	3	61	0	7	3	0	0.44	0.0	29.700	23	12.7	15.0	33	SW	23	26			7	6
06	74	53	64	-6	53	1	0		0	0.00	0.0	29.850	32	6.3	10.8	21	E	16	05			6	5
07	76	51	64	-6	53	1	0		0	0.00	0.0	29.940	03	8.3	9.7	23	NE	15	02			3	2
08	78	56	67	-3	54	0	2		0	0.00	0.0	29.900	08	8.6	10.0	24	E	16	10			7	5
09	79	61	70	0	59	0	5		0	T	0.0	29.740	17	9.6	14.2	38	SE	25	13			10	8
10	75	54	65	-5	51	0	0		0	0.00	0.0	29.770	27	12.1	12.6	31	W	20	28			2	1
11	81	54	68	-3	49	0	3	1	0	0.00	0.0	29.890	28	2.4	6.9	16	W	12	12			0	0
12	84	54	69	-2	51	0	4		0	0.00	0.0	29.890	25	4.2	6.1	24	W	13	20			4	2
13	87*	56	72	1	53	0	7	1	0	0.00	0.0	29.865	29	4.6	6.6	16	E	10	09			2	2
14	86	59	73	2	59	0	8		0	0.00	0.0	29.830	13	7.3	9.1	23	E	15	09			6	5
15	84	66	75	4	64	0	10	3	0	0.70	0.0	29.800	14	9.8	13.9	33	SE	24	31			10	10
16	81	58	70	-1	59	0	5		0	0.01	0.0	29.810	24	8.7	12.1	30	W	18	26			6	6
17	72	55	64	-7	45	1	0		0	0.00	0.0	29.940	32	7.4	9.3	22	N	17	01			8	6
18	78	57	68	-3	47	0	3		0	0.00	0.0	29.950	02	6.5	9.3	18	NE	14	06			5	4
19	78	55	67	-5	51	0	2		0	0.00	0.0	29.970	05	7.2	7.8	20	NE	13	06			3	2
20	81	58	70	-2	55	0	5		0	0.00	0.0	29.970	11	6.0	7.5	21	E	14	11			7	7
21	81	64	73	1	58	0	8		0	0.00	0.0	29.870	23	9.3	11.0	24	W	15	25			10	9
22	70	52	61*	-11	37	4	0		0	0.00	0.0	29.905	30	12.3	13.0	28	NW	20	32			0	1
23	77	48*	63	-9	38	2	0		0	0.00	0.0	30.020	13	0.7	6.1	17	SE	13	13			1	0
24	80	53	67	-6	54	0	2		0	0.00	0.0	30.070	11	8.2	9.3	24	E	15	09			6	6
25	83	63	73	0	61	0	8		0	0.00	0.0	30.050	12	11.4	11.6	23	SE	18	12			8	8
26	86	65	76*	3	64	0	11	1	0	0.00	0.0	29.930	23	5.4	8.6	17	W	14	22			9	7
27	78	59	69	-4	60	0	4	1	0	0.00	0.0	29.955	01	9.7	11.8	25	N	21	02			6	4
28	76	58	67	-6	52	0	2		0	0.00	0.0	30.080	04	11.3	12.0	29	NE	18	05			8	7
29	79	56	68	-6	53	0	3		0	0.00	0.0	30.040	05	7.2	9.6	24	E	15	09			4	4
30	80	57	69	-5	54	0	4	1	0	0.00	0.0	29.970	09	7.3	8.7	23	E	15	10			7	7
	SUM	SUM				TOTAL	TOTAL	NUMBER OF DAYS		TOTAL	TOTAL	FOR THE MONTH:								TOTAL	% FOR MONTH	SUM	SUM
	2381	1712				12	118			1.78	0.0	29.905	25	0.1	10.4	38	SE	26	21			170	147
	AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION ≥ .01 INCH	4	DEP.						DATE: 9+		DATE: 1		POSSIBLE		AVG.	AVG.
	79.4	57.1	68.3	-2.9	53.8	12	-73			-0.02												5.7	4.9

NUMBER OF DAYS				SEASON TO DATE	
MAXIMUM TEMP.		MINIMUM TEMP.		TOTAL	TOTAL
				445	332
≥ 90°	≤ 32°	≤ 32°	≤ 0°	DEP.	DEP.
0	0	0	0	-211	-104

NUMBER OF DAYS	
SNOW, ICE PELLETS ≥ 1.0 INCH	0
THUNDERSTORMS	3
HEAVY FOG	0
CLEAR 8 PARTLY CLOUDY 14 CLOUDY 8	

GREATEST IN 24 HOURS AND DATES				GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE	
PRECIPITATION		SNOW, ICE PELLETS			
0.71	15-16	0.0		0	

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS COLS 16 & 17: PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED ONE OF TWO WIND SPEEDS IS GIVEN UNDER COLS 18 & 19: FASTEST MILE - HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTION IN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES). ERRORS WILL BE CORRECTED IN SUBSEQUENT PUBLICATIONS

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Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

OBSERVATIONS AT 3-HOUR INTERVALS

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISI-BILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISI-BILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISI-BILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
	APR 1st											APR 2nd											APR 3rd										
01	10	110	4		TRW	65	63	62	90	25	12	6	12	7			64	63	62	93	22	9	0	UNL	7			57	54	51	81	30	8
04	10	300	7			66	64	63	90	16	13	0	UNL	7			62	59	57	84	25	8	0	UNL	7			53	50	46	77	36	10
07	10	95	7			66	64	63	90	20	14	0	UNL	7			60	58	57	90	21	9	0	UNL	10			52	48	44	74	36	7
10	8	100	10			72	67	64	76	19	18	3	UNL	10			71	62	56	59	26	12	2	UNL	10			63	54	46	54	07	8
13	8	35	10			80	70	64	58	21	22	0	UNL	10			74	61	51	45	28	20	9	250	10			71	58	47	43	12	6
16	4	UNL	10			80	70	64	58	26	14	1	UNL	10			72	58	47	41	29	22	10	250	10			73	59	47	40	04	3
19	0	UNL	10			75	67	63	66	22	11	2	UNL	10			65	52	40	40	28	12	10	120	10			66	59	54	65	07	8
22	0	UNL	7			68	66	64	87	25	9	0	UNL	10			59	53	48	67	28	9	9	120	8			59	57	55	87	02	6
	APR 4th											APR 5th											APR 6th										
01	10	UNL	7			58	56	54	87	05	6	10	32	7			71	68	66	84	14	12	0	UNL	7			60	58	57	90	25	10
04	9	120	6		F	58	57	56	93	05	7	10	75	5		TRW	66	63	61	84	15	6	6	23	7			60	58	57	90	27	7
07	10	120	7			62	59	57	84	04	6	10	6	7			67	66	65	93	21	11	9	37	7			60	57	54	81	31	6
10	10	120	8			70	63	58	66	12	11	10	25	10			71	66	63	76	24	18	7	33	10			66	57	50	57	31	14
13	10	95	10			77	65	58	52	13	10	4	UNL	10			80	68	61	52	22	17	7	37	10			70	60	52	53	30	12
16	10	140	10			80	66	57	45	16	9	7	48	10			81	69	63	54	22	18	6	48	10			71	60	51	49	33	8
19	10	250	10			73	69	66	79	09	14	0	UNL	10			71	62	55	57	25	15	3	UNL	10			61	56	52	72	05	14
22	10	140	7			71	68	67	87	08	10	0	UNL	10			63	59	56	78	26	9	0	UNL	7			54	51	49	83	03	10
	APR 7th											APR 8th											APR 9th										
01	0	UNL	7			53	51	50	90	32	5	0	UNL	7			57	56	55	93	01	5	10	UNL	7			63	59	56	78	10	6
04	0	UNL	7			53	51	50	90	30	5	0	UNL	7			57	56	55	93	04	6	3	UNL	7			62	60	58	87	11	7
07	0	UNL	10			53	52	52	96	34	7	7	250	10			57	56	55	93	04	6	7	250	10			65	61	58	78	13	11
10	0	UNL	10			66	59	54	65	05	10	9	UNL	10			72	61	52	50	09	12	10	250	10			73	64	58	60	16	14
13	6	39	10			74	63	55	52	05	6	8	50	10			76	63	54	47	09	11	10	49	10			75	66	60	60	18	12
16	7	47	10			73	62	55	53	04	10	5	UNL	10			76	62	52	43	10	13	9	90	10			76	69	65	69	17	20
19	2	UNL	10			65	59	55	70	04	9	5	UNL	10			70	60	52	53	10	9	8	100	10			74	68	65	74	20	12
22	0	UNL	7			60	57	55	84	03	11	10	UNL	7			65	59	54	68	09	7	9	65	8		RW	64	59	56	75	27	12
	APR 10th											APR 11th											APR 12th										
01	0	UNL	7			61	57	54	78	27	12	0	UNL	8			57	55	53	87	29	6	0	UNL	10			59	55	52	78	00	0
04	0	UNL	7			57	55	53	87	25	7	0	UNL	6		F	57	56	55	93	26	6	0	UNL	10			54	52	50	86	00	0
07	0	UNL	10			58	55	53	84	29	8	0	UNL	6		F	58	57	57	97	28	5	3	UNL	7			59	56	54	84	00	0
10	3	UNL	10			68	59	52	57	29	13	0	UNL	10			73	58	45	37	35	6	6	UNL	10			73	61	53	50	31	6
13	2	UNL	10			73	60	50	45	28	11	0	UNL	10			78	59	42	28	02	4	4	UNL	10			83	64	50	32	21	3
16	0	UNL	10			74	60	49	41	25	14	0	UNL	10			80	60	43	27	23	6	1	UNL	10			83	65	53	36	20	11
19	0	UNL	10			66	55	46	49	27	12	0	UNL	10			74	60	49	41	12	10	0	UNL	10			77	62	50	39	21	7
22	0	UNL	10			60	54	48	65	27	10	0	UNL	10			63	55	49	61	26	6	0	UNL	10			69	58	48	47	28	9
	APR 13th											APR 14th											APR 15th										
01	0	UNL	10			64	59	56	75	29	9	4	UNL	10			65	60	56	73	12	4	9	UNL	8			68	64	62	81	15	9
04	0	UNL	10			61	60	59	93	31	5	2	UNL	10			60	57	55	84	04	3	10	250	8			69	65	63	81	13	11
07	0	UNL	3		F	61	60	60	97	32	3	3	UNL	8			63	60	57	81	09	5	10	250	8			69	66	64	84	13	12
10	0	UNL	10			75	64	56	52	26	7	7	250	10			79	68	62	56	18	9	10	250	10			78	69	64	62	13	18
13	1	UNL	10			84	61	43	24	32	6	9	250	10			83	67	58	43	17	11	10	220	10			82	70	64	55	17	16
16	3	UNL	10			86	63	45	24	31	6	8	250	10			85	67	56	37	12	11	10	220	7			82	70	64	55	14	12
19	7	UNL	10			80	63	50	35	02	3	4	UNL	10			76	65	58	54	12	11	10	120	7			79	69	64	60	12	7
22	0	UNL	7			70	59	51	51	23	6	0	UNL	7			71	66	63	76	12	10	10	45	5		TRW	66	65	64	93	29	9
	APR 16th											APR 17th											APR 18th										
01	8	250	7			67	65	64	90	14	10	3	UNL	7			58	55	53	84	28	6	7	UNL	10			62	56	51	67	30	9
04	3	UNL	7			65	64	64	97	15	6	0	UNL	7			57	54	51	81	32	7	6	120	10			59	54	49	70	31	8
07	10	65	10			68	67	66	93	19	6	0	UNL	10			57	53	49	75	34	10	9	UNL	10			59	53	48	67	35	6
10	10	17	10			74	70	67	79	24	14	9	200	10			66	55	44	45	01	15	3	UNL	10			71	56	43	37	36	10
13	3	UNL	10			80	68	61	52	24	14	10	200	10			69	54	40	35	32	10	9	250	10			73	57	44	36	06	8
16	2	UNL	10			79	65	55	44	26	16	10	250	10			70	54	38	31	33	5	2	UNL	10			77	58	42	29	01	9
19	9	250	10			69	58	50	51	25	9	10	140	10			67	53	40	37	25	6	0	UNL	10			68	58	50	53	07	9
22	5	UNL	10			59	55	51	75	27	11	8	250	10			61	53	46	58	26	7	0	UNL	10			62	57	52	70	04	6

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.08	0.15	0.21	0.24	0.25	0.27	0.29	0.33	0.39	0.44	0.53	0.60
ENDED: DATE	15	15	15	15	15	15	15	15	15	15	15	15
ENDED: TIME	2003	2005	2010	2012	2020	2036	2054	2111	2133	2155	2225	2252

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

			VISI-BILITY			TEMPERATURE				WIND	
HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	WHOLE MILES	16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	DIRECTION	SPEED (KNOTS)
APR 19th											
01	0	UNL	10			58	55	52	81	04	6
04	0	UNL	10			56	54	53	90	01	3
07	0	UNL	8			60	57	54	81	01	5
10	1	UNL	10			73	61	52	48	05	8
13	5	UNL	10			75	60	48	39	04	8
16	5	UNL	10			75	60	48	39	06	11
19	0	UNL	10			70	58	48	46	07	9
22	0	UNL	7			63	57	52	68	07	6
APR 20th											
01	0	UNL	10			59	56	53	81	00	0
04	3	UNL	10			61	58	56	84	05	3
07	10	UNL	8			62	59	57	84	05	6
10	9	250	10			74	61	51	45	15	8
13	4	UNL	10			79	63	51	38	11	10
16	7	250	10			78	64	55	45	12	9
19	6	250	10			72	64	58	62	11	12
22	10	75	10			69	63	59	71	12	8
APR 21st											
01	10	48	10			67	63	60	78	00	0
04	10	45	8			66	64	62	87	17	5
07	10	250	8			67	64	62	84	16	7
10	9	250	10			74	66	61	64	20	10
13	10	250	10			79	65	56	45	24	11
16	10	250	10			79	64	53	41	22	11
19	10	75	10			75	62	52	45	24	9
22	10	100	10			71	63	57	61	25	13
APR 22nd											
01	3	UNL	8			65	63	61	87	29	12
04	0	UNL	10			58	51	44	60	32	17
07	4	UNL	10			55	48	40	57	30	10
10	0	UNL	10			60	48	35	39	31	14
13	0	UNL	10			66	49	29	25	31	16
16	0	UNL	10			70	51	28	21	30	12
19	0	UNL	10			65	49	29	26	32	7
22	0	UNL	10			58	50	42	56	28	6
APR 23rd											
01	0	UNL	10			50	46	42	74	27	6
04	0	UNL	10			49	45	41	74	29	4
07	0	UNL	10			55	44	31	40	32	4
10	0	UNL	10			68	49	26	21	35	4
13	0	UNL	10			73	53	31	21	19	4
16	2	UNL	10			76	54	31	19	21	5
19	1	UNL	10			70	53	36	29	19	5
22	0	UNL	10			62	54	47	58	11	9
APR 24th											
01	0	UNL	10			57	52	48	72	11	5
04	0	UNL	10			53	52	51	93	29	3
07	0	UNL	10			59	56	53	81	00	0
10	3	UNL	10			74	61	52	46	12	11
13	8	250	10			79	64	53	41	14	12
16	9	250	10			79	64	53	41	08	13
19	10	250	10			72	63	57	59	10	11
22	10	250	10			67	62	59	76	12	9
APR 25th											
01	10	250	10			66	62	60	81	10	7
04	10	250	8			65	62	60	84	10	5
07	9	UNL	8			65	62	59	81	11	8
10	10	250	10			75	65	59	58	13	14
13	7	41	10			81	68	61	51	12	10
16	7	250	10			82	69	62	51	12	12
19	9	45	10			76	67	62	62	11	13
22	0	UNL	10			70	65	62	76	12	8
APR 26th											
01	9	48	8			69	65	63	81	14	7
04	4	UNL	8			67	65	64	90	16	5
07	9	80	6		F	69	67	65	87	18	5
10	10	UNL	10			78	69	64	62	18	11
13	7	250	10			83	70	63	51	23	10
16	10	250	10			83	69	61	48	22	12
19	7	250	10			79	70	65	62	28	8
22	0	UNL	7			73	69	66	79	30	9
APR 27th											
01	2	UNL	8			69	67	66	90	28	6
04	8	13	6		F	66	65	65	97	26	6
07	8	17	7			67	65	64	90	36	8
10	9	22	10			73	66	62	69	05	12
13	10	30	10			76	67	62	62	36	9
16	5	UNL	10			75	64	57	54	02	14
19	0	UNL	10			64	57	52	65	04	11
22	0	UNL	10			61	58	55	81	36	10
APR 28th											
01	6	43	10			59	57	55	87	36	6
04	7	47	10			59	56	53	81	33	5
07	9	250	10			63	57	53	70	04	10
10	7	250	10			73	60	50	45	04	15
13	7	55	10			74	61	51	45	05	15
16	8	250	10			73	61	53	50	03	14
19	8	250	10			68	59	52	57	06	9
22	8	UNL	10			63	59	56	78	01	8
APR 29th											
01	9	47	10			60	58	56	87	34	7
04	7	250	10			58	56	55	90	33	7
07	4	UNL	10			60	57	55	84	01	6
10	6	49	10			72	61	52	50	10	9
13	5	UNL	10			77	62	51	40	05	11
16	1	UNL	10			77	61	49	37	08	13
19	1	UNL	10			71	60	51	49	08	11
22	3	UNL	10			64	57	52	65	09	6
APR 30th											
01	0	UNL	10			59	58	57	93	29	3
04	4	UNL	7			58	57	56	93	01	3
07	8	41	7			60	58	57	90	08	4
10	9	42	10			73	61	53	50	14	9
13	7	UNL	10			79	63	52	39	11	11
16	4	UNL	10			79	63	51	38	10	8
19	6	UNL	10			72	60	50	46	10	13
22	10	UNL	10			65	59	54	68	10	7

SUMMARY BY HOURS

	AVERAGES							RESULTANT WIND	
			TEMPERATURE						
HOUR L.S.T.	SKY COVER (TENTHS)	STATION PRESSURE (INCHES)	AIR TEMP °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND SPEED (MPH)	DIRECTION	SPEED (MPH)
01	4	29.910	62	59	56	83	7.8	27	2.0
04	4	29.880	60	57	55	86	7.2	31	1.3
07	5	29.920	61	58	55	82	7.9	01	0.8
10	6	29.945	72	61	53	54	13.0	14	1.7
13	6	29.910	77	63	52	43	12.5	20	2.0
16	5	29.865	77	63	52	42	13.1	18	1.3
19	5	29.880	71	61	52	53	11.3	11	3.0
22	4	29.930	64	59	55	72	9.8	31	1.4

WEATHER CODES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXP RESSED IN KNOTS (MPH=KNOTS X 1.15).

NATIONAL CLIMATIC DATA CENTER
FEDERAL BUILDING
37 BATTERY PARK AVE
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APR 1993 12815
ORLANDO, FL
USCOMM --NOAA - ASHEVILLE, NC 225

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

DATE	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												DATE
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
01	0.10	0.15	0.23	T	0.10	0.05	T		T																01
02																									02
03																									03
04																									04
05		0.05	0.14	0.16	0.09																				05
06																									06
07																									07
08																									08
09																					T	T			09
10																									10
11																									11
12																									12
13																									13
14																									14
15																				0.25	0.10	0.16	0.14	0.05	15
16	0.01																								16
17																									17
18																									18
19																									19
20																									20
21																									21
22																									22
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25																									25
26																									26
27																									27
28																									28
29																									29
30																									30

MAY 1993
ORLANDO, FL
NAT'L WEA SER OFC
SUITE 100

INQUIRIES/COMMENTS CALL
(704) 271-4800

INTERNATIONAL AIRPORT

ISSN 0198-1390

LOCAL CLIMATOLOGICAL DATA
Monthly Summary

MAY 1993
ORLANDO, FL

LATITUDE 28° 26'N LONGITUDE 81° 19'W ELEVATION (GROUND) 96 FEET TIME ZONE EASTERN 12815

DATE	TEMPERATURE °F					DEGREE DAYS BASE 65°F		WEATHER TYPES 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	SNOW ICE PELLETS OR ICE ON GROUND AT 0700 INCHES	PRECIPITATION		AVERAGE STATION PRESSURE IN INCHES ELEV. 106 FEET ABOVE M.S.L.	WIND (M.P.H.)			PEAK GUST		FASTEST 1-MIN		SUNSHINE		SKY COVER (TENTHS)	
	MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	HEATING (SEASON BEGINS WITH JUL)	COOLING (SEASON BEGINS WITH JAN)			WATER EQUIVALENT (INCHES)	SNOW, ICE PELLETS (INCHES)		RESULTANT DIR.	RESULTANT SPEED	AVERAGE SPEED	SPEED	DIRECTION	SPEED	DIRECTION	MINUTES	PERCENT OF TOTAL POSSIBLE	SUNRISE TO SUNSET	MIDNIGHT TO MIDNIGHT
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
01	82	57*	70*	-4	57	0	5		0	0.00	0.0	29.960	11	8.8	9.8	25	E	17	09			8	7
02	82	64	73	-1	61	0	8		0	0.00	0.0	29.950	11	11.3	11.8	28	E	18	13			9	9
03	80	65	73	-1	64	0	8		0	0.00	0.0	29.940	11	10.8	11.2	23	E	17	11			10	10
04	88	67	78	3	66	0	13	3	0	0.23	0.0	29.950	13	9.5	11.6	25	NW	18	11			5	6
05	89	66	78	3	66	0	13		0	T	0.0	29.990	13	6.3	7.8	21	E	16	10			8	8
06	88	69	79	4	65	0	14		0	0.00	0.0	29.960	09	4.5	7.3	22	E	15	12			7	7
07	87	64	76	1	63	0	11		0	0.00	0.0	29.910	06	7.5	8.3	23	NE	17	07			4	3
08	86	65	76	0	63	0	11		0	0.00	0.0	29.950	06	9.3	9.6	24	NE	18	06			6	4
09	81	66	74	-2	65	0	9		0	T	0.0	30.005	05	9.0	9.8	21	NE	16	03			7	5
10	83	62	73	-3	59	0	8	1	0	0.00	0.0	30.000	06	8.8	9.9	25	NE	17	08			4	2
11	84	61	73	-3	58	0	8		0	0.00	0.0	29.950	10	7.6	8.7	21	E	15	11			3	3
12	87	67	77	1	62	0	12		0	T	0.0	29.810	17	7.8	10.0	22	SE	17	12			5	6
13	85	69	77	1	65	0	12		0	T	0.0	29.700	21	10.8	12.2	25	SW	17	23			8	7
14	85	66	76	-1	60	0	11		0	T	0.0	29.720	26	10.8	11.6	28	W	18	28			3	3
15	87	62	75	-2	60	0	10		0	0.00	0.0	29.840	27	3.4	7.4	20	E	13	09			4	4
16	90	65	78	1	60	0	13	1	0	0.00	0.0	29.880	28	7.2	8.1	17	NW	12	30			3	3
17	90	62	76	-1	59	0	11	1	0	0.00	0.0	29.870	20	2.7	7.5	22	SE	17	12			2	2
18	90*	71	81*	4	65	0	16	1	0	0.00	0.0	29.810	16	9.2	10.6	24	SE	18	14			3	4
19	88	65	77	-1	61	0	12	1	0	0.00	0.0	29.700	24	10.6	11.1	24	SW	17	25			6	6
20	89	66	78	0	62	0	13		0	0.00	0.0	29.660	27	9.1	10.0	30	W	17	28			3	3
21	85	64	75	-3	53	0	10		0	0.00	0.0	29.790	29	9.3	10.5	23	W	15	25			0	0
22	84	62	73	-5	52	0	8		0	0.00	0.0	29.910	01	10.2	12.2	29	NE	16	05			1	1
23	83	61	72	-6	58	0	7		0	0.00	0.0	29.980	08	10.3	11.7	24	E	18	11			4	3
24	86	62	74	-4	60	0	9		0	0.00	0.0	29.990	09	9.5	10.1	23	E	16	09			4	2
25	85	63	74	-5	62	0	9	1	0	0.00	0.0	29.980	08	9.7	10.3	25	E	17	10			6	4
26	86	65	76	-3	64	0	11	1	0	0.00	0.0	29.960	08	8.0	8.8	23	E	15	07			9	7
27	84	67	76	-3	63	0	11		0	0.00	0.0	29.980	06	10.0	10.3	25	E	16	06			9	9
28	83	71	77	-2	71	0	12		0	0.08	0.0	29.990	08	9.5	10.3	25	SE	20	13			10	10
29	86	70	78	-1	71	0	13	3	0	1.74	0.0	29.950	09	5.8	8.2	26	SE	21	13			10	9
30	81	70	76	-3	72	0	11		0	0.27	0.0	29.835	10	7.1	7.9	18	E	14	11			9	8
31	88	72	80	1	70	0	15		0	T	0.0	29.690	09	6.3	7.7	20	E	14	11			8	7
	SUM	SUM				TOTAL	TOTAL	NUMBER OF DAYS		TOTAL	TOTAL	FOR THE MONTH:								TOTAL	%	SUM	SUM
	2652	2026				0	334			2.32	0.0	29.890	10	3.6	9.8	30	W	21	13		FOR MONTH	178	162
	AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION		DEP.						DATE:20		DATE: 29		POSSIBLE		AVG.	AVG.
	85.5	65.4	75.5	-1.4	62.4	0	-35	≥ .01 INCH.	4	-1.23												5.7	5.2

NUMBER OF DAYS				SEASON TO DATE		SNOW, ICE PELLETS ≥ 1.0 INCH	0	GREATEST IN 24 HOURS AND DATES			GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE	
				TOTAL	TOTAL							
MAXIMUM TEMP.		MINIMUM TEMP.		445	666	THUNDERSTORMS	2	PRECIPITATION		SNOW, ICE PELLETS		
≥ 90°	≤ 32°	≤ 32°	≤ 0°	DEP.	DEP.	HEAVY FOG	0	1.80	29-30	0.0	0	
3	0	0	0	-211	-139	CLEAR 8	PARTLY CLOUDY 12	CLOUDY 11				

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS. COLS 16 & 17: PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED. ONE OF TWO WIND SPEEDS IS GIVEN UNDER COLS 18 & 19: FASTEST MILE - HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTION IN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES). ERRORS WILL BE CORRECTED IN SUBSEQUENT PUBLICATIONS.

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER

Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

noaa
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE
NATIONAL CLIMATIC DATA CENTER ASHEVILLE NORTH CAROLINA

OBSERVATIONS AT 3-HOUR INTERVALS

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					MAY 1st											MAY 2nd											MAY 3rd						
01	7	UNL	10			61	58	55	81	08	7	10	250	10			66	64	62	87	11	9	10	140	10			68	65	63	84	10	7
04	8	UNL	10			58	56	55	90	26	3	6	250	10			65	63	61	87	08	6	6	UNL	8			65	64	63	93	09	5
07	6	250	10			61	58	56	84	12	6	10	140	10			67	64	62	84	10	8	10	140	10			68	65	63	84	10	11
10	9	32	10			74	65	59	60	10	12	9	140	10			75	65	58	56	12	15	10	140	10			75	67	63	66	12	12
13	7	250	10			80	66	58	47	14	11	7	250	10			81	66	56	42	13	14	10	85	10			78	69	63	60	12	12
16	8	250	10			79	66	57	47	10	13	10	140	10			80	67	59	49	11	12	10	120	10			79	69	64	60	11	13
19	5	UNL	10			73	65	59	62	09	12	10	250	10			73	66	62	69	10	10	10	250	10			75	69	66	74	09	10
22	8	250	10			67	63	60	78	10	8	9	250	10			70	65	62	76	10	8	10	250	10			72	68	66	82	11	11
					MAY 4th											MAY 5th											MAY 6th						
01	7	41	10			71	68	67	87	13	10	3	UNL	8			67	66	65	93	17	5	6	49	10			71	68	67	87	17	5
04	7	60	10			69	67	66	90	12	9	8	250	10			69	67	66	90	14	6	8	49	10			70	68	67	90	29	3
07	2	UNL	10			71	68	67	87	15	9	9	250	10			69	68	67	93	11	4	7	95	10			71	69	68	90	07	5
10	4	UNL	10			82	72	67	61	17	13	10	250	10			80	71	66	63	16	9	4	UNL	10			80	70	65	60	00	0
13	7	43	10			86	73	66	51	13	10	7	250	10			86	73	66	51	16	6	7	43	10			86	72	64	48	35	5
16	5	UNL	10			87	74	67	52	13	12	6	250	10			89	72	64	44	06	6	7	250	10			84	70	63	49	12	13
19	8	250	10			78	70	66	67	09	11	9	250	10			78	69	64	62	09	9	8	110	10			78	69	64	62	11	12
22	10	40	7		TRW	68	66	65	90	19	11	5	UNL	10			73	69	66	79	11	7	6	UNL	10			72	68	65	79	08	6
					MAY 7th											MAY 8th											MAY 9th						
01	0	UNL	10			68	66	64	87	19	4	0	UNL	8			67	65	64	90	07	5	0	UNL	10			68	66	65	90	06	6
04	0	UNL	7			65	64	64	97	36	3	0	UNL	8			65	64	63	93	06	4	0	UNL	10			67	66	65	93	04	5
07	2	UNL	10			69	67	66	90	01	4	0	UNL	8			68	67	66	93	04	6	0	UNL	8			69	68	67	93	05	6
10	3	UNL	10			80	71	66	63	04	7	6	250	10			81	69	62	53	06	9	6	28	10			81	70	64	56	13	8
13	4	UNL	10			85	69	60	43	08	9	7	250	10			86	69	60	42	03	11	10	75	10			76	70	66	71	03	12
16	8	40	10			83	69	61	48	07	12	10	250	10			84	68	59	43	06	16	9	85	10			78	69	63	60	06	12
19	3	UNL	10			77	68	63	62	08	12	5	UNL	10			77	68	63	62	06	11	9	95	10			72	68	65	79	05	11
22	0	UNL	10			70	66	64	81	07	6	3	UNL	10			71	67	64	79	05	5	0	UNL	10			69	66	64	84	08	10
					MAY 10th											MAY 11th											MAY 12th						
01	0	UNL	7			67	65	64	90	07	7	0	UNL	8			64	61	58	81	06	6	9	80	10			68	66	64	87	10	5
04	0	UNL	8			66	63	61	84	10	5	8	36	8			63	60	58	84	07	4	8	80	10			70	66	64	81	14	5
07	0	UNL	7			68	64	61	78	02	6	0	UNL	10			68	63	59	73	05	4	3	UNL	10			71	67	64	79	12	6
10	4	UNL	10			78	66	59	52	08	13	4	UNL	10			77	63	53	43	11	10	3	UNL	10			80	69	63	56	23	8
13	7	48	10			81	67	59	47	08	15	3	UNL	10			82	65	53	37	15	5	4	UNL	10			85	68	58	40	19	8
16	6	49	10			81	67	58	46	08	13	5	UNL	10			81	65	55	41	08	8	4	UNL	10			86	66	54	34	20	9
19	4	UNL	10			75	63	54	48	06	9	3	UNL	10			76	66	59	56	11	13	8	UNL	10			79	69	64	60	12	15
22	0	UNL	10			67	62	58	73	06	7	0	UNL	10			69	65	63	81	09	8	10	44	10			74	68	64	71	17	13
					MAY 13th											MAY 14th											MAY 15th						
01	10	48	7			72	69	68	87	20	10	0	UNL	7			69	67	66	90	22	6	0	UNL	10			65	62	60	84	23	4
04	10	43	7			70	68	67	90	16	9	10	70	7			69	68	67	93	23	7	0	UNL	7			62	61	60	93	25	4
07	7	250	10			71	68	66	84	18	9	0	UNL	10			69	67	66	90	26	7	1	UNL	7			66	64	63	90	24	4
10	9	45	10			79	70	65	62	17	12	4	UNL	10			78	66	59	52	22	13	2	UNL	10			78	67	61	56	31	7
13	10	85	10		RW	80	68	61	52	22	12	5	UNL	10			82	67	57	43	26	16	3	UNL	10			85	69	59	42	26	8
16	8	80	10			78	70	66	67	27	8	6	65	10			84	66	55	37	29	12	7	65	10			86	67	54	34	20	8
19	4	UNL	10			79	69	63	58	23	11	0	UNL	10			77	64	56	48	26	13	10	70	10			80	69	63	56	09	11
22	0	UNL	10			73	69	66	79	25	8	0	UNL	10			70	64	60	71	25	6	8	UNL	10			73	67	63	71	27	6
					MAY 16th											MAY 17th											MAY 18th						
01	5	UNL	10			70	66	64	81	30	6	0	UNL	8			68	65	63	84	28	6	7	55	7			74	70	67	79	17	4
04	2	UNL	7			68	66	65	90	29	6	0	UNL	6		F	63	62	61	93	25	4	0	UNL	7			73	70	68	84	15	8
07	0	UNL	6		F	69	67	66	90	28	6	0	UNL	5		F	68	66	64	87	25	4	0	UNL	6		F	73	70	69	87	16	8
10	0	UNL	8			79	69	64	60	28	7	0	UNL	10			82	68	60	47	25	6	0	UNL	10			84	72	65	53	22	7
13	3	UNL	10			85	67	55	36	29	9	4	UNL	10			87	66	52	30	23	7	4	UNL	10			86	69	59	40	13	6
16	6	40	10			87	66	53	31	25	6	8	250	10			89	65	47	23	20	12	5	UNL	10			90	70	59	35	20	12
19	6	75	10			83	66	55	38	25	10	2	UNL	7			82	66	55	40	12	15	7	110	10			78	66	58	50	11	14
22	2	UNL	10			76	65	58	54	30	10	3	UNL	7			76	68	64	67	13	10	5	UNL	10			76	69	65	69	15	12

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.35	0.65	0.97	1.11	1.17	1.18	1.18	1.18	1.18	1.19	1.20	1.26
ENDED: DATE	29	29	29	29	29	29	29	29	29	29	29	29
ENDED: TIME	1443	1448	1452	1455	1500	1517	1517	1517	1517	1559	1659	1731

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

MAY 1993
ORLANDO, FL

12815

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
MAY 19th											
01	7	85	8			72	68	65	79	23	6
04	0	UNL	7			66	64	63	90	22	5
07	3	UNL	7			69	66	64	84	22	5
10	3	UNL	10			81	71	65	58	22	9
13	10	250	10			86	69	60	42	23	13
16	7	250	10			88	71	62	42	23	12
19	8	250	10			81	63	51	35	25	15
22	8	250	10			75	65	58	56	24	8
MAY 20th											
01	9	50	10			71	64	60	68	24	6
04	10	48	10			68	64	62	81	23	6
07	0	UNL	8			69	66	64	84	21	6
10	3	UNL	10			79	69	63	58	31	8
13	5	UNL	10			84	69	61	46	25	9
16	5	UNL	10			88	70	59	38	25	13
19	1	UNL	10			81	69	62	53	28	14
22	0	UNL	10			74	65	60	62	28	11
MAY 21st											
01	0	UNL	7			68	65	63	84	25	8
04	0	UNL	7			67	65	64	90	27	8
07	0	UNL	7			70	63	58	66	31	8
10	0	UNL	10			79	63	52	39	31	8
13	0	UNL	10			83	63	49	31	30	12
16	0	UNL	10			85	63	47	27	30	13
19	0	UNL	10			78	60	46	32	28	12
22	0	UNL	10			70	60	52	53	31	7
MAY 22nd											
01	0	UNL	10			65	59	55	70	28	6
04	0	UNL	10			62	58	54	75	36	7
07	0	UNL	10			65	57	51	61	34	13
10	0	UNL	10			76	62	52	43	01	10
13	1	UNL	10			82	63	49	32	01	9
16	6	65	10			79	63	51	38	06	14
19	0	UNL	10			72	61	52	50	05	13
22	0	UNL	10			66	58	51	59	03	10
MAY 23rd											
01	0	UNL	10			62	57	53	73	02	7
04	0	UNL	8			61	58	55	81	01	7
07	0	UNL	8			67	61	56	68	05	8
10	0	UNL	10			79	65	56	45	11	15
13	9	50	10			82	67	58	44	10	11
16	7	55	10			80	67	59	49	09	15
19	2	UNL	10			75	65	59	58	09	11
22	0	UNL	10			70	65	61	73	11	8
MAY 24th											
01	0	UNL	8			66	63	61	84	08	6
04	0	UNL	8			63	61	60	90	06	4
07	0	UNL	7			68	64	61	78	08	7
10	6	40	10			78	67	60	54	10	9
13	7	55	10			84	68	58	41	07	11
16	6	60	10			85	68	57	39	09	11
19	1	UNL	10			78	66	59	52	10	11
22	0	UNL	10			71	65	62	73	11	9
MAY 25th											
01	0	UNL	8			67	63	61	81	08	3
04	0	UNL	7			64	62	61	90	03	5
07	0	UNL	6		F	68	65	63	84	08	9
10	7	49	8			78	69	64	62	06	10
13	8	55	10			83	69	60	46	10	11
16	6	60	10			82	69	61	49	11	13
19	8	250	10			77	68	63	62	09	11
22	3	UNL	7			71	67	64	79	07	8
MAY 26th											
01	0	UNL	7			69	67	65	87	07	8
04	0	UNL	7			66	65	64	93	05	3
07	10	47	7			72	70	69	90	14	5
10	8	UNL	10			81	69	63	54	10	8
13	9	250	10			84	70	62	48	09	13
16	8	80	10			83	70	63	51	07	13
19	9	250	10			78	68	62	58	10	11
22	5	UNL	7			71	66	63	76	08	7
MAY 27th											
01	9	UNL	7			68	65	63	84	06	5
04	10	UNL	7			67	65	64	90	04	6
07	10	UNL	7			71	67	64	79	05	7
10	10	250	10			79	68	62	56	05	9
13	9	250	10			83	70	62	49	08	13
16	9	250	10			81	69	63	54	06	14
19	9	250	10			77	68	62	60	06	10
22	10	250	7			71	66	63	76	05	7
MAY 28th											
01	8	140	7			71	67	65	81	06	7
04	10	44	7		RW	72	69	67	84	05	7
07	10	85	8			73	70	68	84	07	8
10	10	37	7		RW	78	75	73	85	10	10
13	10	19	10			81	75	72	74	13	17
16	10	100	10			80	75	72	77	06	7
19	10	38	10		RW	78	74	72	82	09	7
22	10	100	10		R	75	74	73	94	08	10
MAY 29th											
01	10	120	6		RW	74	73	72	94	09	7
04	10	100	6		R	74	73	72	94	01	5
07	10	130	6		R	74	73	73	97	03	6
10	9	75	10			82	76	73	74	13	12
13	9	250	10			85	75	70	61	13	8
16	10	19	8		RW	73	71	70	90	05	12
19	10	70	5		RW	72	71	70	94	12	9
22	7	70	10			72	71	71	97	13	4
MAY 30th											
01	9	8	8			71	70	70	97	04	4
04	10	12	7			72	71	71	97	05	3
07	8	48	7			74	73	72	94	09	6
10	9	13	8			80	76	74	82	08	8
13	10	22	8			80	75	72	77	12	12
16	8	80	6		RW	77	74	72	85	14	9
19	8	60	10			79	74	71	77	12	8
22	5	UNL	10			74	72	71	90	12	6
MAY 31st											
01	8	65	7			74	73	72	94	10	6
04	4	UNL	8			73	72	72	97	10	7
07	9	80	10			74	73	72	94	13	3
10	8	25	10			81	74	70	69	14	4
13	9	35	10			84	75	71	65	35	10
16	10	45	10			84	73	68	59	07	11
19	6	100	10			81	72	68	65	09	9
22	4	UNL	10			75	72	71	87	05	5

SUMMARY BY HOURS

HOUR L.S.T.	AVERAGES							RESULTANT WIND	
	SKY COVER (TENTHS)	STATION PRESSURE (INCHES)	TEMPERATURE			REL HUMIDITY %	WIND SPEED (MPH)	DIRECTION	SPEED (MPH)
			AIR TEMP °F	WET BULB °F	DEW POINT °F				
01	4	29.900	68	65	64	85	7.1	11	2.3
04	4	29.880	67	65	64	89	6.3	08	1.4
07	4	29.910	69	66	64	85	7.6	08	2.7
10	5	29.920	79	69	63	58	10.7	12	4.5
13	7	29.895	83	69	61	48	12.1	12	3.8
16	7	29.850	83	69	60	48	13.1	10	5.7
19	6	29.870	77	67	61	59	13.0	10	6.9
22	4	29.905	72	66	63	75	9.3	11	3.7

WEATHER CODES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXP RESSED IN KNOTS (MPH=KNOTS X 1.15).

NATIONAL CLIMATIC DATA CENTER
FEDERAL BUILDING
37 BATTERY PARK AVE
ASHEVILLE, NORTH CAROLINA 28801-2733

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

FIRST CLASS
POSTAGE AND FEES PAID
NOAA
PERMIT G-19

LCD-08-12815-PD-9309

45740
JHK & ASSOCIATES
ATTN: M SCOTT MACCALDEN JR
PO BOX 193727
SAN FRANCISCO CA 94119

MAY 1993 12815
ORLANDO, FL
USCOMM - NOAA - ASHEVILLE, NC 225

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

DATE	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												DATE
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
01																									01
02																									02
03																									03
04																				T	0.01	0.22	T		04
05																		T							05
06																									06
07																									07
08																									08
09												T													09
10																									10
11																									11
12																						T	T		12
13												T	T	T		T	T								13
14			T	T	T	T																			14
15																									15
16																									16
17																									17
18																									18
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20																									20
21																									21
22																									22
23																									23
24																									24
25																									25
26																									26
27																									27
28				T	T			T	0.03	T	0.03								T	0.01	T	0.01	T		28
29	T	0.01	T	0.03	0.01	T	T	T							1.18	0.01	0.03	0.16	0.22	0.08	0.01				29
30								0.02		T	0.06	0.01	T	0.02	0.16	T	T								30
31																T									31

JUN 1993
ORLANDO, FL
NAT'L WEA SER OFC
SUITE 100

INQUIRIES/COMMENTS CALL
(704) 271-4800

INTERNATIONAL AIRPORT

ISSN 0198-1390

LOCAL
CLIMATOLOGICAL DATA
Monthly Summary

JUN 1993
ORLANDO, FL

LATITUDE 28° 26'N LONGITUDE 81° 19'W ELEVATION (GROUND) 96 FEET TIME ZONE EASTERN 12815

	TEMPERATURE °F					DEGREE DAYS BASE 65°F		WEATHER TYPES 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	SNOW ICE PELLETS OR ICE ON GROUND AT 0700 INCHES	PRECIPITATION		AVERAGE STATION PRESSURE IN INCHES ELEV. 106 FEET ABOVE M.S.L.	WIND (M.P.H.)			PEAK GUST		FASTEST 1-MIN		SUNSHINE		SKY COVER (TENTHS)	
DATE 1	MAXIMUM 2	MINIMUM 3	AVERAGE 4	DEPARTURE FROM NORMAL 5	AVERAGE DEW POINT 6	HEATING (SEASON BEGINS WITH JUL) 7A	COOLING (SEASON BEGINS WITH JAN) 7B	8	9	WATER EQUIVALENT (INCHES) 10	SNOW, ICE PELLETS (INCHES) 11	12	RESULTANT DIR. 13	RESULTANT SPEED 14	AVERAGE SPEED 15	SPEED 16	DIRECTION 17	SPEED 18	DIRECTION 19	MINUTES 20	PERCENT OF TOTAL POSSIBLE 21	SUNRISE TO SUNSET 22	MIDNIGHT TO MIDNIGHT 23
01	94	71	83	3	70	0	18		0	0.00	0.0	29.640	03	3.8	6.4	18	E	13	04			4	4
02	93	73	83	3	71	0	18	1 3	0	1.03	0.0	29.745	16	4.1	6.4	32	W	29	28			5	5
03	92	72	82	2	69	0	17	1 8	0	0.00	0.0	29.830	25	5.3	6.4	14	SW	12	26			6	4
04	92	70	81	1	68	0	16	1	0	0.00	0.0	29.860	22	3.7	6.0	16	SE	15	15			3	3
05	94	71	83	3	70	0	18		0	0.00	0.0	29.930	26	5.8	7.5	16	W	12	29			3	3
06	94	71	83	3	69	0	18		0	0.00	0.0	29.990	27	3.7	7.0	16	NW	12	27			2	2
07	96*	75	86*	6	71	0	21	1	0	0.00	0.0	29.980	07	2.2	6.7	17	SE	14	12			6	4
08	95	75	85	5	71	0	20	1	0	0.00	0.0	29.960	13	7.4	8.9	21	E	17	11			1	1
09	93	73	83	2	71	0	18		0	0.00	0.0	29.980	13	8.3	9.4	21	E	17	13			2	1
10	95	73	84	3	71	0	19		0	0.00	0.0	29.990	13	5.6	8.0	21	E	15	11			4	3
11	94	73	84	3	69	0	19		0	0.00	0.0	29.970	14	7.6	8.5	21	SE	16	12			5	5
12	93	72	83	2	72	0	18	3	0	0.99	0.0	29.950	14	2.7	7.0	46	E	33	07			5	6
13	94	76	85	4	72	0	20	3	0	T	0.0	29.910	14	5.0	8.7	30	NE	22	03			8	9
14	92	74	83	2	72	0	18	3	0	0.13	0.0	29.870	06	4.0	5.7	25	E	12	07			9	9
15	91	73	82	1	70	0	17		0	0.02	0.0	29.880	04	7.7	8.8	18	NE	13	05			6	4
16	89	73	81	0	71	0	16		0	0.10	0.0	29.940	06	8.9	9.9	30	E	20	07			6	4
17	88	71	80	-1	68	0	15		0	T	0.0	30.020	06	10.6	11.2	28	NE	20	08			6	4
18	88	68*	78*	-3	67	0	13		0	T	0.0	30.050	07	10.4	11.1	29	E	18	08			7	6
19	89	71	80	-1	68	0	15		0	T	0.0	30.020	08	9.8	10.6	26	E	18	08			5	3
20	89	70	80	-2	68	0	15		0	0.01	0.0	30.010	09	8.9	9.8	22	E	16	09			6	4
21	92	71	82	0	69	0	17	3	0	T	0.0	29.950	09	6.0	7.9	24	E	16	11			5	5
22	93	73	83	1	70	0	18	3	0	0.11	0.0	29.880	17	5.3	8.2	31	SW	23	23			7	7
23	89	72	81	-1	70	0	16		0	0.00	0.0	29.910	18	1.7	6.7	15	E	12	10			10	9
24	90	73	82	0	70	0	17	3	0	0.60	0.0	30.005	10	6.1	8.4	29	E	18	08			8	8
25	92	71	82	0	71	0	17	3	0	0.02	0.0	30.020	12	3.6	8.0	25	E	18	09			8	8
26	92	73	83	1	72	0	18	3	0	0.07	0.0	29.975	10	1.9	6.5	24	N	16	07			9	9
27	89	71	80	-2	72	0	15	1 3	0	0.39	0.0	29.940	19	3.5	7.3	25	NW	18	31			7	7
28	88	72	80	-2	73	0	15	3	0	0.72	0.0	29.950	23	4.3	7.3	31	W	18	35			9	8
29	89	74	82	0	74	0	17	3	0	0.02	0.0	29.950	25	6.7	8.2	26	W	14	25			9	8
30	87	72	80	-2	72	0	15	1	0	0.26	0.0	29.920	26	9.8	10.6	29	NW	23	31			9	8
	SUM	SUM				TOTAL	TOTAL	NUMBER OF DAYS		TOTAL	TOTAL	FOR THE MONTH:								TOTAL	% FOR MONTH	SUM	SUM
	2746	2167				0	514			4.47	0.0	29.930	11	2.4	8.1	46	E	33	07			180	161
	AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION		DEP.						DATE:12		DATE: 12		POSSIBLE		AVG.	AVG.
	91.5	72.2	81.9	0.8	70.3	0	31	≥ .01 INCH. 14		-2.85												6.0	5.4

NUMBER OF DAYS				SEASON TO DATE			
				TOTAL	TOTAL	SNOW, ICE PELLETS ≥ 1.0 INCH	0
MAXIMUM TEMP.		MINIMUM TEMP.		445	1180	THUNDERSTORMS	12
≥ 90°	≤ 32°	≤ 32°	≤ 0°	DEP.	DEP.	HEAVY FOG	0
20	0	0	0	-211	-108	CLEAR 5 PARTLY CLOUDY 16 CLOUDY 9	

GREATEST IN 24 HOURS AND DATES				GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE	
PRECIPITATION		SNOW, ICE PELLETS			
1.03	02	0.0		0	

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS. COLS 16 & 17: PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED. ONE OF TWO WIND SPEEDS IS GIVEN UNDER COLS 18 & 19: FASTEST MILE - HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTION IN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES). ERRORS WILL BE CORRECTED IN SUBSEQUENT PUBLICATIONS.

ERRATA - FEB 1993 - CORRECT HEATING DEGREE DAYS DEPARTURES TO READ - MTH: -41 SEASON: -235

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER

Kenneth D Hadeen
DIRECTOR
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noaa
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE
NATIONAL CLIMATIC DATA CENTER ASHEVILLE NORTH CAROLINA

OBSERVATIONS AT 3-HOUR INTERVALS

JUN 1993
ORLANDO, FL

12815

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
	JUN 1st										
01	0	UNL	10			72	71	71	97	34	3
04	0	UNL	10			72	71	71	97	33	3
07	0	UNL	10			75	73	72	90	10	3
10	5	UNL	10			82	75	71	69	28	4
13	4	UNL	10			91	75	68	47	35	6
16	8	60	10			91	74	66	44	04	9
19	4	UNL	10			83	74	70	65	08	9
22	4	UNL	10			76	73	71	85	13	6
	JUN 4th										
01	0	UNL	8			73	69	66	79	31	5
04	4	UNL	8			71	69	68	90	25	4
07	10	47	6		F	73	70	69	87	29	4
10	0	UNL	10			83	72	67	59	25	6
13	4	UNL	10			88	74	68	52	20	6
16	6	55	10			91	75	67	45	18	7
19	3	UNL	10			88	74	67	50	24	6
22	2	UNL	10			80	74	71	74	15	13
	JUN 7th										
01	0	UNL	10			78	75	73	85	26	3
04	0	UNL	10			75	74	73	94	00	0
07	0	UNL	7			79	76	75	88	33	5
10	7	UNL	10			87	76	71	59	01	4
13	10	UNL	10			95	74	64	36	36	5
16	7	300	10			96	74	63	34	31	3
19	3	UNL	10			87	76	71	59	12	12
22	2	UNL	10			81	76	74	79	13	10
	JUN 10th										
01	0	UNL	10			77	74	73	88	11	7
04	0	UNL	8			75	74	73	94	16	4
07	0	UNL	10			77	75	74	91	23	4
10	4	UNL	10			86	77	73	65	19	6
13	3	UNL	10			91	74	66	44	22	9
16	3	UNL	10			94	75	66	40	08	6
19	5	UNL	10			86	80	78	77	11	13
22	3	UNL	10			80	73	69	69	13	9
	JUN 13th										
01	10	120	10			77	74	72	85	14	8
04	10	120	10			76	73	72	88	13	5
07	10	55	10			78	75	74	88	18	5
10	8	19	10			82	76	74	77	19	7
13	8	37	10			90	77	72	56	21	5
16	7	50	10			85	74	69	59	12	12
19	10	120	10			83	74	69	63	15	12
22	9	70	10			78	74	72	82	26	5
	JUN 16th										
01	0	UNL	10			74	72	71	90	02	4
04	1	UNL	8			73	72	71	94	02	7
07	1	UNL	10			77	74	72	85	05	5
10	6	31	10			85	75	70	61	05	8
13	6	80	10			89	75	69	52	12	10
16	8	100	10			87	74	68	53	08	14
19	6	250	10			79	74	72	79	07	7
22	4	UNL	10			76	73	71	85	06	8

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
	JUN 2nd										
01	1	UNL	8			75	73	72	90	21	3
04	4	UNL	8			73	72	72	97	09	3
07	1	UNL	10			75	74	73	94	18	5
10	1	UNL	10			85	75	71	63	24	4
13	4	UNL	10			91	75	68	47	11	7
16	7	250	10			88	77	72	59	09	10
19	10	60	8			75	71	69	82	12	5
22	5	UNL	8			73	72	71	94	15	4
	JUN 5th										
01	0	UNL	8			74	71	70	87	17	8
04	0	UNL	8			72	71	70	94	25	5
07	0	UNL	7			76	73	71	85	28	4
10	1	UNL	10			85	74	69	59	31	6
13	4	UNL	10			90	76	70	52	28	8
16	6	60	10			91	75	68	47	29	10
19	3	UNL	10			89	75	68	50	28	7
22	7	75	10			81	74	71	72	28	8
	JUN 8th										
01	0	UNL	8			77	75	74	91	17	6
04	0	UNL	7			76	74	73	91	18	4
07	1	UNL	2	8	F	78	76	75	91	16	4
10	1	UNL	10			88	76	70	55	19	4
13	1	UNL	10			93	74	64	38	08	9
16	3	UNL	10			94	75	66	40	15	7
19	3	UNL	10			85	74	68	57	10	11
22	0	UNL	7			80	75	72	77	13	12
	JUN 11th										
01	2	UNL	10			76	73	71	85	19	6
04	0	UNL	7			75	73	72	90	15	7
07	4	UNL	7			75	74	73	94	00	0
10	6	250	10			85	74	69	59	15	4
13	4	UNL	10			92	76	68	46	13	8
16	8	250	10			94	74	65	39	14	11
19	9	250	10			86	73	67	53	10	12
22	8	UNL	10			80	72	68	67	14	8
	JUN 14th										
01	6	UNL	8			76	74	73	91	04	3
04	9	UNL	8			74	73	72	94	10	4
07	10	UNL	8			78	75	73	85	01	3
10	10	UNL	10			84	76	72	67	04	7
13	8	41	10			91	76	69	49	03	7
16	8	120	7			80	76	74	82	12	9
19	9	120	10			78	74	72	82	03	4
22	4	UNL	7			76	73	72	88	06	4
	JUN 17th										
01	0	UNL	10			74	71	70	87	04	6
04	1	UNL	8			72	71	70	94	03	6
07	1	UNL	10			76	73	72	88	05	9
10	8	45	10		RW	82	75	72	72	09	12
13	8	36	10			85	74	68	57	05	15
16	7	250	10			87	71	63	45	05	15
19	7	UNL	10			81	71	65	58	07	9
22	0	UNL	10			74	68	64	71	06	7

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
	JUN 3rd										
01	0	UNL	5		F	73	72	72	97	27	4
04	0	UNL	4		F	73	72	72	97	23	3
07	10	7	2		F	74	73	73	97	26	5
10	8	21	7			81	74	71	72	30	4
13	3	UNL	8			86	74	68	55	23	3
16	6	60	10			91	74	65	42	24	8
19	4	UNL	10			87	74	67	52	23	6
22	0	UNL	10			79	69	64	60	28	9
	JUN 6th										
01	0	UNL	10			76	71	69	79	27	5
04	0	UNL	8			72	70	69	90	27	5
07	0	UNL	10			76	73	72	88	26	6
10	1	UNL	10			85	74	69	59	31	8
13	2	UNL	10			90	74	66	45	31	8
16	4	UNL	10			92	73	63	38	26	5
19	3	UNL	10			89	71	62	41	17	7
22	0	UNL	10			81	76	73	77	09	5
	JUN 9th										
01	0	UNL	8			77	74	73	88	16	7
04	0	UNL	8			74	73	72	94	18	5
07	1	UNL	10			78	75	74	88	12	5
10	3	UNL	10			86	76	72	63	15	7
13	3	UNL	10			91	75	68	47	15	10
16	4	UNL	10			92	77	70	49	13	15
19	2	UNL	10			86	74	68	55	10	11
22	0	UNL	10			80	75	73	79	11	11
	JUN 12th										
01	7	65	10			76	73	71	85	16	5
04	1	UNL	7			76	73	72	88	12	6
07	0	UNL	10			77	74	73	88	16	5
10	0	UNL	10			86	77	73	65	13	6
13	4	UNL	10			92	78	72	52	09	4
16	10	17	6		TRW	74	71	70	87	22	8
19	10	140	8			75	72	71	87	34	4
22	10	100	8			75	74	73	94	05	5
	JUN 15th										
01	5	UNL	7			74	73	72	94	36	5
04	2	UNL	7			73	72	72	97	35	6
07	2	UNL	7			76	74	73	91	36	6
10	4	UNL	10			85	75	71	63	36	8
13	8	41	10			87	74	68	53	07	9
16	8	100	10			86	74	68	55	05	11
19	6	120	10			82	73	68	63	07	10
22	0	UNL	10			76	73	71	85	06	5
	JUN 18th										
01	0	UNL	7			71	67	65	81	04	7
04	0	UNL	7			69	67	65	87	03	3
07	9	UNL	10			74	70	67	79	05	5
10	8	250	10			84	72	66	55	09	12
13	9	UNL	10			87	74	68	53	08	16
16	6	44	10			86	73	67	53	09	15
19	8	UNL	10			81	72	67	63	07	12
22	2	UNL	10			76	71	69	79	04	5

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.25	0.50	0.60	0.85	1.00	1.00	1.03	1.03	1.03	1.03	1.03	1.03
ENDED: DATE	02	02	02	02	02	02	02	02	02	02	02	02
ENDED: TIME	1750	1750	1750	1752	1804	1810	1815	1815	1815	1815	1815	1815

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

JUN 1993
ORLANDO, FL

12815

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					JUN 19th						
01	6	65	7			74	72	71	90	05	6
04	8	UNL	7			71	70	69	93	03	6
07	4	UNL	10			76	72	70	82	06	5
10	4	UNL	10			84	73	68	59	10	14
13	7	55	10			86	74	69	57	05	14
16	7	70	10			87	72	65	48	09	10
19	2	UNL	10			82	72	67	61	10	11
22	0	UNL	10			76	71	68	76	10	8
					JUN 22nd						
01	5	UNL	10			75	72	71	87	18	5
04	4	UNL	10			74	72	71	90	18	4
07	9	120	10			75	73	72	90	19	5
10	3	UNL	10			84	75	70	63	19	13
13	5	UNL	10			90	75	68	48	16	6
16	10	250	10			92	74	66	42	20	9
19	10	110	10			76	73	71	85	09	6
22	10	120	7			73	70	69	87	12	8
					JUN 25th						
01	5	UNL	10			74	71	70	87	16	4
04	3	UNL	7			72	71	70	94	09	5
07	10	250	10			74	72	71	90	09	6
10	7	250	10			86	76	71	61	11	6
13	7	41	10			91	76	70	50	28	4
16	8	110	8		RW	83	76	73	72	10	11
19	9	75	8		RW	78	75	73	85	21	10
22	10	100	10			75	72	71	87	22	6
					JUN 28th						
01	2	UNL	7			73	72	72	97	21	4
04	1	UNL	7			73	72	72	97	19	5
07	9	UNL	8			76	75	75	97	20	7
10	8	21	10			84	78	75	75	25	12
13	10	80	10			81	76	73	77	28	5
16	10	37	10			87	77	73	63	29	10
19	10	100	10			77	74	73	88	32	4
22	10	90	7			75	74	73	94	16	6

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					JUN 20th						
01	0	UNL	10			73	70	69	87	06	4
04	0	UNL	10			71	69	68	90	08	6
07	1	UNL	10			75	70	67	76	06	7
10	6	28	10			84	74	69	61	08	10
13	8	85	10			85	74	69	59	06	10
16	7	80	10			86	72	65	50	10	11
19	5	UNL	10			82	73	69	65	09	13
22	6	75	10			77	72	69	76	12	6
					JUN 23rd						
01	3	UNL	7			73	70	69	87	16	5
04	10	250	8			73	70	69	87	20	3
07	10	250	10			74	73	72	94	20	4
10	10	250	10			81	74	71	72	30	5
13	10	220	10			84	75	71	65	35	8
16	10	220	10			87	74	67	52	33	4
19	9	250	10			83	72	66	57	10	8
22	9	250	10			78	74	72	82	18	9
					JUN 26th						
01	6	250	7			73	72	71	94	02	4
04	7	140	7			74	72	71	90	11	7
07	10	13	7			75	73	72	90	07	7
10	8	250	10			87	77	73	63	14	5
13	9	45	10			88	76	71	57	32	6
16	10	55	10			75	72	71	87	12	8
19	10	120	10			76	73	72	88	17	6
22	10	140	8			75	74	73	94	18	5
					JUN 29th						
01	10	120	7			75	74	73	94	21	4
04	7	120	7			74	73	73	97	23	5
07	8	250	7			78	76	75	91	23	7
10	7	250	10			87	78	74	65	29	7
13	10	250	10		R	80	75	72	77	32	8
16	10	100	10		R	81	76	73	77	26	8
19	10	250	10			79	76	74	85	23	7
22	6	UNL	7			78	77	76	94	20	8

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					JUN 21st						
01	1	UNL	10			72	70	69	90	36	4
04	6	25	10			73	71	70	90	11	3
07	2	UNL	10			78	73	71	79	03	3
10	3	UNL	10			85	75	71	63	12	9
13	6	50	10			89	74	67	48	09	9
16	7	50	10			85	75	70	61	09	13
19	7	300	10			83	74	70	65	09	10
22	8	120	10			78	72	69	74	09	7
					JUN 24th						
01	9	140	10			75	70	68	79	00	0
04	10	140	10			73	70	69	87	02	4
07	10	140	10			77	72	69	76	06	4
10	9	100	10			85	77	73	67	12	6
13	10	37	7		RW	75	72	71	87	10	9
16	5	UNL	10			88	74	68	52	09	15
19	8	150	10			83	74	70	65	09	9
22	10	120	10			76	72	70	82	17	5
					JUN 27th						
01	8	140	8			74	73	72	94	23	5
04	3	UNL	7			72	71	71	97	21	3
07	2	UNL	8			74	73	72	94	18	7
10	6	250	10			84	77	74	72	22	6
13	7	41	10			89	77	72	57	18	12
16	10	65	10			85	77	73	67	31	6
19	10	70	8		RW	76	73	72	88	29	4
22	10	250	8			75	73	72	90	17	7
					JUN 30th						
01	6	UNL	7			77	76	75	94	23	6
04	8	UNL	7			76	75	74	94	23	7
07	10	30	6		RW	72	70	69	90	23	5
10	9	18	10			83	77	74	74	28	11
13	9	150	10			79	74	71	77	24	13
16	8	250	10			86	75	70	59	27	12
19	10	150	10			80	73	70	72	26	12
22	2	UNL	10			75	72	70	85	26	4

SUMMARY BY HOURS

HOUR L.S.T.	AVERAGES							RESULTANT WIND	
	SKY COVER (TENTHS)	STATION PRESSURE (INCHES)	TEMPERATURE			REL HUMIDITY %	WIND SPEED (MPH)	DIRECTION	SPEED (MPH)
			AIR TEMP °F	WET BULB °F	DEW POINT °F				
01	3	29.940	75	72	71	89	5.6	16	1.2
04	3	29.915	73	72	71	92	5.3	14	1.2
07	5	29.950	76	73	72	88	5.8	14	0.8
10	5	29.960	85	75	71	65	8.5	14	1.4
13	6	29.940	88	75	69	55	9.5	08	2.3
16	7	29.900	87	74	68	55	11.2	10	4.3
19	7	29.915	82	74	70	68	9.9	11	5.0
22	5	29.950	77	73	71	81	8.2	13	4.4

WEATHER CODES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXP RESSED IN KNOTS (MPH=KNOTS X 1.15).

NATIONAL CLIMATIC DATA CENTER
FEDERAL BUILDING
37 BATTERY PARK AVE
ASHEVILLE, NORTH CAROLINA 28801-2733

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PO BOX 193727
SAN FRANCISCO CA 94119

JUN 1993 12815
ORLANDO, FL
USCOMM - NOAA - ASHEVILLE, NC 200

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

DATE	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												DATE
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
01																									01
02																		0.99	0.04						02
03																									03
04																									04
05																									05
06																									06
07																									07
08																									08
09																									09
10																									10
11																									11
12															0.16	0.77	0.03	0.03	T						12
13																	T	T					T	T	13
14														0.10	0.02	T	T	0.01	T						14
15													T	0.02											15
16												T		T			0.10	T	T	T	T				16
17										T	T														17
18																							T	T	18
19	T																								19
20											0.01	T													20
21																T									21
22																	0.10	~~0.01~~	T						22
23																									23
24													0.59	0.01											24
25															T	T	T	T	0.02	T					25
26														0.04	0.01	T	T	0.02	T						26
27														0.26	0.01			0.02	0.10	T					27
28											0.02	0.34	0.01				0.34				0.01	T			28
29												T	T	T		0.01	0.01	T	T						29
30							0.25	0.01																	30

JUL 1993
ORLANDO, FL
NAT'L WEA SER OFC
SUITE 100

INQUIRIES/COMMENTS CALL
(704) 271-4800

INTERNATIONAL AIRPORT

LOCAL
CLIMATOLOGICAL DATA
Monthly Summary

ISSN 0198-1390

JUL 1993
ORLANDO, FL

LATITUDE 28° 26'N LONGITUDE -81° 19'W ELEVATION (GROUND) 96 FEET TIME ZONE EASTERN 12815

	TEMPERATURE °F					DEGREE DAYS BASE 65°F		WEATHER TYPES 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	SNOW ICE PELLETS OR ICE ON GROUND AT 0700 INCHES	PRECIPITATION		AVERAGE STATION PRESSURE IN INCHES ELEV. 106 FEET ABOVE M.S.L.	WIND (M.P.H.)							SUNSHINE		SKY COVER (TENTHS)	
																PEAK GUST		FASTEST 1-MIN					
DATE 1	MAXIMUM 2	MINIMUM 3	AVERAGE 4	DEPARTURE FROM NORMAL 5	AVERAGE DEW POINT 6	HEATING (SEASON BEGINS WITH JUL) 7A	COOLING (SEASON BEGINS WITH JAN) 7B	8	9	WATER EQUIVALENT (INCHES) 10	SNOW, ICE PELLETS (INCHES) 11	12	RESULTANT DIR. 13	RESULTANT SPEED 14	AVERAGE SPEED 15	SPEED 16	DIRECTION 17	SPEED 18	DIRECTION 19	MINUTES 20	PERCENT OF TOTAL POSSIBLE 21	SUNRISE TO SUNSET 22	MIDNIGHT TO MIDNIGHT 23
01	95	71	83	1	72	0	18	1 3	0	0.06	0.0	29.900	28	3.9	7.2	28	NW	14	30			5	4
02	95	72	84	2	71	0	19	1 3	0	0.25	0.0	29.910	19	1.6	6.5	35	E	25	11			5	3
03	92	72	82	0	72	0	17	1 3	0	T	0.0	29.930	18	5.4	6.8	18	E	13	14			5	5
04	95	75	85	3	72	0	20	3	0	0.00	0.0	29.970	17	4.8	6.5	16	S	13	10			4	4
05	93	75	84	2	74	0	19	1 3	0	0.20	0.0	29.990	16	1.5	5.5	21	NE	17	04			8	7
06	96	74	85	3	73	0	20	1 3	0	0.55	0.0	29.985	26	1.0	5.8	24	NE	16	05			9	8
07	94	74	84	2	71	0	19	3	0	T	0.0	29.980	14	1.6	6.2	26	NE	22	06			8	7
08	93	73	83	1	72	0	18	3	0	0.03	0.0	29.970	11	4.8	6.7	23	E	17	10			4	3
09	93	74	84	2	72	0	19	3	0	0.00	0.0	30.000	15	3.4	6.5	21	E	16	09			5	5
10	94	71	83	1	71	0	18	3	0	0.30	0.0	30.045	24	1.9	6.9	35	N	29	35			5	5
11	94	71*	83	1	71	0	18	3	0	0.20	0.0	29.980	05	0.9	5.1	21	E	13	22			6	6
12	93	73	83	1	70	0	18	3	0	0.15	0.0	29.920	16	1.3	5.2	24	SW	17	06			4	4
13	91	74	83	1	72	0	18	3	0	T	0.0	29.980	13	6.0	7.7	21	SE	16	11			4	4
14	89	72	81	-1	73	0	16	3	0	0.40	0.0	30.040	08	3.0	6.2	23	SW	13	21			9	7
15	90	72	81*	-1	72	0	16	3	0	0.48	0.0	30.020	15	4.4	6.9	22	SE	15	17			6	5
16	93	72	83	1	71	0	18		0	0.02	0.0	29.940	20	5.5	7.2	23	SW	18	21			5	4
17	95	75	85	3	73	0	20	1 3	0	0.04	0.0	29.930	25	5.5	6.9	21	N	14	31			7	6
18	94	76	85	3	73	0	20		0	0.00	0.0	29.970	26	6.2	7.1	17	W	13	26			9	8
19	95	76	86	4	73	0	21	3	0	0.00	0.0	29.960	27	7.9	8.7	17	W	14	31			9	7
20	91	77	84	2	75	0	19	1 3	0	0.10	0.0	29.920	25	6.3	7.9	28	SW	15	28			10	8
21	93	76	85	3	76	0	20	1 3	0	0.90	0.0	29.905	21	6.1	7.5	24	W	18	25			9	9
22	92	74	83	1	73	0	18	1 3	0	T	0.0	29.930	22	5.3	7.2	28	W	18	30			8	6
23	91	76	84	1	74	0	19	1	0	0.00	0.0	29.940	21	4.4	7.1	29	W	18	29			9	8
24	94	75	85	2	73	0	20	3	0	0.20	0.0	29.990	16	4.8	8.0	26	SW	21	12			5	6
25	96	74	85	2	72	0	20		0	0.00	0.0	30.000	13	2.9	6.0	18	E	12	10			10	7
26	94	76	85	2	74	0	20	3	0	0.00	0.0	29.920	26	2.3	6.3	18	N	15	02			8	7
27	95	74	85	2	73	0	20	3	0	0.01	0.0	29.860	30	1.3	6.1	21	NE	14	17			7	7
28	96	73	85	2	74	0	20	1	0	0.00	0.0	29.900	04	1.5	6.6	18	E	12	07			2	3
29	97	77	87	4	74	0	22	1	0	0.00	0.0	29.900	09	1.8	5.7	15	SE	12	13			4	4
30	97*	77	87*	4	74	0	22	1 3	0	0.00	0.0	29.880	25	5.9	9.2	25	N	17	34			5	6
31	96	72	84	1	74	0	19	1 3 5 8	0	2.60	T	29.860	22	5.7	8.2	53	SW	35	21			5	6
	SUM	SUM				TOTAL	TOTAL	NUMBER OF DAYS		TOTAL	TOTAL	FOR THE MONTH:								TOTAL	% FOR MONTH	SUM	SUM
	2906	2293				0	591			6.49	T	29.950	21	2.2	6.8	53	SW	35	21			199	179
	AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION		DEP.						DATE:31		DATE: 31		POSSIBLE		AVG.	AVG.
	93.7	74.0	83.9	1.6	72.7	0	55	≥ .01 INCH.	17	-0.76												6.4	5.8

NUMBER OF DAYS				SEASON TO DATE		SNOW, ICE PELLETS ≥ 1.0 INCH	0	GREATEST IN 24 HOURS AND DATES				GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE
				TOTAL	TOTAL							
MAXIMUM TEMP.		MINIMUM TEMP.		0	1771	THUNDERSTORMS	25	PRECIPITATION		SNOW, ICE PELLETS		
≥ 90°	≤ 32°	≤ 32°	≤ 0°	DEP.	DEP.	HEAVY FOG	0	2.60	31	trace	31	0
30	0	0	0	0	-53	CLEAR 1	PARTLY CLOUDY 18	CLOUDY 12				

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS. COLS 16 & 17: PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED. ONE OF TWO WIND SPEEDS IS GIVEN UNDER COLS 18 & 19: FASTEST MILE - HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTION IN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES). ERRORS WILL BE CORRECTED IN SUBSEQUENT PUBLICATIONS.

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER

Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

noaa

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ENVIRONMENTAL SATELLITE, DATA
AND INFORMATION SERVICE

NATIONAL
CLIMATIC DATA CENTER
ASHEVILLE NORTH CAROLINA

OBSERVATIONS AT 3-HOUR INTERVALS

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					JUL 1st											JUL 2nd											JUL 3rd						
01	0	UNL	7			72	71	70	94	21	6	0	UNL	7			73	72	71	94	27	4	0	UNL	7			72	71	71	97	20	3
04	0	UNL	7			71	70	70	97	24	3	0	UNL	5		F	72	72	72	97	23	5	1	UNL	5		F	73	72	72	97	15	4
07	0	UNL	10			75	74	73	94	22	4	7	120	7			77	73	71	82	01	5	10	5	7			75	74	73	94	16	5
10	4	UNL	10			85	76	72	65	28	10	2	UNL	10			85	75	71	63	26	3	4	UNL	10			84	77	74	72	23	8
13	4	UNL	10			93	79	74	54	29	5	2	UNL	10			90	76	70	52	31	7	4	UNL	10			88	76	71	57	19	6
16	9	55	10		T	83	74	69	63	09	11	7	50	10			94	76	68	43	03	4	5	UNL	10			91	76	70	50	17	8
19	9	55	10			81	73	69	67	30	8	8	120	8			73	72	71	94	22	3	8	55	10		T	83	76	73	72	14	11
22	3	UNL	8			76	73	71	85	36	5	2	UNL	7			74	72	71	90	17	6	6	80	10			80	76	74	82	15	5
					JUL 4th											JUL 5th											JUL 6th						
01	1	UNL	7			77	75	74	91	17	5	0	UNL	10			80	76	74	82	20	5	8	UNL	7			76	75	74	94	16	4
04	0	UNL	7			76	74	73	91	12	3	0	UNL	8			77	75	74	91	05	4	4	UNL	8			75	74	73	94	07	3
07	1	UNL	7			77	76	75	94	17	4	8	UNL	8			80	77	76	88	16	6	10	UNL	6		F	77	76	75	94	31	4
10	2	UNL	10			87	79	75	68	22	5	6	UNL	10			88	79	76	68	21	6	9	250	10			85	77	74	70	31	5
13	7	47	10			91	76	69	49	18	9	7	43	10			91	78	73	56	18	7	9	250	10			94	80	74	52	02	5
16	5	UNL	10			94	76	67	41	01	3	10	50	7		TRW	76	74	73	91	03	6	10	100	10			81	73	69	67	03	8
19	6	250	10			90	75	68	48	16	7	10	90	10			81	76	73	77	12	5	7	250	10			86	77	73	65	15	6
22	8	80	10		T	83	75	71	67	14	8	8	UNL	8			77	75	74	91	32	4	6	250	7			80	73	70	72	29	8
					JUL 7th											JUL 8th											JUL 9th						
01	9	UNL	7			76	73	71	85	25	3	3	UNL	7			74	72	71	90	06	3	5	UNL	7			76	74	73	91	16	5
04	5	UNL	7			75	73	72	90	11	3	0	UNL	7			74	71	70	87	06	4	0	UNL	7			75	74	73	94	12	4
07	7	250	7			78	75	73	85	00	0	0	UNL	7			77	73	71	82	09	4	0	UNL	10			77	75	74	91	17	5
10	5	UNL	10			87	78	74	65	21	4	3	UNL	10			87	77	73	63	16	5	2	UNL	10			86	78	74	68	17	9
13	6	250	10			90	77	72	56	03	5	3	UNL	10			91	77	71	52	13	6	7	46	10			91	77	71	52	30	3
16	8	250	10			87	77	73	63	28	8	9	45	10		TRW	78	74	72	82	10	15	8	50	10			91	75	68	47	15	9
19	9	250	10		TRW	78	73	70	77	12	11	4	UNL	10			78	74	72	82	14	6	8	70	10			85	77	74	70	07	7
22	6	120	7			75	72	70	85	22	5	1	UNL	10			76	73	72	88	08	5	9	250	10			80	75	73	79	31	3
					JUL 10th											JUL 11th											JUL 12th						
01	3	UNL	7			76	72	70	82	23	5	4	UNL	10			73	72	71	94	23	3	5	UNL	8			74	71	69	85	27	4
04	0	UNL	7			76	71	68	76	18	3	3	UNL	8			72	71	71	97	11	3	3	UNL	10			73	70	69	87	00	0
07	1	UNL	10			79	75	73	82	18	4	2	UNL	8			75	72	71	87	02	3	0	UNL	10			78	74	72	82	17	5
10	3	UNL	10			86	78	74	68	19	4	6	UNL	10			85	79	76	75	34	4	0	UNL	10			86	75	70	59	19	5
13	4	UNL	10			91	78	72	54	29	4	5	UNL	10			92	77	71	50	36	7	4	UNL	10			90	76	69	50	12	3
16	9	33	8		T	87	77	72	61	33	20	7	250	10			93	77	70	47	09	6	6	250	10			92	76	68	46	18	4
19	10	70	6		TRW	74	71	69	85	18	8	10	90	10		T	76	73	71	85	19	6	9	120	10		T	73	69	66	79	01	4
22	10	250	10			75	73	72	90	33	5	10	250	7			76	74	73	91	00	0	4	UNL	8			76	73	72	88	10	3
					JUL 13th											JUL 14th											JUL 15th						
01	2	UNL	10			78	74	72	82	16	8	2	UNL	8			76	74	73	91	33	3	5	UNL	10			74	73	72	94	17	6
04	7	UNL	10			75	72	71	87	26	3	2	UNL	8			74	72	71	90	05	6	2	UNL	8			73	72	71	94	05	4
07	1	UNL	10			79	76	74	85	03	3	9	250	10			77	74	73	88	04	5	1	UNL	10			75	73	72	90	11	3
10	3	UNL	10			86	76	72	63	19	6	9	22	8		RW	84	77	74	72	06	7	4	UNL	10			84	76	73	70	17	9
13	7	250	10			91	76	70	50	12	5	10	29	4		TRW	81	76	74	79	05	7	7	250	10			88	76	70	55	13	3
16	7	250	10			89	77	71	55	13	11	9	100	10		R	76	74	73	91	18	3	9	250	10			83	74	70	65	21	6
19	8	100	10		R	83	75	72	70	12	13	8	250	10			78	75	73	85	12	10	10	30	1		TRW	77	72	70	79	13	12
22	3	UNL	10			78	74	72	82	10	6	6	UNL	10			76	73	72	88	09	6	4	UNL	8			76	75	74	94	19	5
					JUL 16th											JUL 17th											JUL 18th						
01	0	UNL	8			74	73	72	94	18	5	3	UNL	7			77	74	72	85	19	4	8	UNL	8			79	76	74	85	24	4
04	0	UNL	7			73	72	72	97	04	3	0	UNL	7			76	74	73	91	23	5	7	UNL	7			76	75	74	94	23	5
07	9	250	10			76	74	73	91	20	5	8	250	7			77	75	74	91	21	4	10	UNL	8			79	76	75	88	25	6
10	5	UNL	10			84	74	69	61	23	7	7	250	10			87	77	73	63	29	8	6	UNL	10			88	79	76	68	27	9
13	4	UNL	10			90	77	72	56	20	12	4	UNL	10			92	77	70	49	23	6	8	250	10			92	79	73	54	32	4
16	6	250	10			93	77	70	47	16	8	10	250	10			91	78	72	54	19	7	10	250	10			92	78	72	52	23	7
19	7	90	8		RW	83	75	72	70	23	6	10	250	10			86	78	74	68	27	11	9	250	10			89	78	73	59	30	5
22	7	UNL	10			80	73	70	72	17	4	7	250	10			80	77	75	85	24	4	5	UNL	10			84	76	72	67	30	7

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.33	0.65	0.93	1.22	1.54	2.09	2.53	2.60	2.60	2.60	2.60	2.60
ENDED: DATE	31	31	31	31	31	31	31	31	31	31	31	31
ENDED: TIME	1714	1714	1715	1714	1715	1715	1726	1737	1737	1737	1737	1737

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
	JUL 19th										
01	6	UNL	8			81	76	74	79	27	6
04	3	UNL	8			79	76	75	88	22	4
07	10	UNL	8			78	76	75	91	25	6
10	10	UNL	10			88	78	74	63	28	9
13	8	250	10			92	77	70	49	30	8
16	10	250	10			93	78	71	49	27	5
19	10	250	10			90	77	71	54	26	10
22	4	UNL	10			84	76	72	67	27	9
	JUL 22nd										
01	4	UNL	7			75	74	73	94	19	5
04	4	UNL	7			75	74	73	94	19	4
07	9	UNL	6		F	77	76	75	94	20	7
10	6	250	10			87	79	75	68	26	8
13	8	37	10			89	77	72	57	25	14
16	10	250	10			84	76	73	70	23	5
19	7	250	10			85	77	73	67	21	4
22	4	UNL	8			79	76	74	85	18	7
	JUL 25th										
01	3	UNL	8			75	73	72	90	07	5
04	2	UNL	8			76	74	73	91	15	6
07	10	UNL	10			80	77	75	85	24	3
10	10	UNL	10			88	78	73	61	18	4
13	10	250	10			92	76	68	46	15	6
16	10	250	10			95	75	66	39	31	3
19	7	250	10			87	77	72	61	10	10
22	5	UNL	8			82	76	74	77	11	7
	JUL 28th										
01	8	UNL	8			73	72	72	97	25	5
04	8	UNL	5		F	73	73	73	100	23	3
07	2	UNL	6		F	74	73	73	97	21	3
10	0	UNL	10			85	77	74	70	33	4
13	3	UNL	10			93	78	71	49	31	10
16	2	UNL	10			93	79	74	54	06	10
19	1	UNL	10			88	77	73	61	07	10
22	0	UNL	10			82	77	75	79	08	5
	JUL 31st										
01	8	UNL	7			77	74	73	88	23	7
04	4	UNL	4		F	77	76	75	94	21	5
07	4	UNL	2		F	80	78	77	91	21	4
10	2	UNL	8			89	80	77	68	30	5
13	4	UNL	10			94	78	71	47	23	6
16	10	45	7		T	90	81	77	66	23	14
19	10	80	7			78	72	69	74	27	7
22	10	250	7			76	74	73	91	19	6

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
	JUL 20th										
01	3	UNL	8			80	76	74	82	25	8
04	5	UNL	8			78	7.	74	88	25	5
07	10	UNL	10			79	76	74	85	26	5
10	10	23	10			88	80	77	70	28	9
13	10	250	10			89	79	75	63	24	12
16	10	110	8		R	80	77	75	85	24	4
19	8	250	7			80	77	76	88	24	6
22	10	140	6		F	79	78	77	94	21	5
	JUL 23rd										
01	0	UNL	7			76	75	74	94	18	4
04	6	UNL	6		F	76	75	75	97	17	6
07	8	UNL	7			78	76	75	91	18	5
10	9	250	10			87	78	74	65	27	8
13	10	36	10			82	75	72	72	30	13
16	9	250	10			81	76	74	79	21	4
19	10	140	10			82	75	72	72	16	5
22	10	120	10			79	75	73	82	18	6
	JUL 26th										
01	3	UNL	7			78	76	75	91	18	6
04	2	UNL	7			77	75	74	91	17	5
07	4	UNL	8			79	76	75	88	25	4
10	9	UNL	10			88	79	76	68	30	6
13	10	48	10			91	77	71	52	28	8
16	10	120	10			83	76	73	72	09	9
19	10	250	10			83	76	73	72	03	3
22	10	UNL	8			80	75	73	79	17	4
	JUL 29th										
01	6	UNL	7			80	77	76	88	17	4
04	6	UNL	7			78	77	76	94	00	0
07	10	UNL	5		F	79	77	76	91	00	0
10	7	UNL	10			89	79	75	63	02	5
13	3	UNL	8			94	78	72	49	04	8
16	1	UNL	8			96	77	68	40	06	7
19	3	UNL	7			91	79	74	58	13	10
22	2	UNL	7			82	78	76	82	31	3

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
	JUL 21st										
01	10	140	7			78	76	75	91	20	5
04	7	300	6		F	77	76	76	97	19	4
07	10	UNL	6		F	79	77	76	91	20	4
10	7	250	10			89	81	78	70	25	6
13	6	250	10			91	79	74	58	22	7
16	10	80	7		TRW	78	77	76	94	06	6
19	10	120	7			79	77	76	91	20	8
22	8	140	6		F	78	77	76	94	18	6
	JUL 24th										
01	8	250	7			77	75	74	91	22	4
04	6	UNL	7			76	75	75	97	00	0
07	7	250	10			78	76	75	91	17	7
10	2	UNL	10			87	78	74	65	21	5
13	4	UNL	10			91	78	72	54	15	8
16	9	85	10			86	76	72	63	12	18
19	9	25	8		T	81	72	68	65	23	13
22	10	UNL	8			76	74	73	91	09	7
	JUL 27th										
01	10	UNL	8			77	75	74	91	26	3
04	8	UNL	8			76	75	74	94	00	0
07	10	250	8			80	77	75	85	05	4
10	7	250	10			87	78	74	65	33	3
13	3	UNL	10			93	80	75	56	29	6
16	7	250	10			94	78	72	49	32	7
19	8	70	10		RW	76	73	72	88	19	10
22	1	UNL	10			75	73	72	90	01	5
	JUL 30th										
01	0	UNL	7			80	77	75	85	28	7
04	6	UNL	7			80	77	75	85	27	6
07	4	UNL	6		F	80	77	76	88	19	6
10	1	UNL	8			89	80	76	66	29	6
13	4	UNL	8			95	79	73	49	30	6
16	10	75	10			93	77	70	47	24	10
19	10	250	7			81	76	73	77	19	12
22	10	85	7			79	75	73	82	22	7

WEATHER CODES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXP RESSED IN KNOTS (MPH=KNOTS X 1.15).

SUMMARY BY HOURS

HOUR L.S.T.	AVERAGES							RESULTANT WIND	
	SKY COVER (TENTHS)	STATION PRESSURE (INCHES)	TEMPERATURE			REL HUMIDITY %	WIND SPEED (MPH)	DIRECTION	SPEED (MPH)
			AIR TEMP °F	WET BULB °F	DEW POINT °F				
01	4	29.950	76	74	73	89	5.5	21	3.7
04	3	29.930	75	74	73	92	4.2	18	1.6
07	6	29.960	78	75	74	89	4.9	19	2.4
10	5	29.980	87	78	74	66	7.1	25	4.1
13	6	29.960	91	77	72	54	8.0	26	2.7
16	8	29.920	88	76	71	60	9.1	13	1.8
19	8	29.930	82	75	72	73	9.2	17	4.3
22	6	29.960	78	75	73	83	6.2	18	1.6

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JUL 1993 12815
ORLANDO, FL
USCOMM - NOAA - ASHEVILLE, NC 200

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

DATE	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												DATE
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
01															0.04	0.02									01
02																	0.07	0.13	0.05						02
03																					T				03
04																									04
05													T			0.20	T	T							05
06															0.53	0.02									06
07															T				T	T					07
08															T	0.01	0.02	T							08
09																									09
10																0.01	0.23	0.02	0.03	0.01	T				10
11																	0.02	0.08	0.10	T	T				11
12																	0.15	T							12
13																			T	T					13
14										T	T		0.05	0.22	0.12	0.01	T								14
15															T				0.30	0.18	T				15
16																			0.02	T					16
17																		T	0.01	0.01	0.02				17
18																									18
19																									19
20														0.05	0.01	0.02	0.02	T							20
21															0.38	0.47	T	0.04	0.01						21
22														T											22
23																									23
24																			0.06	0.14					24
25																									25
26																									26
27																		T	0.01	T					27
28																									28
29																									29
30																									30
31																	2.00	0.60	T						31

AUG 1993
ORLANDO, FL
NAT'L WEA SER OFC
SUITE 100

INQUIRIES/COMMENTS CALL
(704) 271-4800

INTERNATIONAL AIRPORT

ISSN 0198-1390

DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA

LOCAL CLIMATOLOGICAL DATA

Monthly Summary

AUG 1993
ORLANDO, FL

LATITUDE 28° 26'N LONGITUDE 81° 19'W ELEVATION (GROUND) 96 FEET TIME ZONE EASTERN 12815

	TEMPERATURE °F					DEGREE DAYS BASE 65°F		WEATHER TYPES 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	SNOW ICE PELLETS OR ICE ON GROUND AT 0700 INCHES	PRECIPITATION		AVERAGE STATION PRESSURE IN INCHES ELEV. 106 FEET ABOVE M.S.L.	WIND (M.P.H.)							SUNSHINE		SKY COVER (TENTHS)	
																PEAK GUST		FASTEST 1-MIN					
DATE 1	MAXIMUM 2	MINIMUM 3	AVERAGE 4	DEPARTURE FROM NORMAL 5	AVERAGE DEW POINT 6	HEATING (SEASON BEGINS WITH JUL) 7A	COOLING (SEASON BEGINS WITH JAN) 7B	8	9	WATER EQUIVALENT (INCHES) 10	SNOW, ICE PELLETS (INCHES) 11	12	RESULTANT DIR. 13	RESULTANT SPEED 14	AVERAGE SPEED 15	SPEED 16	DIRECTION 17	SPEED 18	DIRECTION 19	MINUTES 20	PERCENT OF TOTAL POSSIBLE 21	SUNRISE TO SUNSET 22	MIDNIGHT TO MIDNIGHT 23
01	96	74	85	3	71	0	20	1	0	0.00	0.0	29.860	23	5.4	7.5	15	W	12	08			6	6
02	94	75	85	3	72	0	20		0	0.00	0.0	29.900	20	8.4	9.0	20	S	14	17			7	7
03	95	77	86	4	73	0	21	3	0	0.03	0.0	30.040	16	5.0	7.7	29	E	22	10			5	4
04	95	76	86	3	73	0	21	3	0	0.15	0.0	30.090	16	6.7	9.3	36	SW	24	23			2	3
05	95	77	86	3	74	0	21		0	0.00	0.0	30.040	17	6.7	8.1	18	SE	14	12			3	3
06	95	76	86	3	71	0	21		0	0.00	0.0	29.980	17	7.1	9.1	21	SE	15	13			4	3
07	95	75	85	2	71	0	20		0	0.00	0.0	30.010	14	6.7	8.5	22	E	15	11			1	1
08	95	72	84	1	72	0	19		0	0.00	0.0	30.040	09	6.7	7.8	21	E	17	11			6	4
09	95	75	85	2	72	0	20	3	0	0.00	0.0	30.000	06	6.8	7.6	20	E	13	08			5	5
10	88	74	81	-2	72	0	16	3	0	0.18	0.0	29.960	05	7.0	7.7	23	NE	15	07			6	5
11	94	72	83	0	70	0	18		0	0.00	0.0	29.950	03	6.0	6.9	17	NE	13	02			5	3
12	94	74	84	1	71	0	19		0	0.00	0.0	29.960	05	2.7	6.0	20	E	14	07			4	4
13	95	74	85	2	72	0	20	3	0	0.00	0.0	29.960	19	3.5	6.8	22	W	13	28			5	5
14	93	72	83	0	71	0	18	3	0	0.48	0.0	29.950	22	7.2	8.5	41	W	30	29			8	7
15	88	76	82	-1	73	0	17	3	0	0.06	0.0	29.900	23	9.9	10.7	33	W	25	28			9	7
16	93	76	85	2	73	0	20	1 3 8	0	0.04	0.0	29.880	35	4.4	8.0	22	W	16	25			9	9
17	93	74	84	1	71	0	19	1	0	0.00	0.0	29.880	03	5.6	7.0	18	E	13	06			6	4
18	96	70*	83	1	69	0	18	1 8	0	0.00	0.0	29.860	26	3.4	5.5	14	W	12	25			1	0
19	96*	76	86	4	73	0	21	1 8	0	0.00	0.0	29.880	24	5.9	7.3	17	SW	13	21			2	2
20	95	76	86*	4	74	0	21	1 3 8	0	0.13	0.0	29.920	24	5.6	6.7	22	NW	16	27			6	4
21	94	75	85	3	74	0	20	1 3	0	0.03	0.0	29.925	25	5.4	6.4	31	SW	20	22			7	5
22	95	72	84	2	73	0	19	1 3	0	0.48	0.0	29.910	26	4.6	8.1	24	N	18	02			8	7
23	94	75	85	3	74	0	20	1 3	0	0.00	0.0	29.870	31	1.6	6.1	21	NE	14	06			9	9
24	88	76	82	0	75	0	17	1 8	0	0.00	0.0	29.880	06	5.6	6.4	16	E	13	07			9	8
25	86	73	80	-2	74	0	15	1 3	0	0.14	0.0	29.940	07	3.9	6.7	17	N	15	02			10	8
26	91	71	81	-1	71	0	16	3	0	0.09	0.0	29.980	10	2.6	5.7	25	E	13	09			8	7
27	91	72	82	0	72	0	17	3	0	1.22	0.0	29.930	06	2.2	5.1	21	E	16	06			9	7
28	88	72	80	-2	73	0	15	1 3	0	0.89	0.0	29.890	13	3.6	5.6	21	E	14	10			8	8
29	87	72	80	-2	73	0	15	1 3	0	1.82	0.0	29.870	14	6.5	7.6	23	SW	16	09			9	8
30	87	71	79*	-3	72	0	14	3	0	0.06	0.0	29.850	12	7.1	7.7	26	SE	25	15			7	8
31	88	72	80	-2	73	0	15	1	0	0.15	0.0	29.840	15	6.1	7.7	26	E	18	13			9	7
	SUM	SUM				TOTAL	TOTAL	NUMBER OF DAYS		TOTAL	TOTAL	FOR THE MONTH:								TOTAL	% FOR MONTH	SUM	SUM
	2869	2292				0	573			5.95	0.0	29.930	16	1.8	7.4	41	W	30	29			193	168
	AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION		DEP.						DATE:14		DATE: 14		POSSIBLE		AVG.	AVG.
	92.5	73.9	83.2	0.7	72.3	0	30	≥ .01 INCH.	16	-0.83												6.2	5 4

NUMBER OF DAYS				SEASON TO DATE		SNOW, ICE PELLETS		GREATEST IN 24 HOURS AND DATES			GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE
				TOTAL	TOTAL	≥ 1.0 INCH	0				
MAXIMUM TEMP.		MINIMUM TEMP.		0	2344	THUNDERSTORMS	18	PRECIPITATION		SNOW, ICE PELLETS	
≥ 90°	≤ 32°	≤ 32°	≤ 0°	DEP.	DEP.	HEAVY FOG	0	2.58	28-29	0.0	0
23	0	0	0	0	-23	CLEAR 5	PARTLY CLOUDY 14	CLOUDY 12			

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS. COLS 16 & 17: PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED. ONE OF TWO WIND SPEEDS IS GIVEN UNDER COLS 18 & 19: FASTEST MILE - HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTION IN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES). ERRORS WILL BE CORRECTED IN SUBSEQUENT PUBLICATIONS.

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER

Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

noaa

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AND INFORMATION SERVICE

NATIONAL
CLIMATIC DATA CENTER
ASHEVILLE NORTH CAROLINA

AUG 1993
ORLANDO, FL

12815

OBSERVATIONS AT 3-HOUR INTERVALS

			VISIBILITY			TEMPERATURE				WIND	
HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	WHOLE MILES	16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	DIRECTION	SPEED (KNOTS)
AUG 1st											
01	10	UNL	5		F	75	74	74	97	20	5
04	6	UNL	3		F	76	75	75	97	23	8
07	3	UNL	5		F	76	75	74	94	24	6
10	9	UNL	8			87	76	71	59	27	7
13	8	250	10			94	74	65	39	20	6
16	6	250	10			94	73	63	36	30	3
19	5	UNL	10			89	74	66	47	20	5
22	0	UNL	10			83	75	72	70	25	9
AUG 2nd											
01	10	UNL	8			78	75	73	85	23	7
04	7	UNL	7			76	73	72	88	23	4
07	10	UNL	7			77	72	70	79	20	6
10	8	UNL	10			88	76	71	57	19	8
13	7	UNL	10			92	77	70	49	17	12
16	5	UNL	10			93	76	69	46	22	8
19	8	0	10			86	78	74	68	20	11
22	0	UNL	7			81	76	73	77	19	5
AUG 3rd											
01	1	UNL	7			79	76	74	85	17	6
04	1	UNL	7			77	75	74	91	17	4
07	0	UNL	8			80	77	76	88	12	4
10	4	UNL	10			89	80	76	66	23	6
13	6	250	10			93	78	72	51	13	9
16	7	UNL	10		T	95	78	71	46	18	9
19	8	250	10			82	74	70	67	23	6
22	6	UNL	7			79	75	73	82	30	5
AUG 4th											
01	4	UNL	7			79	76	74	85	12	6
04	2	UNL	7			78	75	74	88	14	7
07	1	UNL	7			79	76	75	88	14	6
10	4	UNL	8			88	79	76	68	16	10
13	1	UNL	8			93	78	71	49	16	9
16	2	UNL	8			95	79	72	48	19	7
19	7	250	10			88	75	69	53	10	7
22	8	250	7			78	73	70	77	08	8
AUG 5th											
01	0	UNL	7			79	77	76	91	20	5
04	2	UNL	7			78	76	75	91	17	7
07	4	UNL	7			78	77	76	94	17	6
10	2	UNL	7			87	79	75	68	23	8
13	1	UNL	7			92	79	73	54	19	6
16	4	UNL	7			95	78	71	46	09	4
19	5	UNL	10			89	75	69	52	18	7
22	2	UNL	7			83	77	74	74	13	8
AUG 6th											
01	3	UNL	7			80	76	74	82	17	9
04	4	UNL	7			76	74	73	91	18	7
07	7	UNL	7			77	75	74	91	21	5
10	3	UNL	10			86	77	73	65	20	9
13	3	UNL	10			92	77	71	50	28	4
16	1	UNL	10			95	75	65	37	17	7
19	1	UNL	10			90	73	65	44	18	8
22	0	UNL	10			82	75	71	69	14	12
AUG 7th											
01	0	UNL	10			79	74	72	79	17	7
04	0	UNL	7			75	74	73	94	18	6
07	0	UNL	7			77	75	74	91	20	4
10	0	UNL	10			87	76	71	59	24	4
13	2	UNL	10			92	77	71	50	10	5
16	3	UNL	10			95	75	65	37	11	13
19	0	UNL	10			87	73	66	50	09	10
22	0	UNL	10			79	75	73	82	11	8
AUG 8th											
01	0	UNL	8			77	74	72	85	15	5
04	0	UNL	8			74	73	72	94	11	3
07	3	UNL	8			74	73	72	94	04	4
10	6	UNL	10			86	77	73	65	09	7
13	8	55	10			93	77	70	47	13	9
16	9	55	10			92	77	71	50	06	12
19	5	UNL	10			85	76	72	65	10	10
22	7	120	10			79	75	73	82	07	8
AUG 9th											
01	2	UNL	8			76	74	73	91	07	5
04	1	UNL	7			75	74	73	94	05	5
07	0	UNL	7			78	75	74	88	04	6
10	2	UNL	10			87	76	71	59	07	8
13	4	UNL	10			92	76	68	46	12	5
16	8	95	10		T	88	76	71	57	08	11
19	9	100	10			83	77	74	74	05	7
22	10	250	10			80	75	72	77	09	8
AUG 10th											
01	3	UNL	8			77	74	73	88	36	4
04	3	UNL	8			75	74	73	94	06	4
07	1	UNL	10			78	75	74	88	06	4
10	6	250	10			87	77	73	63	10	6
13	9	80	10		T	75	73	72	90	01	7
16	5	UNL	10			86	75	70	59	05	11
19	5	UNL	7			82	75	71	69	07	9
22	5	UNL	10			76	71	69	79	05	6
AUG 11th											
01	3	UNL	10			74	72	71	90	05	4
04	1	UNL	10			73	71	70	90	02	4
07	1	UNL	10			76	73	71	85	35	6
10	3	UNL	10			86	76	71	61	02	7
13	6	250	10			91	75	67	45	27	3
16	9	250	10			91	77	71	52	02	11
19	4	UNL	10			84	74	69	61	05	10
22	0	UNL	10			77	73	71	82	03	4
AUG 12th											
01	0	UNL	10			75	73	72	90	05	4
04	2	UNL	7			74	73	72	94	32	4
07	4	UNL	10			76	75	74	94	32	5
10	4	UNL	10			85	77	73	67	25	3
13	4	UNL	10			92	76	69	47	33	4
16	7	80	10			91	74	66	44	35	4
19	5	UNL	10			84	74	69	61	06	8
22	5	UNL	10			79	74	72	79	17	7
AUG 13th											
01	2	UNL	10			77	74	72	85	17	4
04	2	UNL	10			74	72	71	90	02	3
07	4	UNL	10			78	75	74	88	00	0
10	4	UNL	10			87	77	73	63	31	3
13	5	UNL	10			92	78	72	52	21	6
16	7	50	10			93	77	70	47	16	4
19	10	80	10			89	75	69	52	24	7
22	10	90	10			78	73	70	77	14	8
AUG 14th											
01	3	UNL	7			77	74	72	85	20	6
04	2	UNL	7			75	74	73	94	17	6
07	6	250	10			77	75	74	91	21	5
10	7	31	10			88	78	74	63	21	7
13	9	44	8		TRW	79	69	64	60	29	26
16	10	250	10			83	71	64	53	21	11
19	10	100	10			80	74	71	74	23	9
22	10	100	10			78	73	70	77	22	6
AUG 15th											
01	2	UNL	10			76	73	72	88	19	5
04	3	UNL	10			76	73	71	85	22	6
07	3	UNL	8			79	77	76	91	20	8
10	10	27	6		TRW	77	72	70	79	28	15
13	10	75	10			81	76	73	77	26	13
16	10	80	10			85	77	73	67	23	14
19	10	100	10			83	77	74	74	25	8
22	7	UNL	10			79	75	73	82	22	6
AUG 16th											
01	3	UNL	8			78	76	75	91	24	5
04	10	300	7			76	74	73	91	28	7
07	5	UNL	5		F	78	76	75	91	29	5
10	10	37	7			86	78	74	68	03	6
13	7	35	6		H	90	79	74	59	03	7
16	10	250	7			91	75	68	47	02	10
19	10	250	7			83	75	71	67	05	7
22	10	250	7			79	74	71	77	35	3
AUG 17th											
01	4	UNL	7			76	74	73	91	34	6
04	2	UNL	7			75	74	73	94	33	3
07	3	UNL	5		F	76	74	73	91	31	5
10	7	30	8			86	76	71	61	01	8
13	7	250	10			89	75	69	52	06	8
16	9	250	10			89	77	71	55	06	11
19	6	UNL	10			83	75	71	67	05	7
22	1	UNL	7			78	71	68	72	08	3
AUG 18th											
01	0	UNL	7			73	71	70	90	02	3
04	0	UNL	7			72	71	70	94	00	0
07	0	UNL	6		F	74	72	71	90	27	3
10	0	UNL	10			85	74	69	59	25	10
13	1	UNL	10			93	75	67	43	27	6
16	3	UNL	7			95	75	66	39	36	4
19	0	UNL	6		H	88	73	66	48	18	8
22	0	UNL	7			82	75	71	69	33	5

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.25	0.50	0.73	0.95	1.29	1.46	1.55	1.56	1.61	1.69	1.73	1.80
ENDED: DATE	29	29	29	29	29	29	29	29	29	29	29	29
ENDED: TIME	1432	1432	1437	1443	1451	1456	1459	1521	1536	1559	1635	1659

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

AUG 1993
ORLANDO, FL

12815

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
					AUG 19th											AUG 20th											AUG 21st						
01	0	UNL	7			80	77	75	85	23	4	0	UNL	7			78	75	73	85	23	4	0	UNL	6		F	77	75	74	91	25	6
04	0	UNL	4		F	77	75	74	91	24	4	0	UNL	4		F	77	76	75	94	21	4	0	UNL	5		F	76	75	74	94	00	0
07	0	UNL	2		F	77	76	75	94	22	4	0	UNL	2	4	F	78	77	76	94	00	0	8	UNL	5		F	77	75	74	91	21	4
10	0	UNL	7			89	79	75	63	24	7	5	UNL	4		H	87	79	76	70	26	7	4	UNL	10			87	78	74	65	27	7
13	1	UNL	7			95	78	70	44	21	10	6	45	7			94	79	73	51	21	10	4	UNL	10			92	77	71	50	25	7
16	3	UNL	8			95	76	68	41	20	10	8	50	7			92	79	73	54	25	9	10	250	10			91	80	75	60	23	9
19	6	85	5		H	88	77	73	61	33	8	9	85	7		RW	79	76	75	88	26	6	10	250	10			85	77	74	70	26	5
22	3	UNL	7			82	75	72	72	26	4	8	UNL	7			79	77	76	91	22	3	5	UNL	8			82	77	75	79	24	4
					AUG 22nd											AUG 23rd											AUG 24th						
01	0	UNL	7			78	75	74	88	26	5	10	250	5		F	75	74	73	94	19	5	10	250	7			78	76	75	91	04	5
04	0	UNL	7			75	74	73	94	23	4	8	250	7			77	75	74	91	27	6	6	UNL	4		F	77	76	75	94	05	3
07	5	UNL	5		F	76	74	73	91	24	4	8	250	6		F	79	77	76	91	24	4	7	250	4		F	77	76	75	94	04	6
10	8	UNL	10			87	79	76	70	28	9	6	250	10			86	78	75	70	27	6	10	250	2	8	F	78	76	75	91	06	6
13	10	45	10			92	78	72	52	31	8	10	250	10			92	79	74	56	32	5	10	250	7			85	78	75	72	08	7
16	6	250	10			94	79	73	51	24	12	10	75	10			82	75	71	69	06	12	10	18	6		H	83	77	75	77	08	10
19	10	47	10			80	74	71	74	11	7	6	UNL	7			82	76	74	77	09	4	7	100	6		H	80	76	74	82	04	4
22	10	85	7			74	73	72	94	25	5	10	250	7			81	76	74	79	24	3	0	UNL	7			78	75	73	85	07	4
					AUG 25th											AUG 26th											AUG 27th						
01	7	48	7			76	75	75	97	00	0	1	UNL	10			73	72	72	97	00	0	5	UNL	7			73	72	71	94	33	5
04	7	250	4		F	77	76	75	94	02	4	0	UNL	7			72	71	71	97	00	0	2	UNL	7			72	71	71	97	35	5
07	8	250	6		F	77	76	76	97	06	7	5	UNL	10			73	72	71	94	09	4	5	UNL	7			74	73	72	94	02	4
10	9	22	10			83	77	75	77	09	5	9	250	10			83	75	72	70	14	8	8	120	10			84	76	72	67	34	3
13	10	60	5		TRW	74	73	73	97	36	9	6	250	10			89	77	71	55	07	3	8	120	10			88	76	70	55	24	3
16	9	250	7			83	77	74	74	10	4	9	75	7		TRW	78	75	73	85	09	11	10	8	1		TRW	74	73	73	97	09	12
19	10	250	7			78	73	71	79	13	8	9	80	7		RW	74	73	72	94	24	5	10	70	10			76	74	73	91	20	3
22	3	UNL	7			75	73	72	90	11	4	10	200	8			74	72	71	90	29	4	10	70	10			75	74	73	94	16	4
					AUG 28th											AUG 29th											AUG 30th						
01	5	UNL	7			74	74	74	100	06	4	4	UNL	7			73	72	72	97	14	5	7	7	7			72	71	71	97	17	4
04	5	UNL	7			73	72	72	97	12	4	4	UNL	7			73	72	72	97	16	6	7	250	7			71	71	71	100	08	4
07	9	6	7			73	72	72	97	19	6	9	4	7			74	73	73	97	16	5	8	140	10			74	73	72	94	11	4
10	7	17	10			79	74	72	79	12	4	8	150	10			80	77	75	85	18	8	5	UNL	10			83	76	73	72	12	9
13	7	37	10			87	77	73	63	12	5	8	37	10			85	77	73	67	08	10	7	32	10			86	76	72	63	11	10
16	9	60	10		T	78	74	72	82	10	12	10	35	5		TRWF	73	72	72	97	18	4	10	95	10			77	75	74	91	15	8
19	10	80	6		RW	74	73	72	94	22	4	10	200	7			73	72	72	97	13	6	10	110	10			77	74	73	88	08	5
22	9	140	10			74	73	73	97	15	3	10	120	7			72	72	72	100	10	5	10	UNL	10			74	73	72	94	12	8
					AUG 31st																												
01	2	UNL	7			72	72	72	100	16	4																						
04	10	2	1		F	72	72	72	100	16	9																						
07	10	5	7			73	73	73	100	18	6																						
10	8	16	10			81	76	74	79	16	11																						
13	7	55	10			87	77	73	63	20	10																						
16	10	70	5		RW	76	74	73	91	18	5																						
19	9	250	7			76	75	74	94	08	9																						
22	3	UNL	10			75	74	73	94	12	5																						

SUMMARY BY HOURS

HOUR L.S.T	AVERAGES SKY COVER (TENTHS)	AVERAGES STATION PRESSURE (INCHES)	AVERAGES TEMPERATURE AIR TEMP °F	AVERAGES TEMPERATURE WET BULB °F	AVERAGES TEMPERATURE DEW POINT °F	AVERAGES REL HUMIDITY %	AVERAGES WIND SPEED (MPH)	RESULTANT WIND DIRECTION	RESULTANT WIND SPEED (MPH)
01	3	29.930	76	74	73	90	5.5	18	2.0
04	3	29.910	75	73	73	93	5.2	18	1.6
07	4	29.945	76	75	74	91	5.4	19	1.3
10	6	29.970	85	77	73	68	8.2	21	2.2
13	6	29.940	89	76	71	56	9.0	20	1.6
16	7	29.900	88	76	70	59	10.1	12	3.1
19	7	29.910	83	75	71	70	8.2	14	2.4
22	6	29.950	78	74	72	82	6.5	14	2.3

WEATHER CODES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXP RESSED IN KNOTS (MPH=KNOTS X 1.15).

NATIONAL CLIMATIC DATA CENTER
FEDERAL BUILDING
37 BATTERY PARK AVE
ASHEVILLE, NORTH CAROLINA 28801-2733

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

FIRST CLASS
POSTAGE AND FEES PAID
NOAA
PERMIT G-19

LCD-08-12815-PD-9309

45740
JHK & ASSOCIATES
ATTN: M SCOTT MACCALDEN JR
PO BOX 193727
SAN FRANCISCO CA 94119

AUG 1993 12815
ORLANDO, FL
USCOMM - NOAA - ASHEVILLE, NC 200

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

DATE	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												DATE
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
01																									01
02																									02
03																	T	0.03							03
04																				T	0.15	T			04
05																									05
06																									06
07																									07
08																									08
09																									09
10												0.16	0.02												10
11																									11
12																									12
13																									13
14													0.25	0.23	T	T									14
15										0.03	0.03	T	T	T											15
16			0.04									T	T												16
17																									17
18																									18
19																									19
20																T	T	0.05	0.08	T					20
21														0.02	0.01										21
22																				0.29	0.17	0.02			22
23																									23
24																									24
25												0.05	0.09	T											25
26															T	0.02	0.02	0.01	0.01	0.02	0.01				26
27															T	0.88	0.31	0.03							27
28															T		0.77	0.04	0.07	0.01					28
29										T				T	1.55	0.14	0.11	0.02	T						29
30														0.03	0.02	0.01									30
31													T	0.01	0.04	0.08	0.02	T							31

SEP 1993
ORLANDO, FL
NAT'L WEA SER OFC
SUITE 100

INQUIRIES/COMMENTS CALL
(704) 271-4800

INTERNATIONAL AIRPORT

ISSN 0198-1390

LOCAL
CLIMATOLOGICAL DATA
Monthly Summary

SEP 1993
ORLANDO, FL

LATITUDE 28° 26'N LONGITUDE 81° 19'W ELEVATION (GROUND) 96 FEET TIME ZONE EASTERN 12815

	TEMPERATURE °F					DEGREE DAYS BASE 65°F		WEATHER TYPES 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	SNOW ICE PELLETS OR ICE ON GROUND AT 0700	PRECIPITATION		AVERAGE STATION PRESSURE	WIND (M.P.H.)							SUNSHINE		SKY COVER (TENTHS)	
																PEAK GUST		FASTEST 1-MIN					
DATE 1	MAXIMUM 2	MINIMUM 3	AVERAGE 4	DEPARTURE FROM NORMAL 5	AVERAGE DEW POINT 6	HEATING (SEASON BEGINS WITH JUL) 7A	COOLING (SEASON BEGINS WITH JAN) 7B	8	INCHES 9	WATER EQUIVALENT (INCHES) 10	SNOW, ICE PELLETS (INCHES) 11	IN INCHES ELEV. 106 FEET ABOVE M.S.L. 12	RESULTANT DIR. 13	RESULTANT SPEED 14	AVERAGE SPEED 15	SPEED 16	DIRECTION 17	SPEED 18	DIRECTION 19	MINUTES 20	PERCENT OF TOTAL POSSIBLE 21	SUNRISE TO SUNSET 22	MIDNIGHT TO MIDNIGHT 23
01	91	73	82	0	73	0	17	3	0	0.82	0.0	29.910	14	7.2	8.6	40	SW	23	13			6	5
02	90	73	82	0	73	0	17		0	0.05	0.0	29.995	12	7.3	8.0	26	SE	16	15			7	4
03	91	73	82	0	73	0	17		0	0.00	0.0	29.995	12	6.0	7.0	17	E	13	12			6	5
04	91	74	83	1	73	0	18		0	T	0.0	29.880	21	1.5	5.6	16	W	10	25			4	4
05	93	73	83	1	72	0	18	3	0	0.05	0.0	29.855	15	1.2	5.6	21	NE	14	12			6	7
06	92	72	82	0	73	0	17	3	0	0.32	0.0	29.900	09	2.5	4.5	29	NE	22	07			7	9
07	91	71	81	-1	72	0	16	3	0	1.03	0.0	29.890	13	1.4	5.9	32	W	23	26			6	6
08	87	71	79	-3	73	0	14	1	0	0.03	0.0	29.855	20	1.9	6.4	16	SE	12	11			8	7
09	90	72	81	-1	73	0	16	3	0	0.32	0.0	29.900	21	3.7	5.8	22	S	14	21			7	5
10	91	74	83	1	74	0	18	3	0	0.10	0.0	29.940	22	7.2	8.0	23	W	16	25			9	7
11	88	71	80	-2	74	0	15	1 3	0	1.47	0.0	29.960	15	0.8	6.1	23	E	14	07			10	8
12	90	70	80	-2	72	0	15	1 3	0	0.00	0.0	30.010	07	5.4	6.7	17	E	12	08			6	4
13	91	74	83	1	73	0	18	1 3	0	T	0.0	30.050	07	7.3	8.8	22	NE	15	04			6	6
14	84	72	78	-3	72	0	13		0	0.00	0.0	30.025	07	5.5	7.6	18	SE	16	11			8	7
15	90	73	82	1	72	0	17		0	0.00	0.0	29.970	08	7.2	8.6	21	E	14	09			7	6
16	90	75	83	2	74	0	18		0	0.00	0.0	29.945	08	7.1	8.2	23	E	17	08			7	5
17	90	75	83	2	74	0	18		0	0.00	0.0	29.930	08	6.8	7.9	20	NE	15	08			8	6
18	92	75	84*	3	74	0	19		0	0.00	0.0	29.870	08	4.9	7.1	22	E	16	11			8	7
19	92	74	83	2	73	0	18		0	T	0.0	29.850	05	5.0	6.7	21	NE	14	07			4	2
20	90	73	82	1	73	0	17		0	T	0.0	29.910	07	7.2	8.1	22	E	15	10			5	3
21	91	73	82	1	72	0	17		0	0.00	0.0	29.970	07	5.0	6.7	20	E	12	08			3	5
22	92	72	82	2	71	0	17	1	0	0.00	0.0	29.990	03	3.7	6.1	16	W	10	07			3	3
23	93*	73	83	3	72	0	18	1	0	0.00	0.0	29.995	05	2.4	5.8	17	E	12	07			5	4
24	90	72	81	1	69	0	16	1 8	0	0.00	0.0	29.940	04	2.8	5.5	16	E	10	07			2	2
25	91	70	81	1	71	0	16		0	0.50	0.0	29.900	10	4.1	5.6	28	SE	21	14			4	3
26	91	72	82	2	72	0	17	3	0	0.63	0.0	29.910	15	4.3	6.8	35	SE	23	15			5	6
27	91	72	82	3	72	0	17		0	T	0.0	29.910	21	4.9	6.8	28	W	20	29			8	8
28	90	72	81	2	71	0	16	1	0	0.03	0.0	29.920	02	5.9	8.2	21	N	13	36			8	8
29	84	69	77	-2	62	0	12		0	0.00	0.0	29.960	36	10.2	10.7	23	N	15	02			9	8
30	84	66*	75*	-4	58	0	10		0	0.00	0.0	29.980	36	9.8	10.7	20	N	14	36			8	9
	SUM	SUM	—	—	—	TOTAL	TOTAL	NUMBER OF DAYS		TOTAL	TOTAL	FOR THE MONTH:								TOTAL	% FOR MONTH	SUM	SUM
	2701	2169	—	—	—	0	492			5.35	0.0	29.940	08	2.8	7.1	40	SW	23	15			190	169
	AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION		DEP.	—	—	—	—	—	DATE: 1		DATE: 26+		POSSIBLE		AVG.	AVG.
	90.0	72.3	81.2	0.2	71.7	0	12	≥ .01 INCH.	12	-0.66	—	—	—	—	—							6.3	5.6

NUMBER OF DAYS				SEASON TO DATE		SNOW, ICE PELLETS		GREATEST IN 24 HOURS AND DATES				GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE	
				TOTAL	TOTAL	≥ 1.0 INCH	0						
MAXIMUM TEMP.		MINIMUM TEMP.		0	2836	THUNDERSTORMS	10	PRECIPITATION		SNOW, ICE PELLETS			
≥ 90°	≤ 32°	≤ 32°	≤ 0°	DEP.	DEP.	HEAVY FOG	0	1.47	11	0.0		0	
25	0	0	0	0	-11	CLEAR 3	PARTLY CLOUDY 17	CLOUDY 10					

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS. COLS 16 & 17: PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED. ONE OF TWO WIND SPEEDS IS GIVEN UNDER COLS 18 & 19: FASTEST MILE - HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTION IN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES). ERRORS WILL BE CORRECTED IN SUBSEQUENT PUBLICATIONS.

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER

Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

noaa

NATIONAL
OCEANIC AND
ATMOSPHERIC ADMINISTRATION

NATIONAL
ENVIRONMENTAL SATELLITE, DATA
AND INFORMATION SERVICE

NATIONAL
CLIMATIC DATA CENTER
ASHEVILLE NORTH CAROLINA

OBSERVATIONS AT 3-HOUR INTERVALS

SEP 1993
ORLANDO, FL

12815

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
	SEP 1st											SEP 2nd											SEP 3rd										
01	3	UNL	7			75	74	73	94	16	5	0	UNL	10			74	73	73	97	10	3	0	UNL	10			74	73	73	97	07	3
04	5	UNL	7			74	73	72	94	15	4	0	UNL	7			73	73	73	100	00	0	5	UNL	8			74	73	73	97	17	3
07	2	UNL	8			75	74	73	94	12	9	6	UNL	10			75	74	73	94	10	4	8	25	7			76	75	74	94	20	3
10	4	UNL	10			84	78	75	75	13	9	7	250	10			85	77	74	70	12	10	4	UNL	10			85	77	73	67	10	8
13	8	41	8			87	78	74	65	10	10	8	250	7			83	77	75	77	06	10	7	250	10			89	77	71	55	22	3
16	7	250	10			91	77	71	52	15	11	7	250	10			87	77	73	63	15	12	8	250	10			89	78	73	59	12	11
19	6	250	10			77	74	73	88	14	6	8	UNL	10			81	75	72	74	12	7	6	UNL	10			83	75	72	70	11	8
22	3	UNL	10			76	73	72	88	23	5	0	UNL	10			78	75	73	85	14	6	1	UNL	7			79	76	75	88	10	6
	SEP 4th											SEP 5th											SEP 6th										
01	0	UNL	10			76	74	73	91	17	5	9	44	10			78	75	74	88	25	4	10	250	7			73	72	71	94	04	5
04	1	UNL	8			75	74	73	94	13	3	4	UNL	8			75	74	73	94	22	3	10	250	7			73	72	71	94	00	0
07	3	UNL	8			76	75	74	94	12	5	4	UNL	8			76	74	73	91	00	0	7	140	7			74	73	73	97	14	4
10	2	UNL	10			85	78	75	72	18	5	7	250	10			86	78	74	68	13	4	4	UNL	10			85	77	73	67	16	7
13	8	37	8		RW	87	77	72	61	23	8	4	UNL	10			90	77	71	54	24	5	7	37	10			90	78	73	58	11	4
16	6	49	10			89	77	72	57	32	4	7	250	10			84	77	74	72	27	7	10	95	7		TRW	73	72	72	97	06	4
19	8	48	10			85	77	73	67	06	4	10	65	10		T	74	71	69	85	12	7	10	90	10			76	75	74	94	34	4
22	3	UNL	10			82	75	72	72	32	5	10	250	7			75	74	73	94	31	4	10	250	10			77	76	75	94	00	0
	SEP 7th											SEP 8th											SEP 9th										
01	7	UNL	7			75	74	73	94	08	4	7	250	7			73	72	71	94	11	10	2	UNL	7			74	73	73	97	00	0
04	4	UNL	7			74	73	73	97	00	0	7	250	7			71	70	70	97	00	0	0	UNL	7			73	73	73	100	18	4
07	1	UNL	7			76	75	74	94	08	4	5	UNL	7			73	72	72	97	17	3	3	UNL	7			74	73	72	94	20	3
10	3	UNL	10			85	77	74	70	23	4	9	100	10			80	75	72	77	20	6	6	250	10			84	78	75	75	19	9
13	7	250	10			89	77	72	57	17	6	9	250	10			86	77	73	65	28	7	9	36	8			88	78	74	63	27	7
16	9	250	10			84	76	73	70	29	8	10	250	10			81	77	75	82	31	7	9	250	10			84	77	74	72	27	6
19	10	80	7		T	77	71	68	74	26	20	9	250	10			80	75	73	79	03	4	10	250	10		T	79	77	76	91	30	8
22	10	35	6		R	71	70	70	97	06	5	2	UNL	7			76	75	75	97	14	7	6	UNL	10			77	75	74	91	11	5
	SEP 10th											SEP 11th											SEP 12th										
01	7	250	7			75	74	73	94	21	4	8	UNL	7			75	74	74	97	23	4	1	UNL	6		F	72	72	72	100	14	3
04	4	UNL	7			74	73	73	97	20	7	9	250	7			74	74	74	100	19	4	2	UNL	4		F	70	70	70	100	03	4
07	8	250	8			75	74	74	97	19	7	10	110	7			76	75	75	97	22	5	7	80	5		F	71	71	71	100	07	5
10	8	250	10			86	78	75	70	25	12	9	250	10			85	79	76	75	33	6	5	UNL	10			83	75	71	67	08	7
13	9	36	7		T	83	75	72	70	25	14	9	250	7		T	84	80	78	82	36	5	4	UNL	10			87	75	70	57	03	7
16	10	250	10			78	75	74	88	23	6	10	21	1		TRW	76	73	71	85	09	12	5	UNL	10			87	77	72	61	11	8
19	10	250	10			78	75	74	88	20	5	9	250	7			73	72	71	94	13	3	8	250	10		T	81	76	73	77	09	8
22	3	UNL	10			77	75	74	91	23	4	2	UNL	7			73	72	72	97	11	4	2	UNL	7			77	75	74	91	05	6
	SEP 13th											SEP 14th											SEP 15th										
01	0	UNL	7			75	74	73	94	03	5	10	UNL	7			74	73	72	94	10	7	2	UNL	10			75	74	73	94	02	6
04	1	UNL	6		F	74	73	73	97	03	4	3	UNL	7			72	71	71	97	36	7	2	UNL	7			74	73	73	97	03	4
07	3	UNL	7			76	74	73	91	06	5	2	UNL	10			74	72	71	90	03	4	7	UNL	10			73	72	72	97	03	6
10	4	UNL	10			85	77	74	70	13	7	8	250	10			83	77	74	74	10	8	7	250	10			85	76	72	65	08	10
13	7	42	10			90	77	72	56	14	8	9	80	10			79	74	72	79	11	14	5	UNL	10			88	76	70	55	13	8
16	9	80	8		T	83	77	75	77	05	9	10	120	10			81	72	68	65	03	6	7	250	10			89	77	71	55	09	12
19	10	250	10			80	76	74	82	05	9	9	120	10			78	74	72	82	03	5	9	220	10			82	76	74	77	11	10
22	9	25	10			77	74	72	85	07	7	3	UNL	10			76	75	74	94	02	4	10	200	7			79	76	75	88	05	6
	SEP 16th											SEP 17th											SEP 18th										
01	5	UNL	7			77	76	75	94	04	5	0	UNL	7			76	75	75	97	04	4	10	250	10			76	75	74	94	06	5
04	1	UNL	7			76	75	74	94	06	6	0	UNL	7			75	75	75	100	01	4	5	UNL	7			75	75	75	100	35	4
07	6	UNL	10			75	73	72	90	08	7	8	250	10			76	75	75	97	04	6	10	250	10			76	75	75	97	01	6
10	7	120	10			85	77	73	67	16	6	10	250	10			84	78	75	75	15	7	8	250	10			84	78	75	75	09	6
13	8	250	10			89	78	73	59	12	8	9	250	10			90	77	72	56	10	8	7	250	10			88	76	71	57	36	4
16	7	250	10			87	77	73	63	07	9	5	UNL	10			88	77	72	59	07	10	7	250	10			86	78	75	70	09	12
19	5	UNL	10			82	77	75	79	08	7	6	250	10			81	75	72	74	11	8	5	UNL	10			82	76	73	74	10	9
22	0	UNL	10			78	76	75	91	07	6	6	250	10			79	76	74	85	07	6	5	UNL	10			78	75	74	88	11	6

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.50	0.75	0.98	1.14	1.26	1.43	1.46	1.47	1.47	1.47	1.47	1.47
ENDED: DATE	11	11	11	11	11	11	11	11	11	11	11	11
ENDED: TIME	1613	1613	1615	1618	1628	1643	1658	1708	1708	1708	1708	1708

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

SEP 1993
ORLANDO, FL

12815

			VISIBILITY			TEMPERATURE				WIND				VISIBILITY			TEMPERATURE				WIND				VISIBILITY			TEMPERATURE				WIND	
HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	WHOLE MILES	16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	DIRECTION	SPEED (KNOTS)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	WHOLE MILES	16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	DIRECTION	SPEED (KNOTS)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	WHOLE MILES	16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	DIRECTION	SPEED (KNOTS)
	SEP 19th											SEP 20th											SEP 21st										
01	1	UNL	7			75	74	74	97	32	3	0	UNL	7			75	74	73	94	01	3	2	UNL	7			75	74	73	94	05	5
04	0	UNL	7			75	75	75	100	30	4	3	UNL	7			74	73	73	97	03	5	2	UNL	7			74	73	73	97	07	4
07	0	UNL	7			76	75	75	97	33	4	0	UNL	7			76	75	74	94	34	3	0	UNL	7			76	74	73	91	05	3
10	2	UNL	10			85	77	74	70	20	3	6	25	10			85	77	74	70	06	7	6	25	8			85	77	74	70	09	8
13	5	UNL	10			90	77	71	54	04	7	8	37	10			88	78	74	63	08	9	4	UNL	10			91	78	73	56	12	6
16	5	UNL	10			87	77	72	61	06	10	6	95	10			86	76	72	63	09	12	4	UNL	8			89	77	71	55	10	9
19	3	UNL	10			81	75	72	74	07	7	4	UNL	10			81	76	73	77	07	7	9	250	7			82	74	70	67	07	8
22	0	UNL	7			78	75	73	85	10	5	2	UNL	10			77	75	74	91	07	7	10	85	7			79	74	72	79	32	3
	SEP 22nd											SEP 23rd											SEP 24th										
01	8	250	7			74	71	70	87	26	6	2	UNL	5		F	76	75	74	94	13	5	0	UNL	7			74	72	71	90	29	3
04	5	UNL	7			72	71	71	97	32	4	6	60	5		F	73	73	73	100	29	3	10	55	6		F	73	72	71	94	25	3
07	2	UNL	7			74	73	72	94	36	4	10	250	5		F	75	75	75	100	30	4	6	120	5		F	74	73	72	94	32	3
10	8	250	10			84	76	73	70	34	6	6	250	8			85	77	74	70	04	5	1	UNL	10			84	74	69	61	33	6
13	1	UNL	10			90	74	66	45	26	4	3	UNL	10			89	76	70	54	29	7	2	UNL	10			88	73	65	47	03	8
16	3	UNL	10			89	75	69	52	02	5	4	UNL	10			89	75	68	50	07	6	3	UNL	10			89	73	65	45	25	3
19	0	UNL	10			81	75	72	74	07	8	2	UNL	10			80	74	71	74	05	6	1	UNL	10			80	72	68	67	08	7
22	0	UNL	7			77	75	74	91	09	5	3	UNL	7			76	72	70	82	08	6	0	UNL	8			75	72	70	85	09	5
	SEP 25th											SEP 26th											SEP 27th										
01	0	UNL	7			73	70	69	87	07	3	3	UNL	10			74	73	72	94	11	6	5	UNL	7			72	71	71	97	15	4
04	2	UNL	7			71	70	69	93	00	0	8	120	10			72	71	71	97	20	3	5	UNL	7			73	72	72	97	17	5
07	0	UNL	7			73	71	70	90	04	4	2	UNL	10			73	72	72	97	15	4	7	250	10			73	72	72	97	18	5
10	3	UNL	10			84	75	71	65	09	7	6	120	10			83	77	74	74	16	9	7	250	10			84	78	75	75	22	9
13	4	UNL	10			89	76	70	54	11	4	5	UNL	10			89	78	73	59	17	10	8	110	10			88	77	73	61	20	8
16	9	55	5		RW	77	74	72	85	18	9	5	UNL	10			90	76	69	50	19	6	10	90	8		RW	80	73	69	69	29	6
19	7	250	10			73	71	70	90	04	4	9	80	7			73	73	73	100	03	5	10	90	10			78	75	74	88	13	8
22	0	UNL	10			74	72	71	90	11	5	10	140	7			73	72	71	94	08	7	10	250	10			76	74	73	91	27	3
	SEP 28th											SEP 29th											SEP 30th										
01	7	UNL	7			73	73	73	100	17	7	7	UNL	7			73	70	68	84	36	8	8	250	10			68	64	62	81	33	8
04	6	UNL	2		F	72	72	72	100	00	0	4	UNL	10			71	66	63	76	36	11	8	UNL	10			67	64	62	84	33	8
07	10	5	5		F	73	73	73	100	33	6	9	200	10			69	64	60	73	01	9	9	250	10			66	62	59	78	33	7
10	8	UNL	10			83	76	73	72	04	9	8	250	10			79	68	62	56	02	12	9	250	10			77	66	59	54	35	10
13	9	250	10			88	76	71	57	30	5	9	250	10			82	69	62	51	02	13	8	250	10			81	67	59	47	02	8
16	7	250	10			84	76	72	67	03	9	9	250	10			80	67	59	49	03	11	7	250	10			81	66	56	42	05	10
19	10	250	10			77	72	70	79	01	9	5	UNL	10			74	65	60	62	36	6	9	250	10			72	63	56	57	02	10
22	9	250	10			75	70	68	79	36	11	8	UNL	10			71	65	61	71	35	8	10	250	10			68	61	55	63	01	10

SUMMARY BY HOURS

	AVERAGES								RESULTANT WIND	
			TEMPERATURE							
HOUR L.S.T	SKY COVER (TENTHS)	STATION PRESSURE (INCHES)	AIR TEMP °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	WIND SPEED (MPH)	DIRECTION	SPEED (MPH)
01	4	29.940	74	73	72	93	5.5	08	1.8
04	4	29.920	73	72	72	96	4.3	36	0.9
07	5	29.950	74	73	72	93	5.4	05	1.7
10	6	29.970	84	76	73	69	8.5	11	3.0
13	7	29.940	87	76	71	59	8.6	10	1.7
16	7	29.900	85	75	71	65	9.6	08	4.2
19	7	29.920	79	74	71	79	8.3	07	4.3
22	5	29.960	76	73	72	87	6.4	07	3.5

WEATHER CODES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXP RESSED IN KNOTS (MPH=KNOTS X 1.15).

P&DF ASHEVILLE NC 288 11/24/93 19:1/

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HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

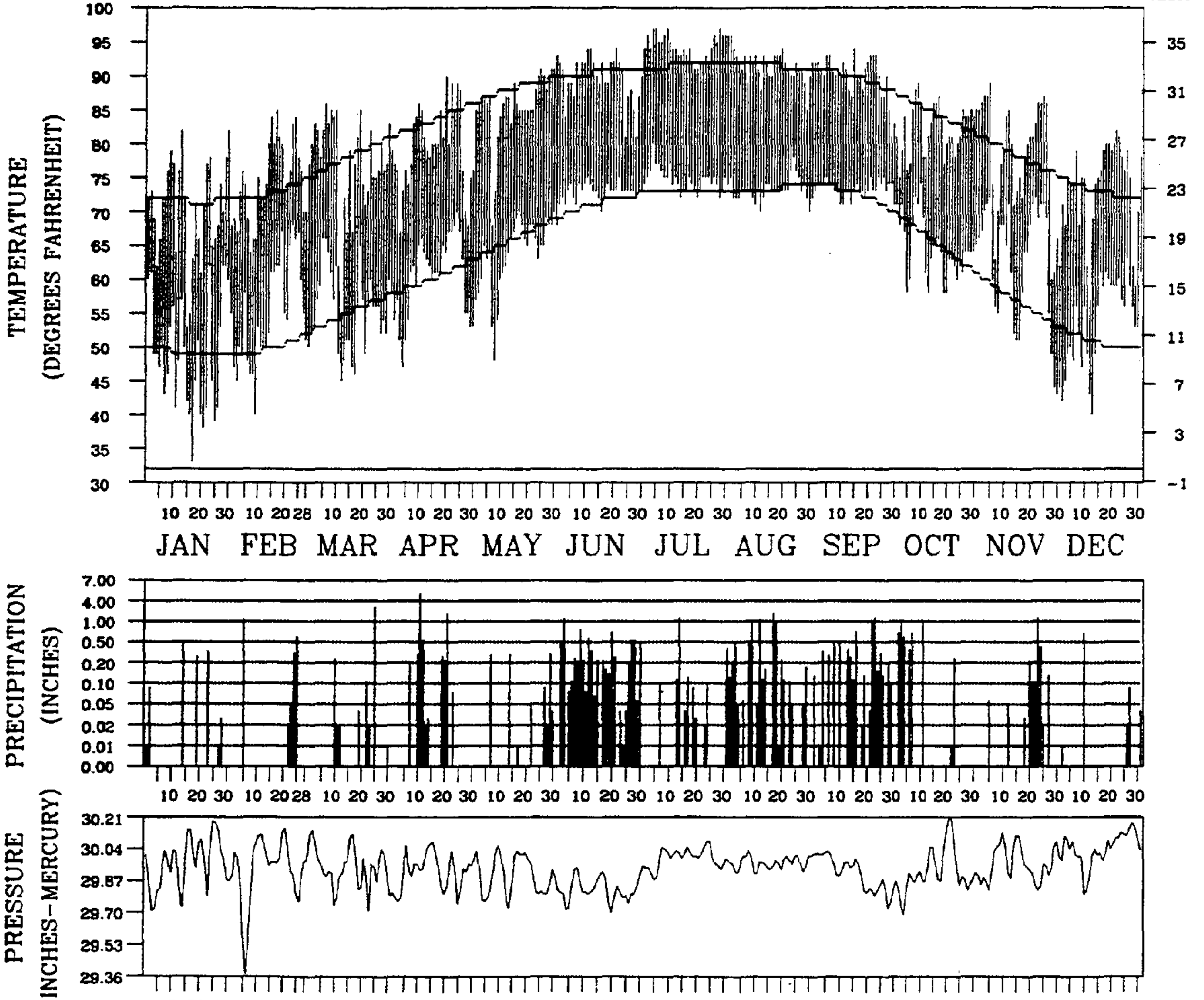
DATE	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												DATE
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
01																		0.80	0.02						01
02													0.05				T	T							02
03																									03
04													T	T											04
05																		T	T	T	0.04	0.01			05
06		T													0.08	0.22	0.01	0.01							06
07																	0.58	0.06		0.06	0.19	0.12	0.02		07
08																	0.03								08
09														0.31	T				0.01						09
10													0.01	0.09	T										10
11													T			0.75	0.72	T							11
12																									12
13															T	T									13
14																									14
15																									15
16																									16
17																									17
18																									18
19														T											19
20												T	T	T											20
21																									21
22																									22
23																									23
24																									24
25															T	0.47	0.03								25
26																	0.01	0.62	T						26
27																T	T								27
28																		0.03							28
29																									29
30																									30

ISSN 0198-1277

1992 LOCAL CLIMATOLOGICAL DATA
ANNUAL SUMMARY WITH COMPARATIVE DATA
ORLANDO, FLORIDA

DEPARTMENT OF COMMERCE UNITED STATES OF AMERICA

Daily Data



TEMPERATURE DEPICTS NORMAL MAXIMUM, NORMAL MINIMUM AND ACTUAL DAILY HIGH AND LOW VALUES (FAHRENHEIT)
PRECIPITATION IS MEASURED IN INCHES, SCALE IS NON-LINEAR
STATION PRESSURE IS MEASURED IN INCHES OF MERCURY

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER, ASHEVILLE, NORTH CAROLINA, 28801

Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

noaa
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE
NATIONAL CLIMATIC DATA CENTER ASHEVILLE NORTH CAROLINA

METEOROLOGICAL DATA FOR 1992

ORLANDO, FLORIDA

LATITUDE: 28°26' N LONGITUDE: 81°19' W ELEVATION: FT. GRND 96 BARO 94 TIME ZONE: EASTERN WBAN: 12815

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F:													
Averages													
-Daily Maximum	70.3	74.8	77.2	79.6	85.9	89.6	94.3	91.5	89.9	82.2	78.3	73.3	82.2
-Daily Minimum	49.0	54.8	55.5	60.2	63.8	72.8	74.6	73.1	73.3	64.5	62.4	53.6	63.1
-Monthly	59.7	64.8	66.4	69.9	74.9	81.2	84.5	82.3	81.6	73.4	70.4	63.5	72.7
-Monthly Dewpt.	48.5	54.1	53.5	58.2	62.3	73.0	73.2	73.3	73.2	64.2	61.7	55.6	62.6
Extremes													
-Highest	82	85	86	90	93	94	97	96	94	89	89	82	97
-Date	30	17	6	20	31	21	28	1	15	9	5	22	JUL 28
-Lowest	33	40	45	47	48	70	72	70	71	58	43	40	33
-Date	17	9	12	4	8	16	28	30	30	20	30	13	JAN 17
DEGREE DAYS BASE 65 °F:													
Heating	187	79	51	19	8	0	0	0	0	0	47	102	493
Cooling	28	79	101	175	325	496	612	540	507	265	217	62	3407
% OF POSSIBLE SUNSHINE													
AVG. SKY COVER (tenths)													
Sunrise - Sunset	6.8	7.2	6.0	6.3	4.8	7.8	4.2	7.5	7.2	5.9	7.6	6.6	6.5
Midnight - Midnight	6.4	7.1	5.9	5.8	4.5	7.1	3.9	7.4	6.6	5.4	7.1	5.9	6.1
NUMBER OF DAYS:													
Sunrise to Sunset													
-Clear	4	4	11	5	8	0	13	0	1	8	3	6	63
-Partly Cloudy	11	9	3	15	17	13	13	14	16	10	6	9	136
-Cloudy	16	16	17	10	6	17	5	17	13	13	21	16	167
Precipitation .01 inches or more	7	5	8	10	8	26	10	20	20	8	10	5	137
Snow, Ice pellets, hail 1.0 inches or more	0	0	0	0	0	0	0	0	0	0	0	0	0
Thunderstorms	2	4	2	7	5	19	14	26	17	2	5	0	103
Heavy Fog, visibility 1/4 mile or less	1	3	2	2	0	0	0	2	1	3	0	4	18
Temperature °F													
-Maximum													
90° and above	0	0	0	1	7	17	31	27	22	0	0	0	105
32° and below	0	0	0	0	0	0	0	0	0	0	0	0	0
-Minimum													
32° and below	0	0	0	0	0	0	0	0	0	0	0	0	0
0° and below	0	0	0	0	0	0	0	0	0	0	0	0	0
AVG. STATION PRESS. (mb)	1014.6	1013.5	1013.9	1013.2	1012.5	1009.8	1015.6	1014.7	1012.9	1013.2	1014.6	1017.3	1013.9
RELATIVE HUMIDITY (%)													
Hour 01	83	86	83	88	89	94	90	94	95	91	87	90	89
Hour 07 (Local Time)	85	92	86	86	90	94	91	95	95	92	89	92	91
Hour 13	54	54	47	53	46	67	53	62	65	58	63	62	57
Hour 19	66	66	57	68	61	80	67	84	84	77	76	78	72
PRECIPITATION (inches):													
Water Equivalent													
-Total	1.35	2.42	3.67	9.10	1.19	8.68	2.60	8.03	7.13	5.17	2.74	0.88	52.96
-Greatest (24 hrs)	0.54	1.36	3.19	5.65	0.33	1.48	1.55	3.07	2.57	1.82	1.57	0.72	5.65
-Date	14	5- 6	25-26	11-12	29	3	14	17-18	22-23	2- 3	23	10	APR 11-12
Snow, Ice pellets, hail													
-Total	0.0	0.0	T	T	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	T
-Greatest (24 hrs)	0.0	0.0	T	T	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	T
-Date			25	10									APR 10
WIND:													
Resultant													
-Direction (!!!)	305	267	260	039	357	187	192	141	049	011	061	360	015
-Speed (mph)	3.0	1.8	1.9	2.1	0.8	4.5	2.3	2.7	3.3	3.2	2.6	2.8	0.4
Average Speed (mph)	9.8	9.8	9.9	9.6	8.7	8.9	7.2	7.5	6.3	8.1	10.2	7.9	8.7
Fastest Obs. 1 Min.													
-Direction (!!!)	24	27	30	16	04	15	18	03	21	23	21	28	27
-Speed (mph)	29	35	33	32	20	25	22	25	23	22	32	28	35
-Date	23	5	25	10	22	25	23	18	23	4	23	10	FEB 5
Peak Gust													
-Direction (!!!)	SW	W	NW	E	SW	E	NE	S	SE	NE	SW	W	E
-Speed (mph)	45	43	53	53	31	37	39	38	35	31	32	35	53
-Date	23	5	25	10	30	12	14	3	4	20	23	10	APR 10

(!!!) See Reference Notes on Page 68

NORMALS, MEANS, AND EXTREMES

ORLANDO, FLORIDA

LATITUDE: 28°26'N LONGITUDE: 81°19'W ELEVATION: FT. GRND 96 BARO 94 TIME ZONE: EASTERN WBAN: 12815

	(a)	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F:														
Normals														
-Daily Maximum		71.7	72.9	78.3	83.6	88.3	90.6	91.7	91.6	89.7	84.4	78.2	73.1	82.8
-Daily Minimum		49.3	50.0	55.3	60.3	66.2	71.2	73.0	73.4	72.5	65.4	56.8	50.9	62.0
-Monthly		60.5	61.5	66.8	72.0	77.3	80.9	82.4	82.5	81.1	74.9	67.5	62.0	72.4
Extremes														
-Record Highest	50	87	90	92	96	102	100	100	100	98	95	89	90	102
-Year		1991	1962	1970	1968	1945	1985	1961	1980	1988	1986	1992	1978	MAY 1945
-Record Lowest	50	19	28	25	38	48	53	64	64	56	43	29	20	19
-Year		1985	1970	1980	1987	1992	1984	1981	1957	1956	1957	1950	1983	JAN 1985
NORMAL DEGREE DAYS:														
Heating (base 65°F)		212	172	68	0	0	0	0	0	0	0	47	157	656
Cooling (base 65°F)		73	74	124	214	381	477	539	543	483	307	122	64	3401
% OF POSSIBLE SUNSHINE														
MEAN SKY COVER (tenths)														
Sunrise - Sunset	44	5.7	5.7	5.6	5.1	5.4	6.4	6.4	6.4	6.5	5.5	5.2	5.7	5.8
MEAN NUMBER OF DAYS:														
Sunrise to Sunset														
-Clear	44	9.1	8.7	9.3	10.3	8.8	4.2	3.4	3.1	3.8	9.6	10.3	9.8	90.4
-Partly Cloudy	44	10.3	8.6	10.4	11.3	13.5	14.3	16.7	17.1	14.6	11.3	10.2	9.3	147.5
-Cloudy	44	11.5	11.0	11.3	8.4	8.7	11.5	10.9	10.8	11.6	10.1	9.5	12.0	127.3
Precipitation .01 inches or more	50	6.2	7.0	7.6	5.6	8.6	14.0	17.1	16.0	13.6	8.5	5.7	5.9	115.7
Snow,Ice pellets,hail 1.0 inches or more	50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thunderstorms	48	1.0	1.5	2.9	3.4	7.7	14.6	19.2	17.5	9.6	2.5	1.2	1.0	82.2
Heavy Fog Visibility 1/4 mile or less	44	5.5	3.3	2.5	1.4	1.5	0.8	0.5	0.9	1.2	1.7	2.7	4.4	26.4
Temperature °F														
-Maximum														
90° and above	29	0.0	0.0	0.4	4.0	11.0	19.6	25.1	25.6	18.5	3.5	0.0	0.*	107.7
32° and below	29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-Minimum														
32° and below	29	1.6	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	2.9
0° and below	29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AVG. STATION PRESS.(mb)	20	1016.6	1015.8	1014.3	1013.7	1012.4	1012.9	1014.5	1013.8	1012.5	1013.5	1015.2	1016.9	1014.3
RELATIVE HUMIDITY (%)														
Hour 01 (Local Time)	28	85	83	84	84	86	89	90	91	90	87	87	87	87
Hour 07	29	88	87	88	88	88	89	90	92	92	89	89	88	89
Hour 13	29	56	52	50	47	49	57	59	60	60	56	56	57	55
Hour 19	29	68	63	61	58	63	72	75	77	77	74	73	73	70
PRECIPITATION (inches):														
Water Equivalent														
-Normal		2.10	2.83	3.20	2.19	3.96	7.39	7.78	6.32	5.62	2.82	1.78	1.83	47.82
-Maximum Monthly	50	7.23	8.32	11.38	9.10	10.36	18.28	19.57	16.11	15.87	14.51	10.29	5.33	19.57
-Year		1986	1983	1987	1992	1976	1968	1960	1972	1945	1950	1987	1983	JUL 1960
-Minimum Monthly	50	0.15	0.10	0.16	0.14	0.43	1.97	2.60	2.92	0.43	0.35	0.03	T	T
-Year		1950	1944	1956	1977	1961	1948	1992	1980	1972	1967	1967	1944	DEC 1944
-Maximum in 24 hrs	50	4.19	4.38	5.03	5.65	3.18	8.40	8.19	5.29	9.67	7.74	5.87	3.61	9.67
-Year		1986	1970	1960	1992	1980	1945	1960	1949	1945	1950	1988	1969	SEP 1945
Snow,Ice pellets,hail														
-Maximum Monthly	20	T	0.0	T	T	0.0	0.0	T	T	0.0	0.0	0.0	0.0	T
-Year		1977		1992	1992			1991	1989					MAR 1992
-Maximum in 24 hrs	20	T	0.0	T	T	0.0	0.0	T	T	0.0	0.0	0.0	0.0	T
-Year		1977		1992	1992			1991	1989					MAR 1992
WIND:														
Mean Speed (mph)	44	9.0	9.6	9.9	9.4	8.8	8.0	7.4	7.2	7.6	8.6	8.7	8.6	8.5
Prevailing Direction through 1963		NNE	S	S	SE	SE	SW	S	S	ENE	N	N	NNE	S
Fastest Obs. 1 Min.														
-Direction (!!)	43	25	25	29	02	17	32	14	32	24	05	26	07	32
-Speed (MPH)	43	42	46	45	50	46	64	46	50	46	48	46	32	64
-Year		1953	1969	1955	1956	1981	1970	1961	1957	1969	1950	1968	1968	JUN 1970
Peak Gust														
-Direction (!!)	9	NW	W	SW	E	S	W	W	SW	NW	W	NE	W	W
-Speed (mph)	9	48	51	56	53	68	62	68	58	54	40	41	43	68
-Date		1991	1991	1991	1992	1991	1985	1991	1991	1988	1990	1984	1984	JUL 1991

(!!) See Reference Notes on Page 6B.

PRECIPITATION (inches)

ORLANDO, FLORIDA

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1963	3.17	4.76	2.69	1.23	3.56	6.67	3.83	3.54	6.72	0.46	6.39	2.26	45.28
1964	6.18	3.42	4.65	2.14	2.74	6.11	6.68	9.00	9.47	1.64	0.45	1.91	54.39
1965	1.79	3.67	3.02	0.66	0.52	7.36	11.55	5.49	5.99	4.06	1.06	2.23	47.40
1966	4.45	6.31	2.57	1.92	6.57	9.77	6.73	7.76	6.25	1.98	0.09	0.99	55.39
1967	0.84	5.49	1.31	0.28	1.69	11.16	4.63	6.83	5.88	0.35	0.03	2.42	40.91
1968	0.65	2.76	2.27	0.30	3.72	18.28	5.60	3.44	5.91	5.47	2.82	0.88	52.10
1969	2.22	3.30	5.52	2.38	1.40	5.04	6.73	7.17	6.44	9.45	0.87	4.66	55.18
1970	4.05	6.77	3.66	0.45	4.08	4.92	5.97	5.91	3.25	2.60	0.24	2.06	43.96
1971	0.45	2.98	1.46	1.52	4.31	4.39	8.29	7.51	2.98	3.06	1.21	1.93	40.09
1972	0.99	4.96	5.06	1.39	3.76	6.33	3.98	16.11	0.43	2.34	4.11	1.89	51.35
1973	4.82	2.73	4.13	2.82	4.74	6.63	6.24	7.33	11.53	1.10	0.74	2.56	55.37
#1974	0.18	0.63	3.67	1.17	2.69	15.28	6.01	6.56	5.78	0.48	0.31	1.62	44.38
1975	0.98	1.49	1.10	1.36	7.52	9.70	9.26	4.75	4.97	4.74	0.66	0.51	47.04
1976	0.37	0.83	1.72	2.16	10.36	9.93	7.05	3.25	5.87	0.74	2.03	2.77	47.08
1977	1.81	1.76	1.82	0.14	1.47	4.47	6.61	6.28	7.03	0.43	2.60	3.70	38.12
1978	2.49	5.45	2.14	0.61	3.16	10.00	11.92	5.13	4.31	1.51	0.18	3.69	50.59
1979	6.48	1.45	3.24	1.08	7.66	4.00	7.95	5.88	9.19	0.43	1.93	0.94	50.23
1980	2.45	1.64	1.51	4.07	6.96	5.25	5.14	2.92	3.70	0.55	6.55	0.47	41.21
1981	0.21	4.36	1.85	0.18	2.02	12.49	3.53	5.60	8.26	3.13	2.50	2.97	47.10
1982	1.72	1.34	4.85	6.27	5.29	6.06	11.81	5.03	6.96	0.74	0.53	1.01	51.61
1983	2.08	8.32	5.37	3.21	1.77	7.82	6.49	4.83	5.16	3.78	1.36	5.33	55.52
1984	2.01	2.73	1.85	6.21	3.20	5.32	6.19	7.89	6.19	0.56	2.10	0.19	44.44
1985	0.91	1.27	4.59	1.69	3.00	4.54	7.28	11.63	5.45	2.55	0.82	3.46	47.19
1986	7.23	1.84	2.63	0.49	0.88	9.50	5.85	5.99	4.50	5.63	1.69	3.60	49.83
1987	1.27	1.74	11.38	0.59	1.40	3.54	7.95	6.07	8.64	3.41	10.29	0.51	56.79
1988	3.12	1.38	6.07	2.02	2.82	4.17	9.44	7.94	5.67	1.42	7.44	1.00	52.49
1989	3.80	0.15	1.35	2.28	2.38	6.79	4.74	6.20	10.29	1.75	1.44	4.49	45.66
1990	0.23	4.13	1.92	1.73	0.55	6.22	6.68	3.78	2.46	2.10	1.05	0.83	31.68
1991	2.37	0.98	6.66	7.72	9.48	5.98	10.78	7.13	4.53	4.76	0.27	0.24	60.90
1992	1.35	2.42	3.67	9.10	1.19	8.68	2.60	8.03	7.13	5.17	2.74	0.88	52.96
Record Mean	2.17	2.72	3.47	2.63	3.42	7.03	7.86	6.69	6.76	3.34	1.91	1.93	49.94

See Reference Notes on Page 6B.
Page 4A

AVERAGE TEMPERATURE (deg. F)

ORLANDO, FLORIDA

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
#1963	59.5	57.2	69.5	73.6	77.9	82.4	82.9	83.9	80.5	73.8	65.4	56.5	71.9
1964	58.5	58.3	68.1	74.1	77.1	82.4	81.6	82.8	79.8	72.5	70.5	64.4	72.5
1965	60.0	64.1	67.0	74.8	77.1	79.0	80.5	82.2	80.8	74.2	69.5	62.6	72.7
1966	58.7	62.3	64.4	70.5	77.4	78.0	82.3	82.3	80.1	75.8	65.8	60.1	71.5
1967	63.2	60.0	68.3	74.3	78.3	80.2	82.4	82.0	79.7	74.0	67.5	65.9	73.0
1968	59.6	54.8	61.4	73.5	76.7	78.8	81.3	82.3	80.3	74.3	63.4	58.7	70.4
1969	59.8	57.8	60.4	72.5	76.9	82.9	84.4	82.2	81.2	77.9	64.0	58.7	71.6
1970	55.1	58.7	67.0	75.8	77.7	81.8	83.8	82.3	83.6	77.0	63.4	64.6	72.6
1971	62.0	64.1	64.8	72.1	78.2	81.7	83.1	83.3	81.8	79.0	69.5	71.4	74.2
1972	68.9	62.0	68.7	72.7	77.4	82.2	83.2	82.8	81.8	76.8	68.9	66.1	74.3
1973	62.4	59.7	71.1	71.1	78.3	83.1	84.2	81.8	81.4	75.6	70.9	60.4	73.3
#1974	71.6	60.5	70.2	71.4	78.0	80.3	80.7	82.0	81.8	72.6	67.6	60.9	73.1
1975	65.8	67.6	67.4	72.4	79.1	80.8	80.5	82.3	80.7	76.6	67.4	60.2	73.4
1976	56.5	63.7	70.4	71.3	76.8	79.7	82.4	81.9	80.5	72.6	63.0	60.1	71.6
1977	50.6	57.4	69.7	70.6	75.2	82.6	82.0	81.5	82.6	72.9	69.6	61.0	71.3
1978	56.8	55.8	66.3	73.4	79.3	82.9	82.6	82.6	81.7	75.0	72.3	66.8	73.0
1979	58.2	58.4	64.6	73.4	75.4	80.7	83.3	82.4	81.3	74.4	68.3	62.6	71.9
1980	60.5	57.2	68.2	70.4	76.4	80.1	83.6	83.6	81.7	75.4	67.1	59.0	71.9
1981	51.3	61.7	64.0	73.1	76.7	83.2	84.1	82.9	80.0	76.4	65.3	60.5	71.6
1982	60.0	68.4	70.4	72.6	75.3	82.0	82.6	82.2	80.2	74.1	70.8	66.7	73.8
1983	58.0	59.9	63.5	68.6	76.4	80.5	83.2	83.5	80.6	76.5	65.8	61.2	71.5
1984	57.8	61.2	64.7	69.2	75.6	78.4	80.7	81.5	78.9	75.4	65.8	66.0	71.3
1985	54.7	62.2	68.4	70.7	77.2	82.4	82.1	82.3	79.8	79.4	73.0	58.8	72.6
1986	59.8	64.3	65.4	69.3	76.7	81.7	82.3	83.3	81.7	77.5	75.8	67.3	73.8
1987	58.8	62.7	65.9	66.8	76.8	83.1	83.5	85.0	82.7	72.2	69.0	64.2	72.6
1988	58.5	60.4	65.5	72.0	75.5	80.3	80.7	82.8	83.9	73.7	70.5	62.4	72.2
1989	66.9	64.5	69.7	71.9	77.9	81.9	83.2	83.3	82.2	75.3	69.0	55.5	73.4
1990	65.8	69.1	69.3	71.5	79.4	81.9	82.8	83.5	82.0	77.1	69.3	66.3	74.8
1991	66.3	64.2	67.7	75.3	79.5	81.1	82.6	83.0	81.7	75.3	65.8	65.5	74.0
1992	59.7	64.8	66.4	69.9	74.9	81.2	84.5	82.3	81.6	73.4	70.4	63.5	72.7
Record													
Mean	60.5	62.2	66.8	71.8	77.3	81.2	82.4	82.6	81.0	74.8	67.6	62.2	72.6
Max	71.5	73.4	78.1	83.2	88.2	90.9	91.8	91.6	89.6	84.1	77.9	72.9	82.8
Min	49.4	50.9	55.6	60.4	66.3	71.5	73.0	73.5	72.4	65.6	57.3	51.4	62.3

See Reference Notes on Page 6B.
Page 4B

HEATING DEGREE DAYS Base 65 deg. F ORLANDO, FLORIDA

SEASON	JULY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	TOTAL
#1963-64	0	0	0	3	72	272	235	199	39	4	0	0	824
1964-65	0	0	0	7	14	84	178	89	82	0	0	0	454
1965-66	0	0	0	1	19	112	215	122	72	5	0	0	546
1966-67	0	0	0	2	70	169	119	157	25	0	0	0	542
1967-68	0	0	0	0	29	80	191	293	149	0	0	0	742
1968-69	0	0	0	19	120	237	168	206	169	0	0	0	919
1969-70	0	0	0	0	93	204	316	187	58	0	0	0	858
1970-71	0	0	0	0	120	79	165	115	92	20	0	0	591
1971-72	0	0	0	0	26	9	51	124	24	6	0	0	240
1972-73	0	0	0	0	54	105	160	169	12	9	0	0	509
#1973-74	0	0	0	6	13	193	0	173	15	8	0	0	408
1974-75	0	0	0	0	40	163	73	44	57	10	0	0	387
1975-76	0	0	0	0	85	174	278	104	18	1	0	0	660
1976-77	0	0	0	4	118	197	440	218	41	8	0	0	1026
1977-78	0	0	0	6	38	179	275	255	71	0	0	0	824
1978-79	0	0	0	0	0	56	230	214	71	0	0	0	571
1979-80	0	0	0	0	47	119	161	245	61	4	0	0	637
1980-81	0	0	0	1	67	190	416	119	76	1	0	0	870
1981-82	0	0	0	0	75	205	204	21	33	7	0	0	545
1982-83	0	0	0	14	16	94	233	148	105	13	0	0	623
1983-84	0	0	0	0	63	188	252	137	86	18	0	0	744
1984-85	0	0	0	0	68	71	340	146	22	12	0	0	659
1985-86	0	0	0	0	14	228	180	82	105	4	0	0	613
1986-87	0	0	0	0	0	42	216	97	48	66	0	0	469
1987-88	0	0	0	0	39	97	221	169	71	7	0	0	604
1988-89	0	0	0	0	11	135	32	119	59	4	0	0	360
1989-90	0	0	0	21	27	308	71	34	11	5	0	0	477
1990-91	0	0	0	6	14	69	75	88	52	0	0	0	304
1991-92	0	0	0	0	85	76	187	79	51	19	8	0	505
1992-93	0	0	0	0	47	102							

See Reference Notes on Page 6B
Page 5A

COOLING DEGREE DAYS Base 65 deg. F ORLANDO, FLORIDA

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	TOTAL
1969	12	10	32	232	376	544	608	540	495	406	68	16	3339
1970	19	14	128	330	399	511	586	544	565	380	77	72	3625
1971	77	97	90	238	411	505	569	573	510	440	167	214	3891
1972	181	44	146	243	391	524	570	561	509	374	179	148	3870
1973	88	28	207	198	421	548	602	529	501	341	199	58	3720
#1974	213	51	183	207	410	463	492	536	510	241	125	43	3474
1975	105	121	141	237	442	481	489	541	479	366	167	32	3601
1976	18	75	194	196	374	449	549	529	474	247	65	49	3219
1977	1	13	192	182	324	534	537	521	536	257	185	62	3344
1978	26	3	116	259	449	541	550	553	508	321	225	115	3666
1979	26	31	65	260	330	479	575	546	498	299	153	53	3315
1980	27	25	169	172	362	459	586	582	508	331	138	12	3371
1981	0	34	52	253	372	552	602	559	458	359	89	73	3403
1982	56	123	211	241	325	518	550	542	465	303	196	152	3682
1983	22	11	68	129	361	473	573	582	476	362	95	77	3229
1984	37	35	84	151	332	411	490	520	426	331	99	107	3023
1985	27	74	137	191	386	531	539	548	451	454	262	45	3645
1986	25	69	124	139	372	506	543	573	507	392	333	121	3704
1987	32	38	82	127	376	549	582	627	540	230	163	78	3424
1988	26	43	95	223	336	466	496	559	573	275	182	61	3335
1989	101	111	213	216	408	509	573	579	523	346	153	19	3751
1990	102	156	156	206	453	514	559	581	518	388	149	116	3898
1991	121	71	143	315	455	490	553	565	508	326	118	98	3763
1992	28	79	101	175	325	496	612	540	507	265	217	62	3407

See Reference Notes on Page 6B.
Page 5B

SNOWFALL (inches)

ORLANDO, FLORIDA

SEASON	JULY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	TOTAL
1970-71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1971-72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1972-73	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
#1973-74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1974-75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1975-76	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1976-77	0.0	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	0.0	0.0	T
1977-78	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978-79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979-80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980-81	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981-82	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982-83	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983-84	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984-85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1985-86	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986-87	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987-88	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1988-89	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1989-90	0.0	T	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	T
1990-91	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991-92	T	0.0	0.0	0.0	0.0	0.0	0.0	0.0	T	T	0.0	0.0	T
1992-93	0.0	0.0	0.0	0.0	0.0	0.0							
Record Mean	T	T	0.0	0.0	0.0	0.0	T	0.0	T	T	0.0	0.0	T

See Reference Notes on Page 6B.

REFERENCE NOTES

ORLANDO, FLORIDA

GENERAL
T - TRACE AMOUNT.
BLANK ENTRIES DENOTE MISSING/UNREPORTED DATA.
# INDICATES A STATION OR INSTRUMENT RELOCATION.
SEE STATION LOCATION TABLE ON PAGE 8.

SPECIFIC
PAGE 2
PM - INCLUDES LAST DAY OF PREVIOUS MONTH
ASOS - AUTOMATED SURFACE OBSERVING SYSTEM IN
OPERATION DURING THESE MONTHS.

PAGE 3
(a) - LENGTH OF RECORD IN YEARS, ALTHOUGH
INDIVIDUAL MONTHS MAY BE MISSING.
0.* OR * - THE VALUE IS BETWEEN 0.0 AND 0.05
NORMALS - BASED ON THE 1951-1980 RECORD PERIOD.
EXTREMES - DATES ARE THE MOST RECENT OCCURRENCE
WIND DIR.- NUMERALS SHOW TENS OF DEGRESS CLOCKWISE
FROM TRUE NORTH. "00" INDICATES CALM.
RESULTANT DIRECTIONS ARE GIVEN TO WHOLE DEGREES.
**BOLD VALUES INDICATE EXTREME VALUES WHICH OCCURRED
AFTER THE ASOS SYSTEM WAS COMMISSIONED.**

PAGE 4B
RECORD = PERIOD OF RECORD
RECORD MEAN PRECIPITATION IS THE MEAN OF ALL DAILY
PRECIPITATION AMOUNTS DURING THE PERIOD OF RECORD.
RECORD MAX(MIN) TEMPERATURE IS THE MEAN OF ALL DAILY
MAX(MIN) TEMPERATURES DURING THE PERIOD OF RECORD.
RECORD MEAN TEMPERATURE IS THE SUM OF THE RECORD
MAX AND RECORD MIN DIVIDED BY 2.
AVERAGE TEMPERATURE IS THE SUM OF THE MEAN DAILY
MAX AND MIN TEMPERATURE DIVIDED BY 2.

EXCEPTIONS

PAGES 4A, 4B, 6A
RECORD MEANS ARE THROUGH THE CURRENT YEAR,
BEGINNING IN 1943 FOR TEMPERATURE
1943 FOR PRECIPITATION
1943 FOR SNOWFALL

ORLANDO, FLORIDA

Orlando is located in the central section of the Florida peninsula, surrounded by many lakes. Relative humidities remain high the year-round, with values near 90 percent at night and 40 to 50 percent in the afternoon. On some winter days, the humidity may drop to 20 percent.

The rainy season extends from June through September, sometimes through October when tropical storms are near. During this period, scattered afternoon thunderstorms are an almost daily occurrence, and these bring a drop in temperature to make the climate bearable. Summer temperatures above 95 degrees are rather rare. There is usually a breeze which contributes to the general comfort.

During the winter months rainfall is light. While temperatures, on infrequent occasion, may drop at night to near freezing, they rise rapidly during the day and, in brilliant sunshine, afternoons are pleasant.

Frozen precipitation in the form of snowflakes, snow pellets, or sleet is rare. However, hail is occasionally reported during thunderstorms.

Hurricanes are usually not considered a great threat to Orlando, since, to reach this area, they must pass over a substantial stretch of land and, in so doing, lose much of their punch. Sustained hurricane winds of 75 mph or higher rarely occur. Orlando, being inland, is relatively safe from high water, although heavy rains sometimes briefly flood sections of the city.

STATION LOCATION

* Type

N = AMOS
T = AUTOB
S = ASOS
W = AWOS

LOCATION	OCCUPIED FROM	OCCUPIED TO	AIRLINE DISTANCES AND DIRECTIONS FROM PREVIOUS LOCATION	LATITUDE NORTH	LONGITUDE WEST	ELEVATION ABOVE SEA LEVEL: GROUND TEMPERATURE SITE	ELEVATION ABOVE GROUND: WIND INSTRUMENTS	EXTREME THERMOMETERS	PSYCHROMETER	SUNSHINE SWITCH	TIPPING BUCKET RAIN GAGE	WEIGHING RAIN GAGE	8 INCH RAIN GAGE	HYGROTHERMOMETER	AUTOMATIC OBSERVING EQUIPMENT *	REMARKS
COOPERATIVE - - NOTE: For period January 1892 through July 13, 1916, refer to previous editions.																
319 N. Orange Avenue	8/01/16	6/20/21	300 ft. N	28°33'	81°22'	107		4					3			
1022 South Hughey	6/21/21	6/15/25	1.3 mi.SSW	28°32'	81°23'	106		5					4			
946 Bradshaw Terrace	6/16/25	10/21/28	2000 ft. E	28°32'	81°23'	80		5					4			
117 Annie Street	10/22/28	11/11/31	400 ft. S	28°32'	81°23'	80		4					2			
Fern Creek and Harding Avenue	11/11/31	5/1934	1 mi. S	28°31'	81°22'	95		4					3			
1537 Clay Street Winter Park	5/1934	9/16/36	3.75 mi. NNW	28°35'	81°22'	93										
933 Bradshaw Terrace	9/17/36	12/1942	3 mi. S	28°32'	81°23'	80		5					3			
AIRPORT Terminal Building Municipal Airport 2 miles east of Post Office	1/01/43	1/03/51	2.6 mi. NE	28°33'	81°20'	106	a40	4	4			3	3			Observations were commenced at the airport by an airway observer on 4/1/29 and at a later date taken over by CAA. Weather Bureau effective 2/15/44. a - 44 feet to 9/10/47.
Administration Building Herndon Airport *	1/03/51	1/31/74	400 ft.WNW	28°33'	81°20'	g108	a20	b16	c16			d13	e13	f4		* Name adopted 3/18/61. a - 41 feet to 2/16/51 and 53 feet to 1/9/60. b - 6 feet to 4/6/60 and 18 feet to 12/1/63. c - 5 feet to 4/6/60 and 17 feet to 12/1/63. d - 3 feet to 3/11/52; 4 feet to 4/6/60 and 14 feet to 12/1/63. e - 3 feet to 4/6/60 and 14 feet to 12/1/63. f - Commissioned 12/1/63 on field 1700 feet east of thermometer. g - 106 feet to 12/1/63.
Weather Service Office Orlando Jetport + at McCoy + International Airport eff. 11/26/76	1/31/74	9/19/84	8 mi. S	28°26'	81°19'	96	12 j20	NA i5	NA h5 n5	NA	NA k3 n3	NA h3 n3	16 h3 n3	NA A10 m4	NA	A - AN/TMQ-11 on field site. h - Effective 5/7/74. i - Effective 7/26/74. j - Effective 5/20/74. k - Added 3/18/76. m - Hygrothermometer commissioned 3/25/76. n - Relocated 7/22/77.
Weather Service Bldg. Orlando International Airport	9/19/84	Present	Unknown	28°26'	81°19'	96	33	NA	6	NA	5	5	5	6 p6	NA	Moved from 9501 Benford Road to 5390 Bear Road p - Type change 5/30/85

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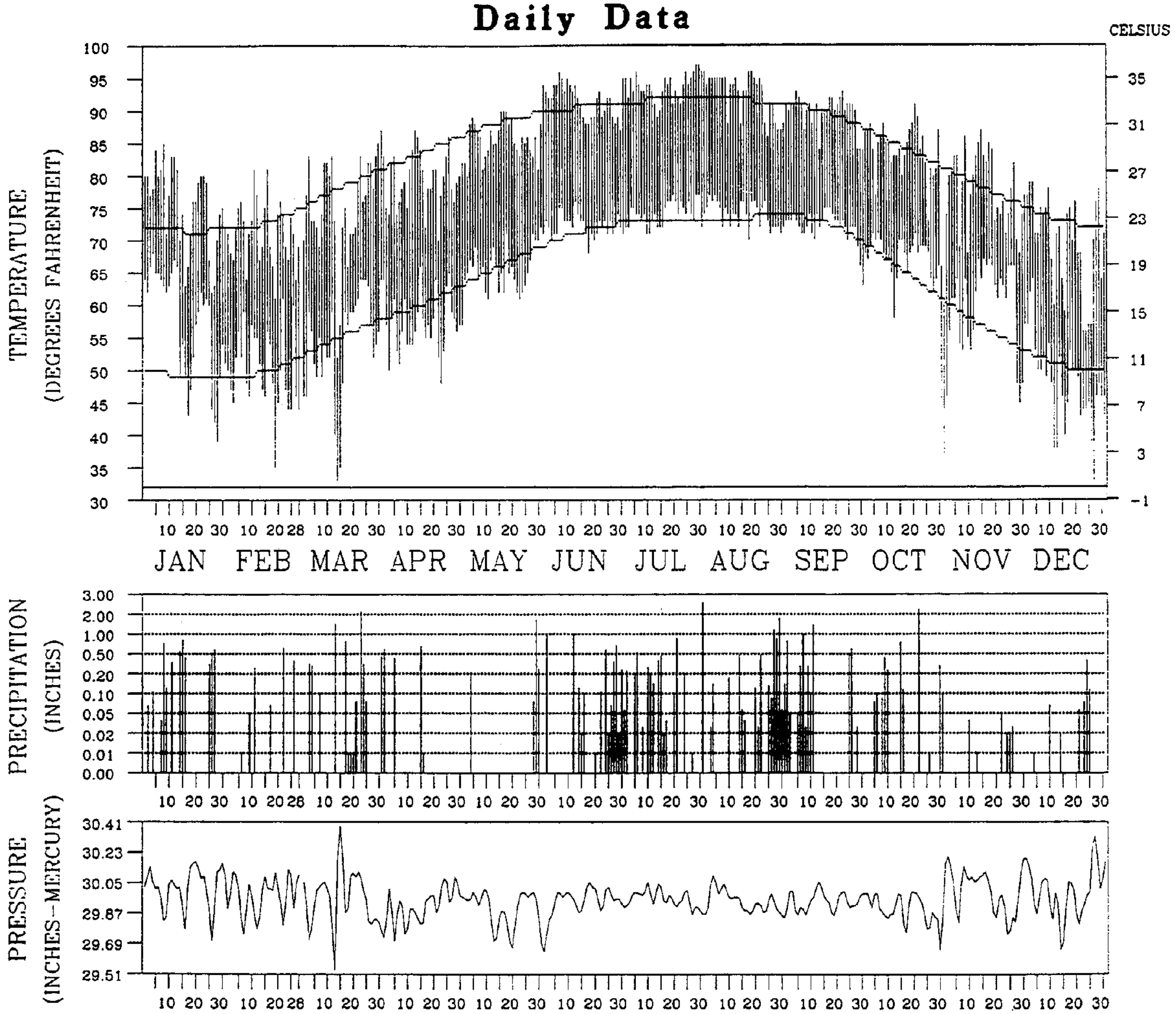
ISSN 0198-1277

1993 LOCAL CLIMATOLOGICAL DATA
ANNUAL SUMMARY WITH COMPARATIVE DATA
ORLANDO,
FLORIDA

DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA

Daily Data



TEMPERATURE DEPICTS NORMAL MAXIMUM, NORMAL MINIMUM AND ACTUAL DAILY HIGH AND LOW VALUES (FAHRENHEIT)
PRECIPITATION IS MEASURED IN INCHES, SCALE IS NON-LINEAR
STATION PRESSURE IS MEASURED IN INCHES OF MERCURY

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER, ASHEVILLE, NORTH CAROLINA, 28801

Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

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NATIONAL
ENVIRONMENTAL SATELLITE, DATA
AND INFORMATION SERVICE

NATIONAL
CLIMATIC DATA CENTER
ASHEVILLE NORTH CAROLINA

METEOROLOGICAL DATA FOR 1993

ORLANDO, FLORIDA

LATITUDE: 28°26′ N LONGITUDE: 81°19′ W ELEVATION: FT. GRND 96 BARO 94 TIME ZONE: EASTERN WBAN: 12815

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F:													
Averages													
-Daily Maximum	75.4	71.2	75.5	79.4	85.5	91.5	93.7	92.5	90.0	83.6	77.5	69.8	82.1
-Daily Minimum	57.2	50.0	54.1	57.1	65.4	72.2	74.0	73.9	72.3	66.5	59.0	48.0	62.5
-Monthly	66.3	60.6	64.8	68.3	75.5	81.9	83.9	83.2	81.2	75.1	68.3	58.9	72.3
-Monthly Dewpt.	58.8	49.2	52.8	53.8	62.4	70.3	72.7	72.3	71.7	67.3	60.1	48.9	61.7
Extremes													
-Highest	85	81	87	87	90	96	97	96	93	91	87	79	97
-Date	8	16	31	13	18	7	30	19	23	21	15	4	JUL 30
-Lowest	39	35	33	48	57	68	71	70	66	44	37	33	33
-Date	28	19	14	23	1	18	11	18	30	31	1	27	DEC 27
DEGREE DAYS BASE 65 °F:													
Heating	73	131	80	12	0	0	0	0	0	10	45	201	552
Cooling	120	14	80	118	334	514	591	573	492	331	146	18	3331
% OF POSSIBLE SUNSHINE													
AVG. SKY COVER (tenths)													
Sunrise - Sunset	8.1	6.7	6.4	5.7	5.7	6.0	6.4	6.2	6.3	6.9	6.3	6.2	6.4
Midnight - Midnight	7.3	6.4	6.2	4.9	5.2	5.4	5.8	5.4	5.6	6.5	6.1	5.3	5.8
NUMBER OF DAYS:													
Sunrise to Sunset													
-Clear	3	5	8	8	8	5	1	5	3	7	7	9	69
-Partly Cloudy	6	11	7	14	12	16	18	14	17	6	9	6	136
-Cloudy	22	12	16	8	11	9	12	12	10	18	14	16	160
Precipitation .01 inches or more	12	6	13	4	4	14	17	16	12	11	6	7	122
Snow, Ice pellets, hail 1.0 inches or more	0	0	0	0	0	0	0	0	0	0	0	0	0
Thunderstorms	3	2	5	3	2	12	25	18	10	5	0	2	87
Heavy Fog, visibility 1/4 mile or less	5	3	1	0	0	0	0	0	0	1	3	1	14
Temperature °F													
-Maximum													
90° and above	0	0	0	0	3	20	30	23	25	1	0	0	102
32° and below	0	0	0	0	0	0	0	0	0	0	0	0	0
-Minimum													
32° and below	0	0	0	0	0	0	0	0	0	0	0	0	0
0° and below	0	0	0	0	0	0	0	0	0	0	0	0	0
AVG. STATION PRESS. (mb)	1016.6	1014.9	1014.2	1012.7	1012.2	1013.5	1014.2	1013.5	1013.9	1012.2	1015.9	1015.6	1014.2
RELATIVE HUMIDITY (%)													
Hour 01	92	81	84	83	85	89	89	90	93	92	90	88	88
Hour 07 (Local Time)	93	87	89	82	85	88	89	91	93	94	90	88	89
Hour 13	64	54	52	43	48	55	54	56	59	65	63	54	56
Hour 19	79	64	61	53	59	68	73	70	79	80	78	70	70
PRECIPITATION (inches):													
Water Equivalent													
-Total	4.89	1.48	6.26	1.78	2.32	4.47	6.49	5.95	5.35	4.61	0.17	0.76	44.53
-Greatest (24 hrs)	1.30	0.65	2.35	0.71	1.80	1.03	2.60	2.58	1.47	2.27	0.05	0.52	2.60
-Date	15-16	22	23-24	15-16	29-30	2	31	28-29	11	22	22	24-25	JUL 31
Snow, Ice pellets, hail													
-Total	0.0	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	0.0	0.0	T
-Greatest (24 hrs)	0.0	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	0.0	0.0	T
-Date							31						JUL 31
WIND:													
Resultant													
-Direction (!!!)	039	330	244	249	100	112	205	158	079	355	008	324	030
-Speed (mph)	2.4	1.7	1.7	0.1	3.6	2.4	2.2	1.8	2.8	2.7	5.1	4.2	0.9
Average Speed (mph)	8.5	9.2	11.0	10.4	9.8	8.1	6.8	7.4	7.1	8.4	9.3	9.4	8.8
Fastest Obs. 1 Min.													
-Direction (!!!)	34	25	24	21	13	07	21	29	15	20	22	26	24
-Speed (mph)	25	24	46	26	21	33	35	30	23	26	22	26	46
-Date	26	12	13	1	29	12	31	14	26	30	6	15	MAR 13
Peak Gust													
-Direction (!!!)	S	W	W	SE	W	E	SW	W	SW	SW	NE	W	W
-Speed (mph)	32	32	62	38	30	46	53	41	40	39	29	35	62
-Date	8	12	13	9	20	12	31	14	1	30	26	15	MAR 13

(!!!) See Reference Notes on Page 68

NORMALS, MEANS, AND EXTREMES

ORLANDO, FLORIDA

LATITUDE: 28°26'N LONGITUDE: 81°19' W ELEVATION: FT. GRND 96 BARO 94 TIME ZONE: EASTERN WBAN: 12815

	(a)	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F:														
Normals														
-Daily Maximum		70.8	72.7	78.0	83.0	87.8	90.5	91.5	91.5	89.7	84.6	78.5	72.9	82.6
-Daily Minimum		48.6	49.7	55.2	59.4	65.9	71.8	73.1	73.4	72.4	65.8	57.5	51.3	62.0
-Monthly		59.7	61.2	66.7	71.2	76.9	81.1	82.3	82.5	81.0	75.2	68.0	62.1	72.3
Extremes														
-Record Highest	51	87	90	92	96	102	100	100	100	98	95	89	90	102
-Year		1991	1962	1970	1968	1945	1985	1961	1980	1988	1986	1992	1978	MAY 1945
-Record Lowest	51	19	28	25	38	48	53	64	64	56	43	29	20	19
-Year		1985	1970	1980	1987	1992	1984	1981	1957	1956	1957	1950	1983	JAN 1985
NORMAL DEGREE DAYS:														
Heating (base 65°F)		234	164	65	5	0	0	0	0	0	0	54	164	686
Cooling (base 65°F)		70	58	117	191	369	483	536	543	480	316	144	74	3381
% OF POSSIBLE SUNSHINE														
MEAN SKY COVER (tenths)														
Sunrise - Sunset	45	5.7	5.7	5.6	5.1	5.4	6.4	6.4	6.4	6.5	5.5	5.2	5.7	5.8
MEAN NUMBER OF DAYS:														
Sunrise to Sunset														
-Clear	45	9.0	8.6	9.2	10.2	8.8	4.2	3.4	3.1	3.8	9.6	10.2	9.8	89.9
-Partly Cloudy	45	10.2	8.7	10.4	11.4	13.5	14.3	16.7	17.0	14.6	11.2	10.2	9.2	147.3
-Cloudy	45	11.8	11.0	11.4	8.4	8.7	11.5	10.9	10.9	11.6	10.2	9.6	12.1	128.1
Precipitation														
.01 inches or more	51	6.3	6.9	7.7	5.5	8.5	14.0	17.1	16.0	13.6	8.5	5.7	5.9	115.8
Snow,Ice pellets,hail														
1.0 inches or more	51	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thunderstorms	49	1.0	1.5	2.9	3.4	7.6	14.6	19.3	17.5	9.7	2.6	1.1	1.1	82.3
Heavy Fog Visibility														
1/4 mile or less	45	5.5	3.2	2.5	1.4	1.4	0.8	0.5	0.9	1.2	1.7	2.7	4.3	26.1
Temperature °F														
-Maximum														
90° and above	30	0.0	0.0	0.4	3.9	10.7	19.6	25.2	25.5	18.7	3.4	0.0	0.*	107.5
32° and below	30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-Minimum														
32° and below	30	1.5	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	2.8
0° and below	30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AVG. STATION PRESS.(mb)	21	1016.6	1015.8	1014.3	1013.6	1012.4	1012.9	1014.4	1013.8	1012.6	1013.4	1015.3	1016.8	1014.3
RELATIVE HUMIDITY (%)														
Hour 01	29	85	83	84	84	86	89	90	91	90	87	87	87	87
Hour 07 (Local Time)	30	88	87	88	87	88	89	90	92	92	89	89	88	89
Hour 13	30	56	52	50	46	49	57	58	60	60	56	56	57	55
Hour 19	30	69	63	61	58	62	72	75	77	77	74	73	73	70
PRECIPITATION (inches):														
Water Equivalent														
-Normal		2.30	3.02	3.21	1.80	3.55	7.32	7.25	6.78	6.01	2.42	2.30	2.15	48.11
-Maximum Monthly	51	7.23	8.32	11.38	9.10	10.36	18.28	19.57	16.11	15.87	14.51	10.29	5.33	19.57
-Year		1986	1983	1987	1992	1976	1968	1960	1972	1945	1950	1987	1983	JUL 1960
-Minimum Monthly	51	0.15	0.10	0.16	0.14	0.43	1.97	2.60	2.92	0.43	0.35	0.03	T	T
-Year		1950	1944	1956	1977	1961	1948	1992	1980	1972	1967	1967	1944	DEC 1944
-Maximum in 24 hrs	51	4.19	4.38	5.03	5.65	3.18	8.40	8.19	5.29	9.67	7.74	5.87	3.61	9.67
-Year		1986	1970	1960	1992	1980	1945	1960	1949	1945	1950	1988	1969	SEP 1945
Snow,Ice pellets,hail														
-Maximum Monthly	21	T	0.0	T	T	0.0	0.0	T	T	0.0	0.0	0.0	0.0	T
-Year		1977		1992	1992			1993	1989					JUL 1993
-Maximum in 24 hrs	21	T	0.0	T	T	0.0	0.0	T	T	0.0	0.0	0.0	0.0	T
-Year		1977		1992	1992			1993	1989					JUL 1993
WIND:														
Mean Speed (mph)	45	9.0	9.6	9.9	9.4	8.8	8.0	7.4	7.2	7.6	8.6	8.7	8.6	8.5
Prevailing Direction through 1963		NNE	S	S	SE	SE	SW	S	S	ENE	N	N	NNE	S
Fastest Obs. 1 Min.														
-Direction (!!)	44	25	25	24	02	17	32	14	32	24	05	26	07	32
-Speed (MPH)	44	42	46	46	50	46	64	46	50	46	48	46	32	64
-Year		1953	1969	1993	1956	1981	1970	1961	1957	1969	1950	1968	1968	JUN 1970
Peak Gust														
-Direction (!!)	10	NW	W	W	E	S	W	W	SW	NW	W	NE	W	W
-Speed (mph)	10	48	51	62	53	68	62	68	58	54	40	41	43	68
-Date		1991	1991	1993	1992	1991	1985	1991	1991	1988	1990	1984	1984	JUL 1991

(!!) See Reference Notes on Page 6B.

PRECIPITATION (inches)

ORLANDO, FLORIDA

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1964	6.18	3.42	4.65	2.14	2.74	6.11	6.68	9.00	9.47	1.64	0.45	1.91	54.39
1965	1.79	3.67	3.02	0.66	0.52	7.36	11.55	5.49	5.99	4.06	1.06	2.23	47.40
1966	4.45	6.31	2.57	1.92	6.57	9.77	6.73	7.76	6.25	1.98	0.09	0.99	55.39
1967	0.84	5.49	1.31	0.28	1.69	11.16	4.63	6.83	5.88	0.35	0.03	2.42	40.91
1968	0.65	2.76	2.27	0.30	3.72	18.28	5.60	3.44	5.91	5.47	2.82	0.88	52.10
1969	2.22	3.30	5.52	2.38	1.40	5.04	6.73	7.17	6.44	9.45	0.87	4.66	55.18
1970	4.05	6.77	3.66	0.45	4.08	4.92	5.97	5.91	3.25	2.60	0.24	2.06	43.96
1971	0.45	2.98	1.46	1.52	4.31	4.39	8.29	7.51	2.98	3.06	1.21	1.93	40.09
1972	0.99	4.96	5.06	1.39	3.76	6.33	3.98	16.11	0.43	2.34	4.11	1.89	51.35
1973	4.82	2.73	4.13	2.82	4.74	6.63	6.24	7.33	11.53	1.10	0.74	2.56	55.37
#1974	0.18	0.63	3.67	1.17	2.69	15.28	6.01	6.56	5.78	0.48	0.31	1.62	44.38
1975	0.98	1.49	1.10	1.36	7.52	9.70	9.26	4.75	4.97	4.74	0.66	0.51	47.04
1976	0.37	0.83	1.72	2.16	10.36	9.93	7.05	3.25	5.87	0.74	2.03	2.77	47.08
1977	1.81	1.76	1.82	0.14	1.47	4.47	6.61	6.28	7.03	0.43	2.60	3.70	38.12
1978	2.49	5.45	2.14	0.61	3.16	10.00	11.92	5.13	4.31	1.51	0.18	3.69	50.59
1979	6.48	1.45	3.24	1.08	7.66	4.00	7.95	5.88	9.19	0.43	1.93	0.94	50.23
1980	2.45	1.64	1.51	4.07	6.96	5.25	5.14	2.92	3.70	0.55	6.55	0.47	41.21
1981	0.21	4.36	1.85	0.18	2.02	12.49	3.53	5.60	8.26	3.13	2.50	2.97	47.10
1982	1.72	1.34	4.85	6.27	5.29	6.06	11.81	5.03	6.96	0.74	0.53	1.01	51.61
1983	2.08	8.32	5.37	3.21	1.77	7.82	6.49	4.83	5.16	3.78	1.36	5.33	55.52
1984	2.01	2.73	1.85	6.21	3.20	5.32	6.19	7.89	6.19	0.56	2.10	0.19	44.44
1985	0.91	1.27	4.59	1.69	3.00	4.54	7.28	11.63	5.45	2.55	0.82	3.46	47.19
1986	7.23	1.84	2.63	0.49	0.88	9.50	5.85	5.99	4.50	5.63	1.69	3.60	49.83
1987	1.27	1.74	11.38	0.59	1.40	3.54	7.95	6.07	8.64	3.41	10.29	0.51	56.79
1988	3.12	1.38	6.07	2.02	2.82	4.17	9.44	7.94	5.67	1.42	7.44	1.00	52.49
1989	3.80	0.15	1.35	2.28	2.38	6.79	4.74	6.20	10.29	1.75	1.44	4.49	45.66
1990	0.23	4.13	1.92	1.73	0.55	6.22	6.68	3.78	2.46	2.10	1.05	0.83	31.68
1991	2.37	0.98	6.66	7.72	9.48	5.98	10.78	7.13	4.53	4.76	0.27	0.24	60.90
1992	1.35	2.42	3.67	9.10	1.19	8.68	2.60	8.03	7.13	5.17	2.74	0.88	52.96
1993	4.89	1.48	6.26	1.78	2.32	4.47	6.49	5.95	5.35	4.61	0.17	0.76	44.53
Record Mean	2.23	2.70	3.53	2.62	3.40	6.98	7.83	6.68	6.74	3.36	1.88	1.91	49.84

See Reference Notes on Page 6B.
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AVERAGE TEMPERATURE (deg. F)

ORLANDO, FLORIDA

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1964	58.5	58.3	68.1	74.1	77.1	82.4	81.6	82.8	79.8	72.5	70.5	64.4	72.5
1965	60.0	64.1	67.0	74.8	77.1	79.0	80.5	82.2	80.8	74.2	69.5	62.6	72.7
1966	58.7	62.3	64.4	70.5	77.4	78.0	82.3	82.3	80.1	75.8	65.8	60.1	71.5
1967	63.2	60.0	68.3	74.3	78.3	80.2	82.4	82.0	79.7	74.0	67.5	65.9	73.0
1968	59.6	54.8	61.4	73.5	76.7	78.8	81.3	82.3	80.3	74.3	63.4	58.7	70.4
1969	59.8	57.8	60.4	72.5	76.9	82.9	84.4	82.2	81.2	77.9	64.0	58.7	71.6
1970	55.1	58.7	67.0	75.8	77.7	81.8	83.8	82.3	83.6	77.0	63.4	64.6	72.6
1971	62.0	64.1	64.8	72.1	78.2	81.7	83.1	83.3	81.8	79.0	69.5	71.4	74.2
1972	68.9	62.0	68.7	72.7	77.4	82.2	83.2	82.8	81.8	76.8	68.9	66.1	74.3
1973	62.4	59.7	71.1	71.1	78.3	83.1	84.2	81.8	81.4	75.6	70.9	60.4	73.3
#1974	71.6	60.5	70.2	71.4	78.0	80.3	80.7	82.0	81.8	72.6	67.6	60.9	73.1
1975	65.8	67.6	67.4	72.4	79.1	80.8	80.5	82.3	80.7	76.6	67.4	60.2	73.4
1976	56.5	63.7	70.4	71.3	76.8	79.7	82.4	81.9	80.5	72.6	63.0	60.1	71.6
1977	50.6	57.4	69.7	70.6	75.2	82.6	82.0	81.5	82.6	72.9	69.6	61.0	71.3
1978	56.8	55.8	66.3	73.4	79.3	82.9	82.6	82.6	81.7	75.0	72.3	66.8	73.0
1979	58.2	58.4	64.6	73.4	75.4	80.7	83.3	82.4	81.3	74.4	68.3	62.6	71.9
1980	60.5	57.2	68.2	70.4	76.4	80.1	83.6	83.6	81.7	75.4	67.1	59.0	71.9
1981	51.3	61.7	64.0	73.1	76.7	83.2	84.1	82.9	80.0	76.4	65.3	60.5	71.6
1982	60.0	68.4	70.4	72.6	75.3	82.0	82.6	82.2	80.2	74.1	70.8	66.7	73.8
1983	58.0	59.9	63.5	68.6	76.4	80.5	83.2	83.5	80.6	76.5	65.8	61.2	71.5
1984	57.8	61.2	64.7	69.2	75.6	78.4	80.7	81.5	78.9	75.4	65.8	66.0	71.3
1985	54.7	62.2	68.4	70.7	77.2	82.4	82.1	82.3	79.8	79.4	73.0	58.8	72.6
1986	59.8	64.3	65.4	69.3	76.7	81.7	82.3	83.3	81.7	77.5	75.8	67.3	73.8
1987	58.8	62.7	65.9	66.8	76.8	83.1	83.5	85.0	82.7	72.2	69.0	64.2	72.6
1988	58.5	60.4	65.5	72.0	75.5	80.3	80.7	82.8	83.9	73.7	70.5	62.4	72.2
1989	66.9	64.5	69.7	71.9	77.9	81.9	83.2	83.3	82.2	75.3	69.0	55.5	73.4
1990	65.8	69.1	69.3	71.5	79.4	81.9	82.8	83.5	82.0	77.1	69.3	66.3	74.8
1991	66.3	64.2	67.7	75.3	79.5	81.1	82.6	83.0	81.7	75.3	65.8	65.5	74.0
1992	59.7	64.8	66.4	69.9	74.9	81.2	84.5	82.3	81.6	73.4	70.4	63.5	72.7
1993	66.3	60.6	64.8	68.3	75.5	81.9	83.9	83.2	81.2	75.1	68.3	58.9	72.3
Record													
Mean	60.5	62.2	66.8	71.8	77.2	81.2	82.4	82.6	81.0	74.8	67.6	62.1	72.5
Max	71.6	73.4	78.0	83.1	88.1	90.9	91.8	91.6	89.6	84.0	77.8	72.8	82.7
Min	49.5	50.9	55.5	60.4	66.3	71.5	73.0	73.5	72.4	65.6	57.4	51.3	62.3

See Reference Notes on Page 6B.
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HEATING DEGREE DAYS Base 65 deg. F ORLANDO, FLORIDA

SEASON	JULY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	TOTAL
1964-65	0	0	0	7	14	84	178	89	82	0	0	0	454
1965-66	0	0	0	1	19	112	215	122	72	5	0	0	546
1966-67	0	0	0	2	70	169	119	157	25	0	0	0	542
1967-68	0	0	0	0	29	80	191	293	149	0	0	0	742
1968-69	0	0	0	19	120	237	168	206	169	0	0	0	919
1969-70	0	0	0	0	93	204	316	187	58	0	0	0	858
1970-71	0	0	0	0	120	79	165	115	92	20	0	0	591
1971-72	0	0	0	0	26	9	51	124	24	6	0	0	240
1972-73	0	0	0	0	54	105	160	169	12	9	0	0	509
#1973-74	0	0	0	6	13	193	0	173	15	8	0	0	408
1974-75	0	0	0	0	40	163	73	44	57	10	0	0	387
1975-76	0	0	0	0	85	174	278	104	18	1	0	0	660
1976-77	0	0	0	4	118	197	440	218	41	8	0	0	1026
1977-78	0	0	0	6	38	179	275	255	71	0	0	0	824
1978-79	0	0	0	0	0	56	230	214	71	0	0	0	571
1979-80	0	0	0	0	47	119	161	245	61	4	0	0	637
1980-81	0	0	0	1	67	190	416	119	76	1	0	0	870
1981-82	0	0	0	0	75	205	204	21	33	7	0	0	545
1982-83	0	0	0	14	16	94	233	148	105	13	0	0	623
1983-84	0	0	0	0	63	188	252	137	86	18	0	0	744
1984-85	0	0	0	0	68	71	340	146	22	12	0	0	659
1985-86	0	0	0	0	14	228	180	82	105	4	0	0	613
1986-87	0	0	0	0	0	42	216	97	48	66	0	0	469
1987-88	0	0	0	0	39	97	221	169	71	7	0	0	604
1988-89	0	0	0	0	11	135	32	119	59	4	0	0	360
1989-90	0	0	0	21	27	308	71	34	11	5	0	0	477
1990-91	0	0	0	6	14	69	75	88	52	0	0	0	304
1991-92	0	0	0	0	85	76	187	79	51	19	8	0	505
1992-93	0	0	0	0	47	102	73	131	80	12	0	0	445
1993-94	0	0	0	10	45	201							

See Reference Notes on Page 6B.
Page 5A

COOLING DEGREE DAYS Base 65 deg. F ORLANDO, FLORIDA

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	TOTAL
1969	12	10	32	232	376	544	608	540	495	406	68	16	3339
1970	19	14	128	330	399	511	586	544	565	380	77	72	3625
1971	77	97	90	238	411	505	569	573	510	440	167	214	3891
1972	181	44	146	243	391	524	570	561	509	374	179	148	3870
1973	88	28	207	198	421	548	602	529	501	341	199	58	3720
#1974	213	51	183	207	410	463	492	536	510	241	125	43	3474
1975	105	121	141	237	442	481	489	541	479	366	167	32	3601
1976	18	75	194	196	374	449	549	529	474	247	65	49	3219
1977	1	13	192	182	324	534	537	521	536	257	185	62	3344
1978	26	3	116	259	449	541	550	553	508	321	225	115	3666
1979	26	31	65	260	330	479	575	546	498	299	153	53	3315
1980	27	25	169	172	362	459	586	582	508	331	138	12	3371
1981	0	34	52	253	372	552	602	559	458	359	89	73	3403
1982	56	123	211	241	325	518	550	542	465	303	196	152	3682
1983	22	11	68	129	361	473	573	582	476	362	95	77	3229
1984	37	35	84	151	332	411	490	520	426	331	99	107	3023
1985	27	74	137	191	386	531	539	548	451	454	262	45	3645
1986	25	69	124	139	372	506	543	573	507	392	333	121	3704
1987	32	38	82	127	376	549	582	627	540	230	163	78	3424
1988	26	43	95	223	336	466	496	559	573	275	182	61	3335
1989	101	111	213	216	408	509	573	579	523	346	153	19	3751
1990	102	156	156	206	453	514	559	581	518	388	149	116	3898
1991	121	71	143	315	455	490	553	565	508	326	118	98	3763
1992	28	79	101	175	325	496	612	540	507	265	217	62	3407
1993	120	14	80	118	334	514	591	573	492	331	146	18	3331

See Reference Notes on Page 6B.
Page 5B

SNOWFALL (inches)

ORLANDO, FLORIDA

SEASON	JULY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	TOTAL
1970-71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1971-72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1972-73	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
#1973-74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1974-75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1975-76	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1976-77	0.0	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	0.0	0.0	T
1977-78	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978-79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979-80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980-81	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981-82	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982-83	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983-84	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984-85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1985-86	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986-87	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987-88	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1988-89	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1989-90	0.0	T	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	T
1990-91	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991-92	T	0.0	0.0	0.0	0.0	0.0	0.0	0.0	T	T	0.0	0.0	T
1992-93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1993-94	T	0.0	0.0	0.0	0.0	0.0							
Record Mean	T	T	0.0	0.0	0.0	0.0	T	0.0	T	T	0.0	0.0	T

See Reference Notes on Page 6B.

REFERENCE NOTES

ORLANDO, FLORIDA

GENERAL
T - TRACE AMOUNT.
BLANK ENTRIES DENOTE MISSING/UNREPORTED DATA.
# INDICATES A STATION OR INSTRUMENT RELOCATION.
SEE STATION LOCATION TABLE ON PAGE 8.

SPECIFIC
PAGE 2
PM - INCLUDES LAST DAY OF PREVIOUS MONTH
ASOS - AUTOMATED SURFACE OBSERVING SYSTEM IN OPERATION DURING THESE MONTHS.

PAGE 3
(a) - LENGTH OF RECORD IN YEARS, ALTHOUGH INDIVIDUAL MONTHS MAY BE MISSING.
0.* OR * - THE VALUE IS BETWEEN 0.0 AND 0.05
NORMALS - BASED ON THE 1961-1990 RECORD PERIOD.
EXTREMES - DATES ARE THE MOST RECENT OCCURRENCE
WIND DIR.- NUMERALS SHOW TENS OF DEGRESS CLOCKWISE FROM TRUE NORTH. "00" INDICATES CALM.
RESULTANT DIRECTIONS ARE GIVEN TO WHOLE DEGREES.
BOLD VALUES INDICATE EXTREME VALUES WHICH OCCURRED AFTER THE ASOS SYSTEM WAS COMMISSIONED.

PAGE 4B
RECORD = PERIOD OF RECORD
RECORD MEAN PRECIPITATION IS THE MEAN OF ALL DAILY PRECIPITATION AMOUNTS DURING THE PERIOD OF RECORD.
RECORD MAX(MIN) TEMPERATURE IS THE MEAN OF ALL DAILY MAX(MIN) TEMPERATURES DURING THE PERIOD OF RECORD.
RECORD MEAN TEMPERATURE IS THE SUM OF THE RECORD MAX AND RECORD MIN DIVIDED BY 2.
AVERAGE TEMPERATURE IS THE SUM OF THE MEAN DAILY MAX AND MIN TEMPERATURE DIVIDED BY 2.

EXCEPTIONS

PAGES 4A, 4B, 6A
RECORD MEANS ARE THROUGH THE CURRENT YEAR,
BEGINNING IN 1943 FOR TEMPERATURE
1943 FOR PRECIPITATION
1943 FOR SNOWFALL

ORLANDO,
FLORIDA

Orlando is located in the central section of the Florida peninsula, surrounded by many lakes. Relative humidities remain high the year–round, with values near 90 percent at night and 40 to 50 percent in the afternoon. On some winter days, the humidity may drop to 20 percent.

The rainy season extends from June through September, sometimes through October when tropical storms are near. During this period, scattered afternoon thunderstorms are an almost daily occurrence, and these bring a drop in temperature to make the climate bearable. Summer temperatures above 95 degrees are rather rare. There is usually a breeze which contributes to the general comfort.

During the winter months rainfall is light. While temperatures, on infrequent occasion, may drop at night to near freezing, they rise rapidly during the day and, in brilliant sunshine, afternoons are pleasant.

Frozen precipitation in the form of snowflakes, snow pellets, or sleet is rare. However, hail is occasionally reported during thunderstorms.

Hurricanes are usually not considered a great threat to Orlando, since, to reach this area, they must pass over a substantial stretch of land and, in so doing, lose much of their punch. Sustained hurricane winds of 75 mph or higher rarely occur. Orlando, being inland, is relatively safe from high water, although heavy rains sometimes briefly flood sections of the city.

Notice of Correction

Any previously received edition of the "Local Climatological Data Annual Summary for 1993" should be discarded. This revised edition contains updates to the "Normals" based upon the 1961-1990 record period as noted in the "Reference Notes" on Page 6B.

STATION LOCATION

ORLANDO, FLORIDA

LOCATION	OCCUPIED FROM	OCCUPIED TO	AIRLINE DISTANCES AND DIRECTIONS FROM PREVIOUS LOCATION	LATITUDE NORTH	LONGITUDE WEST	ELEVATION ABOVE									AUTOMATIC OBSERVING EQUIPMENT *	* Type M = AMOS T = AUTOB S = ASOS W = AWOS REMARKS
						SEA LEVEL	GROUND									
						GROUND TEMPERATURE SITE	WIND INSTRUMENTS	EXTREME THERMOMETERS	PSYCHROMETER	SUNSHINE SWITCH	TIPPING BUCKET RAIN GAGE	WEIGHING RAIN GAGE	8 INCH RAIN GAGE	HYGROTHERMOMETER		
COOPERATIVE - - NOTE: for period January 1892 through July 13, 1916, refer to previous editions.																
319 N. Orange Avenue	8/01/16	6/20/21	300 ft. N	28°33'	81°22'	107		4					3			
1022 South Hughey	6/21/21	6/15/25	1.3 mi.SSW	28°32'	81°23'	106		5					4			
946 Bradshaw Terrace	6/16/25	10/21/28	2000 ft. E	28°32'	81°23'	80		5					4			
117 Annie Street	10/22/28	11/11/31	400 ft. S	28°32'	81°23'	80		4					2			
Fern Creek and Harding Avenue	11/11/31	5/1934	1 mi. S	28°31'	81°22'	95		4					3			
1537 Clay Street Winter Park	5/1934	9/16/36	3.75 mi. NNW	28°35'	81°22'	93										
933 Bradshaw Terrace	9/17/36	12/1942	3 mi. S	28°32'	81°23'	80		5					3			
AIRPORT ~~Terminal~~ Building Municipal Airport 2 miles east of Post Office	1/01/43	1/03/51	2.6 mi. NE	28°33'	81°20'	106	a40	4	4			3	3			Observations were commenced at the airport by an airway observer on 4/1/29 and at a later date taken over by CAA. Weather Bureau effective 2/15/44. a - 44 feet to 9/10/47.
Administration Building Herndon Airport *	1/03/51	1/31/74	400 ft.WNW	28°33'	81°20'	g108	a20	b16	c16			d13	e13	f4		* Name adopted 3/18/61. a - 41 feet to 2/16/51 and 53 feet to 1/9/60. b - 6 feet to 4/6/60 and 18 feet to 12/1/63. c - 5 feet to 4/6/60 and 17 feet to 12/1/63. d - 3 feet to 3/11/52; 4 feet to 4/6/60 and 14 feet to 12/1/63. e - 3 feet to 4/6/60 and 14 feet to 12/1/63. f - Commissioned 12/1/63 on field 1700 feet east of thermometer. g - 106 feet to 12/1/63.
Weather Service Office Orlando Jetport + at McCoy + International Airport eff. 11/26/76	1/31/74	9/19/84	8 mi. S	28°26'	81°19'	96	12 j20	NA i5	NA h5 n5	NA	NA k3 n3	NA h3 n3	16 h3 n3	NA A10 m4	NA	A - AN/TMQ-11 on field site. h - Effective 5/7/74. i - Effective 7/26/74. j - Effective 5/20/74. k - Added 3/18/76. m - Hygrothermometer commissioned 3/25/76. n - Relocated 7/22/77.
Weather Service Bldg. Orlando International Airport	9/19/84	Present	Unknown	28°26'	81°19'	96	33	NA	6	NA	5	5	5	6 p6	NA	Moved from 9501 Benford Road to 5390 Bear Road p - Type change 5/30/85

SUBSCRIPTION:
Price and ordering information available through: National Climatic Data Center, Federal Building, Asheville, North Carolina 28801.
INQUIRIES/COMMENTS CALL: (704) 271-4800

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SKY HARBOR INTL AIRPORT

ISSN 0198-0475

LOCAL CLIMATOLOGICAL DATA

Monthly Summary

NOV 1993
PHOENIX, AZ

LATITUDE 33° 26'N LONGITUDE 112° 01'W ELEVATION (GROUND) 1110 FEET TIME ZONE MOUNTAIN 23183

	TEMPERATURE °F					DEGREE DAYS BASE 65°F		WEATHER TYPES	SNOW ICE PELLETS OR ICE ON GROUND AT 0500	PRECIPITATION		AVERAGE STATION PRESSURE	WIND (M.P.H.)							SUNSHINE		SKY COVER (TENTHS)	
																PEAK GUST		FASTEST 1-MIN					
DATE 1	MAXIMUM 2	MINIMUM 3	AVERAGE 4	DEPARTURE FROM NORMAL 5	AVERAGE DEW POINT 6	HEATING (SEASON BEGINS WITH JUL) 7A	COOLING (SEASON BEGINS WITH JAN) 7B	1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW 8	INCHES 9	WATER EQUIVALENT (INCHES) 10	SNOW, ICE PELLETS (INCHES) 11	IN INCHES ELEV. 1107 FEET ABOVE M.S.L. 12	RESULTANT DIR. 13	RESULTANT SPEED 14	AVERAGE SPEED 15	SPEED 16	DIRECTION 17	SPEED 18	DIRECTION 19	MINUTES 20	PERCENT OF TOTAL POSSIBLE 21	SUNRISE TO SUNSET 22	MIDNIGHT TO MIDNIGHT 23
01	78	54	66	-2	30	0	1		0	0.00	0.0	28.740	12	0.4	3.6	10	NW	8	30	453	70	5	4
02	80	52	66	-1	22	0	1		0	0.00	0.0	28.930	04	2.6	4.8	17	NE	8	05	648	100	0	0
03	84*	53	69*	2	23	0	4		0	0.00	0.0	28.925	14	0.4	2.3	12	E	6	10	646	100	0	0
04	81	54	68	2	26	0	3		0	0.00	0.0	28.825	12	2.1	4.2	13	SE	7	28	644	100	0	0
05	79	54	67	1	34	0	2		0	0.00	0.0	28.830	11	1.3	3.6	14	W	10	27	643	100	0	0
06	80	53	67	2	26	0	2		0	0.00	0.0	28.850	09	1.7	3.2	16	E	8	08	642	100	0	0
07	78	52	65	0	27	0	0		0	0.00	0.0	28.750	08	2.0	3.3	13	E	7	09	640	100	0	1
08	79	52	66	2	29	0	1		0	0.00	0.0	28.890	10	2.5	3.5	10	SE	7	09	638	100	0	0
09	81	52	67	3	28	0	2		0	0.00	0.0	28.990	11	1.2	2.7	9	E	6	09	636	100	1	0
10	82	54	68	4	29	0	3		0	0.00	0.0	28.830	11	1.8	3.4	9	W	6	26	455	72	10	8
11	71	55	63	0	39	2	0		0	0.09	0.0	28.635	25	3.2	8.5	37	W	24	27	235	37	8	6
12	63	50	57	-6	47	8	0		0	0.10	0.0	28.610	08	4.6	6.7	17	N	13	02	129	20	9	6
13	59	48	54	-9	44	11	0		0	0.44	0.0	28.640	12	1.6	7.6	20	N	12	10	230	37	8	7
14	53	48	51*	-11	45	14	0	1	0	1.58	0.0	28.670	08	10.6	11.6	25	E	18	07	6	1	10	9
15	57	46	52	-10	43	13	0	1	0	0.58	0.0	28.820	08	5.2	6.4	22	E	18	05	174	28	8	6
16	66	43	55	-7	43	10	0		0	0.00	0.0	28.990	09	2.1	4.1	12	E	9	29	532	85	5	3
17	72	50	61	0	43	4	0		0	0.00	0.0	28.920	11	3.4	4.3	13	E	12	10	441	71	9	9
18	74	50	62	2	44	3	0		0	0.00	0.0	28.910	20	0.4	2.6	12	SW	9	24	503	81	5	6
19	73	49	61	1	43	4	0		0	0.00	0.0	28.970	26	2.2	4.6	12	W	9	25	580	93	3	1
20	73	47	60	0	36	5	0		0	0.00	0.0	28.910	27	2.6	3.1	12	W	9	25	592	95	1	1
21	74	46	60	0	37	5	0		0	0.00	0.0	28.830	16	0.9	3.8	12	N	8	11	541	88	8	6
22	74	59	67	7	46	0	2		0	T	0.0	28.825	11	3.3	5.5	15	E	12	09	201	33	10	10
23	76	60	68	9	51	0	3		0	T	0.0	28.810	11	2.3	5.8	14	NW	10	30	337	55	6	6
24	72	52	62	3	44	3	0		0	0.00	0.0	28.805	26	1.4	7.6	15	NW	12	30	614	100	0	0
25	67	44	56	-3	20	9	0		0	0.00	0.0	28.910	26	3.9	6.7	22	W	12	03	613	100	0	0
26	65	39*	52	-6	17	13	0		0	0.00	0.0	29.040	28	1.6	4.5	12	W	10	27	611	100	1	1
27	66	41	54	-4	24	11	0		0	0.00	0.0	29.010	27	1.4	4.2	14	NW	7	28	530	87	8	7
28	76	51	64	6	28	1	0		0	0.00	0.0	28.915	11	2.0	3.9	10	S	8	02	422	69	4	5
29	75	49	62	5	29	3	0		0	0.00	0.0	28.890	11	4.6	5.7	14	E	9	08	609	100	2	2
30	70	47	59	2	34	6	0		0	0.00	0.0	28.830	14	1.3	4.9	15	W	10	27	550	90	2	2
	SUM	SUM	—	—	—	TOTAL	TOTAL	NUMBER OF DAYS		TOTAL	TOTAL	FOR THE MONTH:								TOTAL	% FOR MONTH	SUM	SUM
	2178	1504	—	—	—	125	24			2.79	0.0	28.850	10	1.3	4.9	37	W	24	27	14495		123	106
	AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION		DEP.	—	—	—	—	—	DATE:11		DATE: 11		POSSIBLE		AVG.	AVG.
	72.6	50.1	61.4	-0.5	34.4	-9	-17	≥ .01 INCH	5	2.13	—	—	—	—	—					18805	77	4.1	3.5

NUMBER OF DAYS				SEASON TO DATE	
				TOTAL	TOTAL
MAXIMUM TEMP.		MINIMUM TEMP.		125	4484
≥ 90°	≤ 32°	≤ 32°	≤ 0°	DEP.	DEP.
0	0	0	0	-26	329

SNOW, ICE PELLETS ≥ 1.0 INCH 0
THUNDERSTORMS 0
HEAVY FOG 0
CLEAR 15 PARTLY CLOUDY 5 CLOUDY 10

GREATEST IN 24 HOURS AND DATES				GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE	
PRECIPITATION		SNOW, ICE PELLETS			
2.16	14-15	0.0		0	

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
\+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS. COLS 16 & 17: PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED. ONE OF TWO WIND SPEEDS IS GIVEN UNDER COLS 18 & 19: FASTEST MILE - HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTION IN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES). ERRORS WILL BE CORRECTED IN SUBSEQUENT PUBLICATIONS.

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER

Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

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NATIONAL CLIMATIC DATA CENTER ASHEVILLE NORTH CAROLINA

OBSERVATIONS AT 3-HOUR INTERVALS

NOV 1993
PHOENIX, AZ

23183

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
	NOV 1st										
02	4	UNL	35			59	47	34	39	13	3
05	3	UNL	35			55	45	33	44	11	3
08	6	250	50			56	45	33	42	13	4
11	2	UNL	45			68	51	32	26	08	3
14	7	UNL	45			76	52	25	15	32	5
17	6	250	45			75	51	23	14	30	7
20	2	UNL	35			67	49	29	24	00	0
23	0	UNL	35			62	49	35	37	00	0
	NOV 4th										
02	0	UNL	35			59	46	29	32	00	0
05	0	UNL	35			55	43	28	36	07	5
08	0	UNL	45			57	45	30	36	10	4
11	0	UNL	45			68	50	31	25	12	5
14	0	UNL	40			79	53	22	12	25	3
17	0	UNL	40			79	52	20	11	27	3
20	0	UNL	35			70	50	27	20	09	3
23	0	UNL	35			63	46	25	24	13	3
	NOV 7th										
02	3	UNL	35			57	41	16	20	13	3
05	0	UNL	35			53	43	29	40	05	3
08	0	UNL	45			54	42	26	34	07	3
11	0	UNL	35			68	49	26	21	09	6
14	0	UNL	35			77	53	28	16	00	0
17	0	UNL	40			77	52	25	15	32	4
20	0	UNL	35			66	49	29	25	00	0
23	0	UNL	35			61	47	31	32	11	4
	NOV 10th										
02	2	UNL	35			56	45	32	40	00	0
05	5	UNL	35			54	43	28	37	09	4
08	10	UNL	40			56	44	29	36	08	4
11	10	UNL	40			70	50	26	19	08	4
14	10	UNL	40			82	55	27	13	12	3
17	10	250	35			78	53	27	15	26	5
20	10	250	35			71	51	30	22	00	0
23	10	250	35			67	50	32	27	09	3
	NOV 13th										
02	10	75	15		RW	51	51	50	96	06	4
05	10	44	15		RW	49	48	46	90	11	6
08	9	100	35			49	47	45	86	23	7
11	9	110	40		R	49	47	45	86	24	5
14	6	100	45			59	50	41	52	24	7
17	6	80	40			53	48	43	69	01	7
20	0	UNL	35			51	47	42	72	12	8
23	6	100	35			49	46	42	77	10	8
	NOV 16th										
02	0	UNL	35			47	45	42	83	09	5
05	0	UNL	35			44	43	42	93	11	3
08	0	UNL	50			45	43	41	86	11	6
11	4	UNL	50			55	49	42	62	09	7
14	6	UNL	50			63	52	42	46	13	3
17	9	150	45			64	53	42	45	00	0
20	2	UNL	35			57	52	47	69	27	3
23	6	UNL	35			54	50	46	75	00	0

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
	NOV 2nd										
02	0	UNL	35			57	47	35	44	13	3
05	0	UNL	35			52	44	35	53	00	0
08	0	UNL	45			57	46	34	42	23	3
11	0	UNL	60			73	50	20	13	05	7
14	0	UNL	60			78	51	15	9	02	6
17	0	UNL	60			78	50	12	8	36	4
20	0	UNL	35			72	47	8	8	06	6
23	0	UNL	35			63	44	15	15	34	3
	NOV 5th										
02	0	UNL	35			58	45	30	35	14	3
05	0	UNL	35			55	43	27	34	10	4
08	0	UNL	45			56	44	28	34	08	3
11	0	UNL	40			69	50	29	23	14	3
14	0	UNL	40			77	56	41	28	14	3
17	0	UNL	40			77	56	36	23	27	9
20	0	UNL	35			71	54	39	31	00	0
23	0	UNL	35			64	52	41	43	00	0
	NOV 8th										
02	0	UNL	35			57	45	30	36	09	4
05	0	UNL	35			54	43	29	38	09	6
08	0	UNL	40			55	44	30	39	12	4
11	0	UNL	40			68	50	29	23	13	4
14	0	UNL	40			76	53	28	17	11	3
17	0	UNL	40			77	52	24	14	26	3
20	0	UNL	35			67	49	28	23	00	0
23	0	UNL	35			62	47	30	30	11	3
	NOV 11th										
02	10	95	35			62	47	30	30	08	5
05	10	80	35			60	47	32	35	05	3
08	10	55	20		RW	62	48	32	33	10	6
11	7	35	25			58	56	54	87	10	8
14	8	65	35			69	55	42	38	27	21
17	2	UNL	30			68	52	37	32	26	15
20	0	UNL	35			62	50	37	40	28	8
23	0	UNL	35			57	48	39	51	30	4
	NOV 14th										
02	8	110	35			49	46	42	77	10	7
05	7	100	35			49	45	41	74	11	7
08	10	70	20		R	49	47	44	83	13	10
11	10	43	15		R	50	48	46	86	07	8
14	10	33	4		RF	50	49	47	90	05	10
17	10	50	5		RF	49	48	47	93	04	9
20	10	35	8		R	49	48	46	90	06	11
23	10	23	7		R	50	49	47	90	06	10
	NOV 17th										
02	9	UNL	35			51	48	45	80	12	3
05	9	150	35			52	48	44	74	00	0
08	10	130	50			56	49	41	57	13	6
11	10	UNL	45			64	52	40	42	08	6
14	10	UNL	50			70	53	37	30	12	8
17	9	UNL	50			70	54	39	32	00	0
20	8	UNL	35			62	53	45	54	00	0
23	5	UNL	35			58	51	45	62	10	6

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
	NOV 3rd										
02	0	UNL	35			57	41	16	20	27	3
05	0	UNL	35			53	41	23	31	00	0
08	0	UNL	60			58	42	20	23	00	0
11	0	UNL	60			75	50	19	12	13	3
14	0	UNL	60			82	54	23	11	11	3
17	0	UNL	60			80	53	23	12	33	3
20	0	UNL	35			70	50	27	20	00	0
23	0	UNL	35			63	48	30	29	10	3
	NOV 6th										
02	0	UNL	35			58	46	31	36	14	3
05	0	UNL	35			60	43	20	21	10	5
08	0	UNL	50			57	44	28	33	00	0
11	0	UNL	50			69	48	22	17	35	5
14	0	UNL	50			77	52	22	13	09	3
17	0	UNL	50			76	51	21	13	10	3
20	0	UNL	35			66	48	27	23	00	0
23	0	UNL	35			60	46	30	32	00	0
	NOV 9th										
02	0	UNL	35			56	44	30	37	11	4
05	0	UNL	35			54	43	29	38	06	3
08	0	UNL	40			55	44	30	39	07	4
11	0	UNL	40			69	50	28	22	09	5
14	1	UNL	40			79	53	24	13	25	3
17	1	UNL	35			78	53	24	13	29	3
20	0	UNL	35			68	50	29	23	00	0
23	0	UNL	35			62	48	32	33	00	0
	NOV 12th										
02	0	UNL	35			53	47	41	64	08	6
05	0	UNL	35			52	47	41	66	11	6
08	10	75	35			52	48	43	72	07	7
11	10	75	20		RW	58	53	48	70	17	6
14	10	85	15		RW	58	55	52	81	14	4
17	5	UNL	25			61	55	50	67	11	7
20	4	UNL	35			56	54	53	90	08	6
23	10	45	15		RW	54	49	45	72	33	6
	NOV 15th										
02	10	49	20		R	50	49	47	90	09	15
05	10	12	5		R	49	48	46	90	10	5
08	10	40	10		R	47	46	45	93	11	10
11	10	110	50			50	46	42	74	11	8
14	9	100	70			54	47	40	59	07	4
17	3	UNL	70			55	47	39	55	05	5
20	0	UNL	35			51	46	41	69	00	0
23	0	UNL	35			48	46	43	83	00	0
	NOV 18th										
02	6	UNL	35			53	49	46	77	00	0
05	6	250	35			51	49	46	83	00	0
08	7	UNL	35			54	48	42	64	09	3
11	5	UNL	45			66	54	44	45	08	5
14	7	UNL	45			72	56	41	33	24	4
17	4	UNL	35			69	55	43	39	23	7
20	7	UNL	35			62	54	46	56	00	0
23	8	UNL	35			59	52	46	62	00	0

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.05	0.09	0.12	0.15	0.19	0.24	0.28	0.34	0.40	0.44	0.51	0.59
ENDED: DATE	14	14	14	14	14	14	14	14	14	14	14	14
ENDED: TIME	1314	1312	1317	1317	1317	1325	1340	1408	1420	1432	1821	1844

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

NOV 1993
PHOENIX, AZ

23183

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
	NOV 19th										
02	0	UNL	35			54	51	48	80	09	4
05	1	UNL	35			52	49	47	83	17	4
08	2	UNL	40			52	49	46	80	00	0
11	2	UNL	45			65	54	44	47	20	3
14	4	UNL	45			71	54	38	30	31	3
17	3	UNL	50			71	54	39	31	25	8
20	0	UNL	35			62	52	43	50	26	5
23	0	UNL	35			56	48	39	53	25	3
	NOV 20th										
02	0	UNL	35			51	45	38	61	26	3
05	0	UNL	35			48	44	40	74	00	0
08	0	UNL	50			50	45	39	66	27	3
11	0	UNL	50			64	49	32	30	26	3
14	1	UNL	50			71	52	32	24	32	5
17	4	UNL	60			70	53	36	29	24	6
20	0	UNL	35			60	49	37	43	30	3
23	0	UNL	35			56	47	37	49	00	0
	NOV 21st										
02	1	UNL	35			51	45	38	61	25	4
05	0	UNL	35			48	44	40	74	22	4
08	1	UNL	70			51	43	34	52	11	7
11	9	UNL	60			62	49	34	35	25	3
14	10	UNL	70			72	52	31	22	11	4
17	10	250	50			71	52	33	25	30	4
20	10	140	35			65	53	42	43	24	4
23	10	110	30			63	53	44	50	13	5
	NOV 22nd										
02	10	100	35			60	52	45	58	09	8
05	10	85	35			60	53	46	60	08	7
08	9	70	35			61	53	45	56	12	8
11	10	65	45			68	57	47	47	13	4
14	9	130	45			73	56	42	33	00	0
17	10	110	35			71	57	45	40	25	6
20	10	100	35			67	57	48	51	25	4
23	10	90	35			66	56	48	53	16	3
	NOV 23rd										
02	10	80	35			64	57	51	63	10	5
05	10	65	35			63	57	52	68	11	4
08	10	130	30			62	56	52	70	09	6
11	8	250	30			67	57	49	53	09	7
14	8	70	30			73	60	51	46	30	9
17	2	UNL	30			74	60	50	43	25	6
20	0	UNL	35			66	58	51	59	00	0
23	1	UNL	35			63	57	53	70	11	6
	NOV 24th										
02	0	UNL	35			58	54	51	78	09	9
05	0	UNL	35			55	52	50	83	09	8
08	0	UNL	40			55	52	50	83	10	5
11	0	UNL	30			66	57	50	57	28	3
14	0	UNL	35			70	58	48	46	30	8
17	0	UNL	40			69	56	44	41	25	8
20	0	UNL	35			63	52	41	45	30	10
23	0	UNL	35			54	40	20	26	26	9
	NOV 25th										
02	0	UNL	35			50	39	24	36	24	6
05	0	UNL	35			46	37	22	39	27	5
08	1	UNL	60			45	36	23	42	32	4
11	0	UNL	60			54	43	28	37	26	7
14	0	UNL	60			64	47	25	23	21	8
17	0	UNL	60			64	46	21	19	27	10
20	0	UNL	35			58	40	8	13	03	9
23	0	UNL	35			52	36	6	15	01	7
	NOV 26th										
02	0	UNL	35			45	35	19	35	24	4
05	0	UNL	35			41	33	20	43	00	0
08	4	UNL	50			40	33	21	47	00	0
11	1	UNL	50			56	39	10	16	05	7
14	0	UNL	50			62	42	9	12	36	3
17	0	UNL	70			63	44	14	15	27	9
20	0	UNL	35			53	40	22	30	00	0
23	0	UNL	35			49	40	27	43	00	0
	NOV 27th										
02	0	UNL	35			45	38	27	49	26	3
05	1	UNL	35			42	37	29	60	00	0
08	8	UNL	70			42	35	24	49	11	5
11	8	UNL	60			55	42	23	29	27	4
14	7	UNL	50			64	46	22	20	32	3
17	10	UNL	40			63	44	18	18	28	6
20	10	250	35			58	44	24	27	27	5
23	10	250	35			57	44	28	33	07	4
	NOV 28th										
02	10	250	35			53	43	31	43	10	6
05	10	250	35			52	42	30	43	17	4
08	10	160	70			52	43	32	47	00	0
11	6	UNL	60			63	47	29	28	00	0
14	1	UNL	70			73	51	24	16	08	4
17	1	UNL	60			73	50	21	14	21	5
20	2	UNL	35			61	47	29	30	10	5
23	0	UNL	35			57	46	32	39	10	6
	NOV 29th										
02	5	UNL	35			51	43	32	48	09	6
05	2	UNL	35			50	42	31	48	11	8
08	5	UNL	45			50	41	30	46	12	7
11	3	UNL	45			63	47	29	28	08	7
14	0	UNL	45			72	50	24	17	14	3
17	0	UNL	50			72	50	24	17	19	4
20	0	UNL	35			61	47	32	34	26	3
23	4	UNL	35			56	45	31	39	11	7
	NOV 30th										
02	1	UNL	35			50	43	35	57	11	7
05	10	150	35			49	41	31	50	13	6
08	7	250	40			48	41	33	56	13	3
11	1	UNL	45			59	45	28	31	09	5
14	0	UNL	45			68	49	27	21	24	8
17	0	UNL	35			67	52	37	33	27	8
20	1	UNL	35			61	50	39	44	00	0
23	0	UNL	35			55	48	40	57	13	3

SUMMARY BY HOURS

HOUR L.S.T.	AVERAGES							RESULTANT WIND	
	SKY COVER (TENTHS)	STATION PRESSURE (INCHES)	TEMPERATURE			REL HUMIDITY %	WIND SPEED (MPH)	DIRECTION	SPEED (MPH)
			AIR TEMP °F	WET BULB °F	DEW POINT °F				
02	3	28.850	54	46	36	54	5.2	11	3.4
05	3	28.850	52	45	35	57	4.3	11	3.3
08	5	28.880	53	45	35	54	5.1	11	3.7
11	4	28.900	63	50	34	40	5.8	10	3.0
14	4	28.830	70	52	32	29	5.8	27	0.9
17	4	28.810	70	52	32	30	6.7	27	4.0
20	3	28.830	62	50	35	41	3.6	35	0.6
23	3	28.860	58	48	35	47	4.1	09	1.9

WEATHER CODES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXP RESSED IN KNOTS (MPH=KNOTS X 1.15).

NATIONAL CLIMATIC DATA CENTER
FEDERAL BUILDING
37 BATTERY PARK AVE
ASHEVILLE, NORTH CAROLINA 28801-2733

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

FIRST CLASS
POSTAGE AND FEES PAID
NOAA
PERMIT G-19

NOV 1993 23183
PHOENIX, AZ
USCOMM - NOAA - ASHEVILLE, NC 300

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

DATE	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												DATE
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
01																									01
02																									02
03																									03
04																									04
05																									05
06																									06
07																									07
08																									08
09																									09
10																									10
11							T	T	0.01	0.08	T				T	T	T								11
12											T	0.02	T	0.04	T								T	0.04	12
13	0.03	0.05	0.14	0.14	0.03	T	T			T	0.05	T				T	T								13
14								T	0.09	0.11	T	T	0.11	0.25	0.10	0.11	0.20	0.20	0.16	0.04	0.10	0.04	0.07	T	14
15	0.06	0.03	0.05	0.02	0.05	0.22	0.09	0.06	T	T															15
16																									16
17																									17
18																									18
19																									19
20																									20
21																									21
22																			T	T					22
23							T	T																	23
24																									24
25																									25
26																									26
27																									27
28																									28
29																									29
30																									30

DEC 1993
PHOENIX, AZ
NATIONAL WEATHER SERVICE OFC.
2633 EAST BUCKEYE ROAD

INQUIRIES/COMMENTS CALL
(704) 271-4800

SKY HARBOR INTL AIRPORT

ISSN 0198-0475

LOCAL CLIMATOLOGICAL DATA
Monthly Summary

DEC 1993
PHOENIX, AZ

LATITUDE 33° 26'N LONGITUDE 112° 01'W ELEVATION (GROUND) 1110 FEET TIME ZONE MOUNTAIN 23183

	TEMPERATURE °F					DEGREE DAYS BASE 65°F		WEATHER TYPES 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	SNOW ICE PELLETS OR ICE ON GROUND AT 0500 INCHES	PRECIPITATION		AVERAGE STATION PRESSURE IN INCHES ELEV. 1107 FEET ABOVE M.S.L.	WIND (M.P.H.)							SUNSHINE		SKY COVER (TENTHS)	
																PEAK GUST		FASTEST 1-MIN					
DATE 1	MAXIMUM 2	MINIMUM 3	AVERAGE 4	DEPARTURE FROM NORMAL 5	AVERAGE DEW POINT 6	HEATING (SEASON BEGINS WITH JUL) 7A	COOLING (SEASON BEGINS WITH JAN) 7B	8	9	WATER EQUIVALENT (INCHES) 10	SNOW, ICE PELLETS (INCHES) 11	12	RESULTANT DIR. 13	RESULTANT SPEED 14	AVERAGE SPEED 15	SPEED 16	DIRECTION 17	SPEED 18	DIRECTION 19	MINUTES 20	PERCENT OF TOTAL POSSIBLE 21	SUNRISE TO SUNSET 22	MIDNIGHT TO MIDNIGHT 23
01	71	46	59	2	37	6	0		0	0.00	0.0	28.940	28	1.8	4.6	14	W	9	27	606	100	0	0
02	73	46	60	4	32	5	0		0	0.00	0.0	28.900	28	3.3	4.4	13	NW	9	29	545	90	3	3
03	70	47	59	3	19	6	0		0	0.00	0.0	29.020	04	3.2	5.3	18	NE	13	02	604	100	0	0
04	71	44	58	2	22	7	0		0	0.00	0.0	28.940	11	3.6	4.7	15	E	10	10	603	100	0	0
05	72	43	58	2	26	7	0		0	0.00	0.0	28.820	10	2.7	3.9	12	SE	9	11	603	100	0	0
06	74	45	60	4	28	5	0		0	0.00	0.0	28.820	10	4.1	5.0	15	E	12	09	576	96	4	2
07	74	45	60	5	30	5	0		0	0.00	0.0	28.850	11	4.6	5.6	17	E	9	10	560	93	4	2
08	66	49	58	3	35	7	0		0	0.00	0.0	28.880	10	4.0	4.7	13	E	9	09	188	31	9	9
09	73	44	59	4	37	6	0		0	0.00	0.0	28.910	11	1.9	4.6	12	SE	7	12	599	100	1	1
10	76*	46	61	7	36	4	0		0	0.00	0.0	28.930	12	1.4	4.9	12	E	8	10	556	93	3	4
11	74	52	63*	9	40	2	0		0	T	0.0	28.750	09	2.6	5.4	15	NW	12	32	333	56	8	8
12	63	49	56	2	34	9	0		0	T	0.0	28.770	28	10.9	11.6	30	W	21	28	598	100	1	2
13	65	41	53	-1	30	12	0		0	0.00	0.0	28.900	10	1.2	4.3	9	E	7	10	598	100	1	1
14	69	42	56	2	32	9	0		0	0.00	0.0	28.710	11	3.9	5.8	14	E	10	11	598	100	4	2
15	59	45	52	-2	37	13	0		0	0.02	0.0	28.700	25	1.1	6.6	23	NW	15	27	434	73	4	4
16	62	40	51	-3	34	14	0		0	0.00	0.0	28.870	11	4.0	5.2	13	E	10	07	597	100	0	1
17	65	40	53	-1	31	12	0		0	0.00	0.0	28.920	10	0.8	3.2	10	E	7	28	557	93	6	5
18	70	48	59	6	34	6	0		0	0.00	0.0	28.870	14	0.7	4.0	16	E	9	29	497	83	3	4
19	62	43	53	0	35	12	0		0	0.00	0.0	28.875	11	2.9	5.2	10	SW	8	12	417	70	5	5
20	64	40	52	-1	32	13	0		0	0.00	0.0	28.930	08	2.3	5.5	12	E	9	08	538	90	0	2
21	56	43	50	-3	26	15	0		0	0.00	0.0	28.805	28	2.3	5.1	14	E	12	10	48	8	10	8
22	62	36	49	-4	20	16	0		0	0.00	0.0	28.990	02	0.9	4.9	14	NW	9	12	596	100	0	0
23	60	35*	48*	-5	14	17	0		0	0.00	0.0	28.990	02	7.1	9.3	39	N	18	02	596	100	0	0
24	61	37	49	-4	9	16	0		0	0.00	0.0	29.200	17	0.3	4.6	21	N	12	23	596	100	0	0
25	71	37	54	1	21	11	0		0	0.00	0.0	29.000	08	6.6	7.2	23	E	17	07	578	97	3	3
26	68	47	58	5	24	7	0		0	0.00	0.0	28.870	11	4.6	6.1	14	E	12	10	505	85	10	8
27	67	50	59	6	33	6	0		0	0.00	0.0	28.935	10	2.8	4.9	12	E	9	11	390	65	10	10
28	71	51	61	8	39	4	0		0	0.00	0.0	29.020	27	1.5	3.4	12	W	10	27	566	95	1	3
29	71	46	59	6	34	6	0		0	0.00	0.0	29.010	07	3.3	4.9	21	E	14	07	598	100	0	0
30	69	55	62	9	35	3	0		0	0.00	0.0	28.950	07	8.6	9.6	24	E	21	08	568	95	1	3
31	73	51	62	9	40	3	0		0	0.00	0.0	28.900	11	2.9	3.9	13	E	9	10	576	96	2	3
	SUM	SUM				TOTAL	TOTAL	NUMBER OF DAYS		TOTAL	TOTAL	FOR THE MONTH:								TOTAL	% FOR MONTH	SUM	SUM
	2102	1383				264	0			0.02	0.0	28.900	09	1.6	5.4	39	N	21	08	16224		93	93
	AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION		DEP.						DATE:23		DATE: 30+		POSSIBLE		AVG.	AVG.
	67.8	44.6	56.2	2.1	30.2	-81	-7	≥ .01 INCH.	1	-0.98										18557	87	3.0	3.0

NUMBER OF DAYS				SEASON TO DATE		SNOW, ICE PELLETS ≥ 1.0 INCH	0	GREATEST IN 24 HOURS AND DATES				GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE
				TOTAL	TOTAL							
MAXIMUM TEMP.		MINIMUM TEMP.		389	4484	THUNDERSTORMS	0	PRECIPITATION		SNOW, ICE PELLETS		
≥ 90°	≤ 32°	≤ 32°	≤ 0°	DEP.	DEP.	HEAVY FOG	0	0.02	15	0.0		0
0	0	0	0	-107	322	CLEAR 20	PARTLY CLOUDY 6	CLOUDY 5				

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
\+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS. COLS 16 & 17: PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED. ONE OF TWO WIND SPEEDS IS GIVEN UNDER COLS 18 & 19: FASTEST MILE - HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTION IN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES). ERRORS WILL BE CORRECTED IN SUBSEQUENT PUBLICATIONS.

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER

Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

noaa
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE
NATIONAL CLIMATIC DATA CENTER ASHEVILLE NORTH CAROLINA

OBSERVATIONS AT 3-HOUR INTERVALS

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					DEC 1st											DEC 2nd											DEC 3rd						
02	0	UNL	35			51	45	39	64	09	4	0	UNL	35			50	44	37	61	29	3	0	UNL	35			50	42	32	50	27	3
05	0	UNL	35			48	44	39	71	13	5	0	UNL	35			48	42	35	61	00	0	0	UNL	35			47	41	33	58	13	5
08	0	UNL	45			47	43	39	74	00	0	1	UNL	35			48	40	30	50	34	4	0	UNL	70			56	40	14	19	03	8
11	0	UNL	40			60	49	38	44	26	3	1	UNL	35			65	48	29	26	07	3	0	UNL	70			63	43	11	13	02	11
14	0	UNL	45			68	52	36	31	29	7	3	UNL	35			70	50	28	21	27	3	0	UNL	70			68	45	9	10	27	6
17	0	UNL	50			70	52	33	26	27	7	8	UNL	50			70	51	30	23	27	7	0	UNL	70			68	45	10	10	00	0
20	0	UNL	35			60	49	38	44	27	3	8	160	35			62	49	34	35	00	0	0	UNL	35			57	43	22	26	02	3
23	0	UNL	35			55	47	38	53	27	3	1	UNL	35			56	45	31	39	00	0	0	UNL	35			54	42	24	31	07	4
					DEC 4th											DEC 5th											DEC 6th						
02	0	UNL	35			47	38	25	42	00	0	0	UNL	35			47	40	31	54	11	4	0	UNL	35			49	41	30	48	09	10
05	0	UNL	35			44	36	24	45	00	0	0	UNL	35			45	38	27	49	10	4	0	UNL	35			48	39	27	44	10	6
08	0	UNL	70			47	37	21	36	10	7	0	UNL	70			45	37	25	46	09	5	3	UNL	50			47	39	27	46	10	4
11	0	UNL	70			60	43	18	20	11	8	0	UNL	70			61	45	23	23	13	3	3	UNL	50			60	45	25	26	09	7
14	0	UNL	70			68	47	19	15	13	6	0	UNL	70			69	48	22	17	00	0	7	UNL	50			70	49	25	18	10	3
17	0	UNL	70			68	47	17	14	14	6	0	UNL	60			70	49	22	16	00	0	3	UNL	50			71	49	23	16	00	0
20	0	UNL	35			57	43	24	28	27	3	0	UNL	35			57	45	30	36	00	0	0	UNL	35			59	47	32	36	27	3
23	0	UNL	35			51	42	29	43	00	0	0	UNL	35			53	43	30	42	13	5	0	UNL	35			52	42	30	43	11	6
					DEC 7th											DEC 8th											DEC 9th						
02	0	UNL	35			48	41	31	52	11	6	7	UNL	35			49	43	35	59	11	4	6	UNL	35			49	45	41	74	11	4
05	2	UNL	35			47	39	29	50	07	6	9	250	35			50	42	32	50	12	5	0	UNL	35			45	42	39	80	36	4
08	7	UNL	70			46	39	29	52	07	4	9	250	45			51	42	31	47	10	7	0	UNL	35			47	42	36	66	07	5
11	3	UNL	60			60	45	27	29	09	7	10	250	45			58	46	33	39	08	5	2	UNL	35			59	48	36	42	13	3
14	6	UNL	60			70	49	25	18	13	5	10	250	45			65	50	33	30	13	4	0	UNL	35			70	53	36	29	36	4
17	1	UNL	60			72	51	26	18	13	4	9	200	45			63	50	36	37	00	0	0	UNL	40			70	53	35	28	31	3
20	0	UNL	35			58	47	34	41	00	0	9	200	35			57	49	40	53	34	3	0	UNL	35			60	50	39	46	31	3
23	0	UNL	35			54	46	36	51	11	6	8	200	35			53	47	40	62	00	0	0	UNL	35			54	47	40	59	08	3
					DEC 10th											DEC 11th											DEC 12th						
02	0	UNL	30			51	45	38	61	11	4	9	180	35			54	46	37	53	09	4	10	60	35			59	53	47	65	00	0
05	0	UNL	35			47	42	37	68	10	7	7	140	35			54	47	40	59	10	8	0	UNL	35			55	47	39	55	29	14
08	0	UNL	35			47	42	36	66	14	5	8	140	50			55	48	40	57	12	3	0	UNL	50			51	45	37	59	28	9
11	1	UNL	50			62	48	33	34	14	3	7	140	45			65	51	38	37	09	5	0	UNL	60			57	46	32	39	29	16
14	3	UNL	50			71	53	35	27	32	3	9	140	25			71	55	40	33	27	7	2	UNL	60			61	47	31	32	27	12
17	8	UNL	45			72	53	35	26	26	6	6	UNL	35			70	53	37	30	26	3	0	UNL	60			62	47	28	28	27	11
20	9	UNL	35			62	50	38	41	28	4	10	100	35			64	52	41	43	10	5	0	UNL	35			54	43	30	40	27	5
23	10	250	35			58	48	37	46	13	3	9	90	35		RW	60	52	45	58	33	6	0	UNL	35			51	41	27	40	28	6
					DEC 13th											DEC 14th											DEC 15th						
02	0	UNL	35			46	40	31	56	08	3	0	UNL	35			45	40	34	66	09	7	3	UNL	35			46	42	37	71	00	0
05	0	UNL	35			42	39	34	73	14	4	2	UNL	35			43	38	32	65	07	4	3	UNL	35			47	41	33	58	27	4
08	0	UNL	70			43	38	31	63	08	5	5	UNL	45			43	38	32	65	08	7	1	UNL	35			47	41	34	61	00	0
11	1	UNL	50			55	44	30	39	12	5	7	UNL	45			56	44	28	34	11	9	1	UNL	45			55	46	35	47	27	11
14	0	UNL	50			62	45	24	23	35	3	5	UNL	45			64	48	29	27	14	5	5	UNL	45			59	47	34	39	24	12
17	2	UNL	60			62	46	27	27	31	4	0	UNL	45			66	50	33	29	14	3	8	60	45		RW	51	45	39	64	06	4
20	3	UNL	35			55	45	32	42	26	4	0	UNL	35			55	45	34	45	33	3	2	UNL	35			49	45	41	74	08	5
23	2	UNL	35			49	42	33	54	08	3	0	UNL	35			49	43	36	61	00	0	5	UNL	35			47	43	39	74	10	4
					DEC 16th											DEC 17th											DEC 18th						
02	0	UNL	35			45	42	38	77	11	7	0	UNL	35			43	39	33	68	27	3	9	250	35			49	43	36	61	00	0
05	0	UNL	35			41	39	36	83	12	7	0	UNL	35			40	37	34	79	23	3	10	180	35			49	42	32	52	13	3
08	0	UNL	35			40	38	36	86	11	6	3	UNL	50			42	38	33	71	00	0	8	180	35			49	42	34	56	09	6
11	0	UNL	35			49	43	35	59	11	6	6	UNL	45			54	44	32	43	00	0	3	UNL	45			57	47	35	44	00	0
14	0	UNL	35			59	47	33	38	06	3	6	UNL	50			61	46	26	26	09	5	0	UNL	50			67	51	33	28	09	5
17	1	UNL	45			59	45	27	30	23	4	8	UNL	50			62	45	24	23	12	3	1	UNL	45			66	50	34	31	28	6
20	3	UNL	35			51	43	34	52	00	0	8	UNL	35			53	44	33	47	00	0	0	UNL	35			56	45	32	40	27	3
23	0	UNL	35			47	41	34	61	14	3	9	250	35			51	43	32	48	00	0	2	UNL	35			51	43	33	50	00	0

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
ENDED: DATE	15	15	15	15	15	15	15	15	15	15	15	15
ENDED: TIME	1719	1719	1719	1719	1719	1719	1719	1719	1719	1759	1759	1759

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

DEC 1993
PHOENIX, AZ

23183

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISI-BILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					DEC 19th						
02	9	UNL	35			49	42	34	56	07	4
05	7	UNL	35			46	41	35	66	10	6
08	7	UNL	35			43	40	36	76	00	0
11	3	UNL	40			50	44	37	61	13	5
14	5	UNL	35			60	47	33	36	13	3
17	7	250	35			59	47	33	38	27	5
20	0	UNL	35			53	45	35	51	07	3
23	0	UNL	35			49	43	35	59	11	4
					DEC 22nd						
02	0	UNL	35			40	37	32	73	13	4
05	0	UNL	35			37	35	33	86	01	3
08	0	UNL	35			38	36	32	79	12	8
11	0	UNL	35			54	39	13	20	10	7
14	0	UNL	35			59	41	9	14	28	6
17	0	UNL	70			60	41	8	13	31	5
20	0	UNL	35			50	37	14	24	34	3
23	0	UNL	35			44	34	17	34	13	4
					DEC 25th						
02	0	UNL	35			44	34	17	34	11	7
05	0	UNL	35			39	32	19	45	00	0
08	1	UNL	60			41	33	19	41	00	0
11	1	UNL	70			61	43	17	18	07	14
14	4	UNL	70			69	48	19	15	09	11
17	6	UNL	70			69	48	22	17	09	7
20	4	UNL	35			61	44	22	22	08	6
23	2	UNL	35			54	41	23	30	13	4
					DEC 28th						
02	6	90	35			56	47	36	47	00	0
05	7	95	35			53	46	39	59	00	0
08	6	85	40			51	46	40	66	00	0
11	1	UNL	35			63	51	38	40	16	5
14	0	UNL	35			69	54	39	34	32	4
17	0	UNL	50			69	54	40	35	27	9
20	0	UNL	35			61	51	41	48	28	5
23	0	UNL	35			56	49	42	60	00	0
					DEC 31st						
02	10	UNL	35			54	47	40	59	23	3
05	10	250	35			52	46	39	61	10	4
08	7	UNL	45			52	45	38	59	11	7
11	1	UNL	45			62	51	40	45	07	5
14	0	UNL	45			70	54	40	34	11	4
17	0	UNL	45			70	54	40	34	31	4
20	0	UNL	35			60	50	41	50	00	0
23	0	UNL	35			55	49	42	62	00	0

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISI-BILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					DEC 20th						
02	2	UNL	35			44	40	34	68	09	6
05	0	UNL	35			41	38	34	76	00	0
08	0	UNL	35			41	38	34	76	11	3
11	0	UNL	25			54	45	34	47	15	3
14	0	UNL	50			62	46	27	27	11	3
17	0	UNL	50			63	46	25	24	33	4
20	2	UNL	35			53	44	33	47	22	4
23	8	140	35			52	43	31	45	34	3
					DEC 23rd						
02	0	UNL	35			40	33	20	45	36	3
05	0	UNL	35			36	31	21	55	36	4
08	0	UNL	50			35	30	22	59	13	5
11	0	UNL	40			47	36	17	30	29	9
14	0	UNL	50			60	41	9	13	03	16
17	0	UNL	50			57	40	11	16	03	14
20	0	UNL	35			53	37	8	16	02	11
23	0	UNL	35			51	36	6	16	05	6
					DEC 26th						
02	8	UNL	35			50	39	24	36	10	6
05	4	UNL	35			49	38	19	30	13	7
08	9	UNL	60			48	37	19	32	10	5
11	10	250	60			59	44	23	25	13	4
14	10	250	70			67	48	23	19	11	7
17	10	180	70			66	48	26	22	23	3
20	10	250	35			58	46	31	36	24	4
23	9	250	35			53	44	32	45	10	3
					DEC 29th						
02	0	UNL	35			50	46	41	71	18	5
05	0	UNL	35			47	44	40	77	00	0
08	0	UNL	45			47	43	38	71	00	0
11	0	UNL	35			62	49	34	35	14	4
14	0	UNL	60			69	50	30	23	03	8
17	0	UNL	70			69	50	29	23	05	5
20	0	UNL	35			62	47	29	29	02	8
23	0	UNL	35			61	46	28	29	08	8

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISI-BILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					DEC 21st						
02	10	140	35			48	39	26	42	27	6
05	10	130	35			47	37	22	37	28	7
08	10	130	35			49	39	23	36	23	5
11	10	140	40			52	41	25	35	27	3
14	10	140	40			54	43	28	37	11	5
17	10	140	40			55	43	28	36	23	5
20	5	UNL	35			50	41	29	45	23	4
23	0	UNL	35			46	38	27	48	01	5
					DEC 24th						
02	0	UNL	35			47	34	6	19	23	10
05	0	UNL	35			40	30	10	29	10	4
08	0	UNL	60			37	29	11	34	33	3
11	0	UNL	70			53	38	11	19	05	7
14	0	UNL	70			59	40	6	12	10	4
17	0	UNL	70			59	40	4	11	27	4
20	0	UNL	35			50	37	13	23	23	3
23	0	UNL	35			46	35	16	30	12	4
					DEC 27th						
02	10	250	35			51	43	33	50	09	5
05	10	140	35			51	43	32	48	11	5
08	10	200	45			52	43	32	47	09	5
11	10	130	40			58	47	34	41	07	6
14	10	120	40			65	49	32	29	12	5
17	10	95	40			65	50	33	30	33	3
20	10	90	35			62	49	34	35	27	3
23	7	110	35			58	47	35	42	00	0
					DEC 30th						
02	0	UNL	35			58	45	29	33	06	9
05	0	UNL	35			56	44	30	37	08	10
08	0	UNL	60			56	45	33	42	07	13
11	0	UNL	60			63	50	37	38	07	15
14	0	UNL	60			68	52	37	32	06	8
17	8	UNL	50			68	52	37	32	05	6
20	7	UNL	35			61	50	39	44	26	3
23	9	UNL	35			57	48	39	51	12	4

SUMMARY BY HOURS

HOUR L.S.T.	AVERAGES							RESULTANT WIND	
	SKY COVER (TENTHS)	STATION PRESSURE (INCHES)	TEMPERATURE			REL HUMIDITY %	WIND SPEED (MPH)	DIRECTION	SPEED (MPH)
			AIR TEMP °F	WET BULB °F	DEW POINT °F				
02	3	28.900	49	42	32	55	5.0	11	2.6
05	3	28.900	46	40	31	58	5.2	10	2.4
08	3	28.930	46	40	30	56	5.2	09	3.4
11	3	28.960	58	45	29	35	7.1	09	3.2
14	3	28.880	65	48	27	25	6.6	07	1.3
17	3	28.860	65	48	27	26	5.4	29	1.8
20	3	28.885	57	45	32	40	3.9	31	1.3
23	3	28.910	52	43	32	47	3.6	09	2.0

WEATHER CODES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXP RESSED IN KNOTS (MPH=KNOTS X 1.15).

NATIONAL CLIMATIC DATA CENTER
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ASHEVILLE, NORTH CAROLINA 28801-2733

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DEC 1993 23183
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HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

DATE	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												DATE
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
01																									01
02																									02
03																									03
04																									04
05																									05
06																									06
07																									07
08																									08
09																									09
10																									10
11																					T	T	T	T	11
12		T																							12
13																									13
14																									14
15																T	0.01	0.01							15
16																									16
17																									17
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30																									30
31																									31

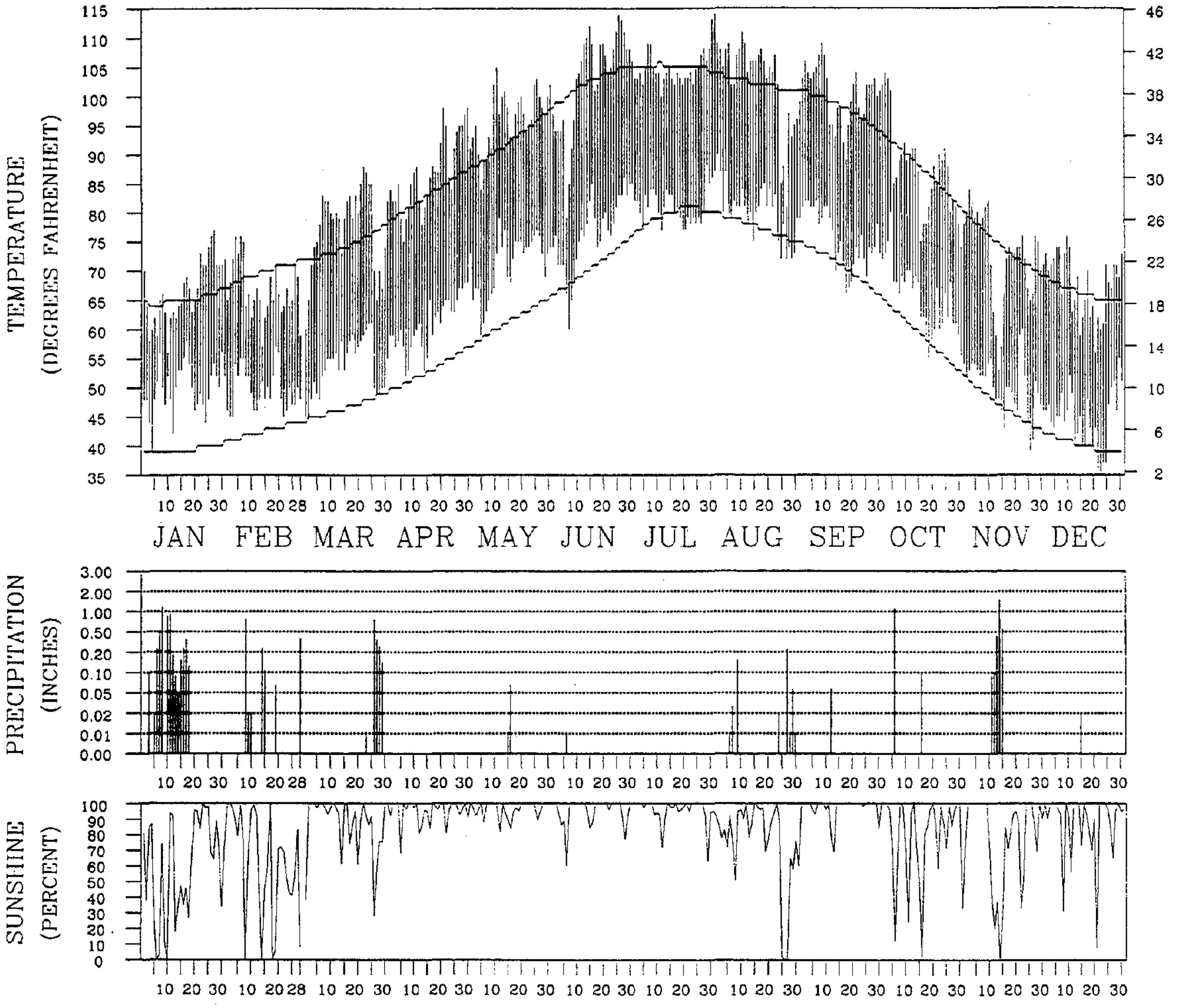
ISSN 0198-0572

1993 LOCAL CLIMATOLOGICAL DATA
ANNUAL SUMMARY WITH COMPARATIVE DATA

PHOENIX,
ARIZONA

DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA

Daily Data



TEMPERATURE DEPICTS NORMAL MAXIMUM, NORMAL MINIMUM AND ACTUAL DAILY HIGH AND LOW VALUES (FAHRENHEIT)
PRECIPITATION IS MEASURED IN INCHES. SCALE IS NON-LINEAR
SUNSHINE IS PERCENT OF THE POSSIBLE SUNSHINE

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER, ASHEVILLE, NORTH CAROLINA, 28801

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CLIMATIC DATA CENTER
ASHEVILLE NORTH CAROLINA

Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

METEOROLOGICAL DATA FOR 1993

PHOENIX, ARIZONA

LATITUDE: 33°26′ N LONGITUDE: 112°01′ W ELEVATION: FT. GRND 1110 BARO 1109 TIME ZONE: MOUNTAIN WBAN: 23183

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F:													
Averages													
-Daily Maximum	66.6	66.8	77.6	86.8	96.3	103.0	104.6	102.9	100.3	87.8	72.6	67.8	86.1
-Daily Minimum	49.8	49.6	53.7	60.7	71.1	76.2	81.1	80.2	75.5	65.5	50.1	44.6	63.2
-Monthly	58.2	58.2	65.7	73.8	83.7	89.6	92.9	91.6	87.9	76.7	61.4	56.2	74.7
-Monthly Dewpt.	44.1	41.3	44.2	33.9	41.2	39.0	51.4	58.7	48.0	44.2	34.4	30.2	42.6
Extremes													
-Highest	77	76	88	98	105	114	113	114	109	104	84	76	114
-Date	27	6	22	30	11	26	31	1	9	3	3	10	AUG 1
-Lowest	39	45	45	52	59	60	77	72	66	55	39	35	35
-Date	4	22	2	7	5	7	21	29	18	31	26	23	DEC 23
DEGREE DAYS BASE 65 °F:													
Heating	205	184	61	0	0	0	0	0	0	0	125	264	839
Cooling	1	1	89	271	585	746	871	832	695	369	24	0	4484
% OF POSSIBLE SUNSHINE	59	62	86	95	96	95	96	76	97	79	77	87	85
AVG. SKY COVER (tenths)													
Sunrise - Sunset	7.3	6.3	4.1	3.1	2.3	1.8	2.1	3.5	0.5	3.4	4.1	3.0	3.5
Midnight - Midnight	6.6	6.2	3.5	2.9	2.0	1.6	2.1	4.0	0.6	3.2	3.5	3.0	3.3
NUMBER OF DAYS:													
Sunrise to Sunset													
-Clear	5	8	14	20	20	23	24	17	29	19	15	20	214
-Partly Cloudy	9	7	10	5	10	6	7	11	1	6	5	6	83
-Cloudy	17	13	7	5	1	1	0	3	0	6	10	5	68
Precipitation .01 inches or more	14	7	5	0	2	1	0	8	1	2	5	1	46
Snow, Ice pellets, hail 1.0 inches or more	0	0	0	0	0	0	0	0	0	0	0	0	0
Thunderstorms	1	3	3	0	1	0	0	4	1	2	0	0	15
Heavy Fog, visibility 1/4 mile or less	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature °F													
-Maximum													
90° and above	0	0	0	9	28	28	31	28	29	12	0	0	165
32° and below	0	0	0	0	0	0	0	0	0	0	0	0	0
-Minimum													
32° and below	0	0	0	0	0	0	0	0	0	0	0	0	0
0° and below	0	0	0	0	0	0	0	0	0	0	0	0	0
AVG. STATION PRESS. (mb)	976.3	976.3	976.3	971.2	970.0	967.8	970.4	971.2	971.6	973.9	977.0	978.7	973.2
RELATIVE HUMIDITY (%)													
Hour 05	79	75	71	41	36	28	37	52	41	49	57	58	52
Hour 11 (Local Time)	60	56	44	21	20	16	24	33	26	31	40	35	34
Hour 17	49	43	31	14	15	11	18	27	17	24	30	26	25
Hour 23	69	61	52	24	24	18	26	42	28	39	47	47	40
PRECIPITATION (inches):													
Water Equivalent													
-Total	5.22	1.72	1.62	0.00	0.08	0.01	T	0.55	0.06	1.27	2.79	0.02	13.34
-Greatest (24 hrs)	1.84	0.84	1.18	0.00	0.08	0.01	T	0.26	0.06	1.17	2.16	0.02	2.16
-Date	10-11	8- 9	26-27		15-16	6	12	27-28	12	6	14-15	15	NOV 14-15
Snow, Ice pellets, hail													
-Total	T	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	T
-Greatest (24 hrs)	T	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	T
-Date	18												JAN 18
WIND:													
Resultant													
-Direction (!!!)	078	074	126	227	262	254	258	129	120	086	100	085	116
-Speed (mph)	2.2	1.3	1.3	1.1	1.6	1.7	1.3	1.7	1.2	2.4	1.3	1.6	0.6
Average Speed (mph)	5.9	6.2	6.8	4.8	5.1	4.2	4.6	5.8	4.4	5.5	4.9	5.4	5.3
Fastest Obs. 1 Min.													
-Direction (!!!)	27	27	25	25	12	25	14	31	11	06	27	08	25
-Speed (mph)	25	18	29	18	24	18	23	23	24	26	24	21	29
-Date	18	20	26	30	15	6	11	6	10	27	11	30	MAR 26
Peak Gust													
-Direction (!!!)	W	W	W	W	E	W	SE	NW	E	NE	W	N	NW
-Speed (mph)	33	30	39	28	40	30	30	45	31	36	37	39	45
-Date	18	28	26	30	15	6	11	6	10	27	11	23	AUG 6

(!!!) See Reference Notes on Page 68

NORMALS, MEANS, AND EXTREMES

PHOENIX, ARIZONA

LATITUDE: 33°26'N LONGITUDE: 112°01' W ELEVATION: FT. GRND 1110 BARO 1109 TIME ZONE: MOUNTAIN WBAN: 23183

	(a)	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F:														
Normals														
-Daily Maximum		65.9	70.7	75.5	84.5	93.6	103.5	105.9	103.7	98.3	88.1	74.9	66.2	85.9
-Daily Minimum		41.2	44.7	48.8	55.3	63.9	72.9	81.0	79.2	72.8	60.8	48.9	41.8	59.3
-Monthly		53.6	57.7	62.2	69.9	78.8	88.2	93.5	91.5	85.6	74.5	61.9	54.1	72.6
Extremes														
-Record Highest	56	88	92	100	105	113	122	118	116	118	107	93	88	122
-Year		1971	1986	1988	1992	1984	1990	1989	1975	1950	1980	1988	1950	JUN 1990
-Record Lowest	56	17	22	25	32	40	50	61	60	47	34	25	22	17
-Year		1950	1948	1966	1945	1967	1944	1944	1942	1965	1971	1938	1948	JAN 1950
NORMAL DEGREE DAYS:														
Heating (base 65°F)		362	227	182	75	8	0	0	0	0	17	134	345	1350
Cooling (base 65°F)		8	22	95	222	436	696	884	822	618	311	41	7	4162
% OF POSSIBLE SUNSHINE	98	78	80	84	89	93	94	85	85	89	88	84	78	86
MEAN SKY COVER (tenths)														
Sunrise - Sunset	48	4.7	4.6	4.3	3.4	2.7	1.9	3.7	3.3	2.3	2.8	3.4	4.1	3.4
MEAN NUMBER OF DAYS:														
Sunrise to Sunset														
-Clear	56	13.9	12.6	14.4	17.2	20.8	23.1	16.6	17.6	21.6	20.3	17.7	15.3	211.0
-Partly Cloudy	56	7.0	6.7	8.1	7.3	6.8	4.7	10.3	9.6	5.4	6.2	6.2	6.3	84.6
-Cloudy	56	10.1	8.9	8.5	5.6	3.5	2.2	4.2	3.8	3.0	4.4	6.1	9.4	69.7
Precipitation .01 inches or more	54	4.1	3.9	3.7	1.7	1.0	0.7	4.2	4.9	2.9	2.7	2.6	3.9	36.5
Snow,Ice pellets,hail 1.0 inches or more	56	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thunderstorms	54	0.4	0.6	0.9	0.7	1.0	1.0	6.1	7.1	3.5	1.4	0.5	0.6	23.7
Heavy Fog Visibility 1/4 mile or less	56	0.6	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.*	0.2	0.5	1.6
Temperature °F														
-Maximum														
90° and above	33	0.0	0.1	2.0	9.8	23.1	29.2	30.9	30.6	27.6	15.2	0.5	0.0	169.0
32° and below	33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-Minimum														
32° and below	33	3.3	1.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.8	7.0
0° and below	33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AVG. STATION PRESS.(mb)	21	978.3	977.5	974.4	972.6	970.6	969.7	971.2	971.6	971.7	974.0	976.5	978.3	973.9
RELATIVE HUMIDITY (%)														
Hour 05	33	67	60	57	43	35	31	44	51	49	50	57	67	51
Hour 11 (Local Time)	33	46	39	34	23	19	16	28	33	31	30	36	46	32
Hour 17	33	33	27	24	16	13	12	20	23	23	22	27	34	23
Hour 23	33	56	48	43	28	23	20	33	38	38	40	48	57	39
PRECIPITATION (inches):														
Water Equivalent														
-Normal		0.67	0.68	0.88	0.22	0.12	0.13	0.83	0.96	0.86	0.65	0.66	1.00	7.66
-Maximum Monthly	56	5.22	2.23	4.16	2.10	1.06	1.70	5.15	5.56	4.23	4.40	3.04	3.98	5.56
-Year		1993	1944	1941	1941	1976	1972	1984	1951	1939	1972	1952	1967	AUG 1951
-Minimum Monthly	56	0.00	0.00	0.00	0.00	0.00	0.00	T	T	0.00	0.00	0.00	0.00	0.00
-Year		1972	1967	1959	1962	1983	1983	1993	1975	1973	1973	1980	1981	MAY 1983
-Maximum in 24 hrs	56	1.84	1.49	2.04	1.38	0.96	1.64	2.75	3.07	2.43	2.32	2.16	1.89	3.07
-Year		1993	1987	1983	1941	1976	1972	1984	1943	1970	1988	1993	1967	AUG 1943
Snow,Ice pellets,hail														
-Maximum Monthly	56	T	0.6	T	T	T	0.0	0.0	0.0	0.0	T	0.0	0.4	0.6
-Year		1993	1939	1991	1949	1992					1992		1990	FEB 1939
-Maximum in 24 hrs	56	T	0.6	T	T	T	0.0	0.0	0.0	0.0	T	0.0	0.4	0.6
-Year		1993	1939	1991	1949	1992					1992		1990	FEB 1939
WIND:														
Mean Speed (mph)	48	5.3	5.9	6.7	6.9	7.0	6.8	7.1	6.6	6.3	5.8	5.3	5.1	6.2
Prevailing Direction through 1963		E	E	E	E	E	E	W	E	E	E	E	E	E
Fastest Obs. 1 Min.														
-Direction (!!)	8	27	14	26	27	11	03	08	10	05	21	29	09	26
-Speed (MPH)	8	32	26	35	28	35	31	35	35	35	28	29	26	35
-Year		1988	1992	1992	1986	1992	1986	1991	1989	1990	1986	1990	1988	MAR 1992
Peak Gust														
-Direction (!!)	56	W	W	W	W	SSE	NE	SE	E	SW	W	W	W	SE
-Speed (mph)	56	60	54	51	49	59	73	86	78	75	61	60	68	86
-Date		1983	1980	1989	1981	1954	1978	1976	1978	1950	1981	1982	1953	JUL 1976

(!!) See Reference Notes on Page 6B.

PRECIPITATION (inches)

PHOENIX, ARIZONA

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1964	0.22	0.01	0.37	0.10	T	0.00	0.60	1.29	1.80	0.17	0.35	1.09	6.00
1965	1.22	0.91	1.39	1.35	0.16	0.91	0.16	0.18	0.60	0.20	0.92	3.19	11.19
1966	0.35	0.95	0.34	T	T	0.22	0.09	2.17	2.00	0.25	0.38	0.52	7.27
1967	0.25	0.00	0.43	0.08	0.05	0.47	0.99	0.02	0.13	0.67	1.27	3.98	8.34
1968	0.19	1.20	1.04	T	T	0.00	1.70	0.59	0.00	0.35	0.91	0.69	6.67
1969	1.37	0.78	0.56	0.03	0.26	0.00	0.28	0.14	2.11	0.08	0.65	0.68	6.94
1970	T	0.30	2.26	T	T	0.00	0.48	1.02	2.85	0.44	0.02	0.26	7.63
1971	0.22	0.35	T	0.13	T	0.00	0.24	0.99	0.92	0.27	T	0.47	3.59
1972	0.00	T	T	T	T	1.70	0.72	1.20	0.28	4.40	1.01	1.56	10.87
1973	0.13	1.36	1.69	0.07	0.10	T	1.30	T	0.00	0.00	1.36	0.00	6.01
1974	0.57	0.02	1.37	0.01	0.00	0.00	0.84	1.15	1.07	2.12	0.44	0.59	8.18
1975	0.02	0.33	0.63	0.43	T	T	0.38	T	0.82	0.23	0.55	1.12	4.51
1976	T	0.47	0.40	0.67	1.06	0.09	1.48	0.12	1.69	0.70	0.43	0.85	7.96
1977	0.35	0.06	0.27	0.06	0.16	0.10	0.30	0.18	0.53	0.61	T	0.54	3.16
1978	2.33	2.21	2.14	0.20	T	0.01	1.44	1.79	T	0.35	2.30	2.46	15.23
1979	2.16	0.09	1.78	0.02	0.76	0.04	0.34	1.18	0.09	0.09	0.12	0.13	6.80
1980	1.58	2.09	0.86	0.44	0.21	0.03	0.56	0.06	0.13	0.02	0.00	0.08	6.06
1981	0.71	1.08	0.98	0.20	0.03	T	1.14	0.11	0.18	1.34	0.95	0.00	6.72
1982	0.81	0.67	1.30	T	0.50	T	0.43	1.97	0.12	T	2.50	1.64	9.94
1983	0.70	1.17	3.17	0.18	0.00	0.00	0.38	2.48	2.43	0.71	0.43	1.16	12.81
1984	0.31	0.00	0.00	0.91	0.18	0.18	5.15	0.87	3.36	0.31	0.71	2.93	14.91
1985	0.95	0.18	0.46	0.17	T	0.00	0.98	0.21	1.60	0.92	1.59	0.86	7.92
1986	0.07	1.19	1.58	0.01	T	0.01	1.19	1.27	0.47	0.41	0.03	1.38	7.61
1987	0.67	2.06	0.28	0.09	0.06	0.01	1.08	0.45	0.57	0.47	1.04	1.62	8.40
1988	0.90	0.23	0.17	1.09	0.00	0.02	0.87	0.63	0.00	2.38	0.78	0.14	7.21
1989	1.19	T	1.25	0.00	T	0.00	0.13	1.11	0.47	0.46	0.14	0.19	4.94
1990	0.80	0.70	0.35	0.17	0.16	0.04	1.05	2.70	1.11	0.04	0.15	0.46	7.73
1991	0.63	0.56	2.05	0.00	0.00	T	0.14	0.12	0.81	1.16	1.25	1.63	8.35
1992	1.62	0.90	2.49	0.49	1.05	0.04	2.95	1.30	0.03	0.26	0.03	3.08	14.24
1993	5.22	1.72	1.62	0.00	0.08	0.01	T	0.55	0.06	1.27	2.79	0.02	13.34
Record Mean	0.82	0.74	0.77	0.33	0.14	0.09	0.93	1.01	0.78	0.53	0.65	0.91	7.71

See Reference Notes on Page 6B.

Page 4A

AVERAGE TEMPERATURE (deg. F)

PHOENIX, ARIZONA

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1964	46.7	49.3	56.5	65.2	73.7	82.6	90.6	86.2	80.9	74.9	55.5	52.0	67.8
1965	52.7	52.4	56.1	63.4	71.8	79.0	91.0	89.0	79.2	73.8	62.1	52.9	68.6
1966	48.2	49.7	61.2	69.8	80.1	86.8	93.0	90.9	82.9	70.9	60.5	52.0	70.5
1967	50.7	55.7	62.8	62.4	75.1	81.1	91.6	91.0	84.8	73.5	63.9	48.2	70.1
1968	52.4	59.7	59.9	66.7	76.6	86.2	90.2	86.5	83.6	72.7	59.2	49.5	70.3
1969	54.9	53.0	56.9	68.5	78.3	84.2	93.1	94.4	86.0	69.5	62.1	54.8	71.3
1970	52.1	60.2	59.5	64.7	79.6	88.1	95.0	92.5	82.2	69.1	61.4	52.6	71.4
1971	52.2	56.3	63.3	66.5	73.3	85.3	94.9	89.6	85.6	69.3	59.7	50.2	70.5
1972	51.4	59.1	70.6	71.4	78.3	87.8	94.4	89.9	84.8	71.9	58.1	52.1	72.5
1973	51.2	57.5	56.6	67.2	80.9	88.1	93.5	93.4	84.7	74.4	60.8	55.4	72.0
1974	54.0	56.7	64.5	70.6	80.2	92.2	92.4	91.2	87.2	75.9	61.5	50.6	73.1
1975	52.3	54.0	59.0	62.6	76.7	86.6	94.3	91.9	86.2	72.9	60.9	54.8	71.0
1976	55.4	60.7	61.5	68.7	80.7	87.9	91.6	90.7	83.0	74.0	64.1	55.6	72.8
1977	53.8	61.7	60.8	73.5	75.7	91.4	95.0	94.1	87.6	78.7	65.8	59.9	74.9
1978	56.6	58.7	65.6	69.2	78.5	90.9	94.6	91.4	86.3	78.6	61.5	51.7	73.6
1979	50.1	55.7	60.4	70.1	78.1	89.5	93.8	89.4	90.2	77.2	58.2	55.9	72.4
1980	56.6	60.6	60.7	69.8	76.0	88.9	95.6	92.2	87.3	75.6	64.1	61.3	74.0
1981	59.2	61.4	63.8	76.0	80.5	93.4	95.2	95.8	89.2	73.6	66.1	58.6	76.0
1982	53.9	60.1	62.4	72.5	80.4	88.1	93.7	93.7	86.7	73.5	61.9	54.1	73.4
1983	56.0	58.4	62.2	66.6	80.6	88.6	95.5	92.6	91.0	77.2	62.4	57.2	74.0
1984	57.4	60.1	67.6	70.7	87.0	88.9	91.7	91.2	87.5	71.4	61.9	53.7	74.1
1985	54.3	57.4	62.8	75.1	84.2	92.4	94.9	94.5	82.3	75.1	61.3	55.9	74.2
1986	61.4	61.0	69.3	74.2	82.3	92.8	92.3	94.5	84.1	74.7	65.0	56.4	75.7
1987	54.7	59.7	63.4	77.9	82.6	93.0	93.1	92.2	86.9	80.9	63.1	52.7	75.0
1988	55.1	62.5	66.3	73.0	81.4	93.1	96.2	93.9	87.4	82.4	64.4	55.7	76.0
1989	54.4	61.9	70.1	80.1	83.1	92.1	97.4	93.7	89.9	77.3	66.4	57.0	77.0
1990	55.6	56.6	67.2	76.2	81.1	93.8	93.6	90.8	87.6	78.7	65.9	53.6	75.1
1991	55.9	66.0	60.3	72.2	79.7	87.8	95.1	94.5	88.5	80.2	63.5	57.3	75.1
1992	56.4	62.1	64.7	77.0	83.1	90.1	92.8	92.3	90.5	79.8	61.5	53.8	75.3
1993	58.2	58.2	65.7	73.8	83.7	89.6	92.9	91.6	87.9	76.7	61.4	56.2	74.7
Record Mean	52.4	56.3	61.1	68.7	76.9	86.2	91.5	89.7	84.2	72.7	60.5	53.0	71.1
Max	65.3	69.6	74.9	83.6	92.3	102.1	104.5	102.3	98.0	87.3	74.7	66.1	85.1
Min	39.4	43.0	47.3	53.8	61.4	70.3	78.4	77.0	70.4	58.0	46.2	40.0	57.1

See Reference Notes on Page 6B.

Page 4B

HEATING DEGREE DAYS Base 65 deg. F

PHOENIX, ARIZONA

SEASON	JULY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	TOTAL
1964-65	0	0	0	0	281	396	375	346	269	133	14	0	1814
1965-66	0	0	4	7	116	370	516	423	145	12	0	0	1593
1966-67	0	0	0	8	139	397	437	256	102	93	10	0	1442
1967-68	0	0	0	6	72	512	384	151	167	39	0	0	1331
1968-69	0	0	0	0	173	473	306	327	265	12	13	0	1569
1969-70	0	0	0	12	95	307	393	134	166	60	0	0	1167
1970-71	0	0	0	19	119	376	396	241	123	53	0	0	1327
1971-72	0	0	0	79	185	455	414	174	22	12	0	0	1341
1972-73	0	0	0	38	205	395	422	200	254	39	0	0	1553
1973-74	0	0	0	2	156	291	333	229	77	5	0	0	1093
1974-75	0	0	0	21	112	439	388	301	191	107	4	0	1563
1975-76	0	0	0	15	159	310	296	123	134	52	0	0	1089
1976-77	0	0	0	2	112	285	339	122	149	33	0	0	1042
1977-78	0	0	0	0	42	155	254	172	67	25	0	0	715
1978-79	0	0	0	1	148	405	455	254	143	30	0	0	1436
1979-80	0	0	0	11	204	277	254	130	129	35	0	0	1040
1980-81	0	0	0	12	108	122	181	131	74	8	0	0	636
1981-82	0	0	0	1	56	196	335	151	99	4	0	0	842
1982-83	0	0	0	1	103	331	272	181	120	53	0	0	1061
1983-84	0	0	0	0	154	236	228	139	16	23	0	0	796
1984-85	0	0	0	7	126	345	328	222	102	5	0	0	1135
1985-86	0	0	0	0	149	274	110	158	66	2	1	0	760
1986-87	0	0	0	0	43	260	318	172	95	4	0	0	892
1987-88	0	0	0	0	98	375	311	100	60	20	2	0	966
1988-89	0	0	0	0	135	284	321	133	46	0	0	0	919
1989-90	0	0	0	1	36	243	291	253	76	0	0	0	900
1990-91	0	0	0	0	65	348	275	27	161	5	0	0	881
1991-92	0	0	0	34	107	233	260	89	56	7	0	0	786
1992-93	0	0	0	0	127	340	205	184	61	0	0	0	917
1993-94	0	0	0	0	125	264							

See Reference Notes on Page 6B.

COOLING DEGREE DAYS Base 65 deg. F

PHOENIX, ARIZONA

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	TOTAL
1969	0	0	22	123	433	582	878	918	638	158	16	0	3768
1970	0	4	4	58	459	700	938	862	527	151	18	0	3721
1971	7	2	76	107	265	614	934	773	623	220	30	0	3651
1972	0	11	200	212	419	691	919	780	599	259	4	0	4094
1973	0	0	0	109	499	701	894	885	598	302	36	0	4024
1974	0	2	69	182	477	825	858	821	673	365	13	0	4285
1975	0	0	12	42	374	654	913	839	640	265	45	1	3785
1976	6	4	34	169	495	692	833	804	548	289	91	0	3965
1977	0	36	25	295	334	797	936	907	683	434	73	1	4521
1978	3	1	92	158	422	787	928	828	644	431	49	0	4343
1979	0	0	11	191	411	741	901	763	764	397	7	0	4186
1980	0	5	2	187	344	724	956	852	675	346	88	13	4192
1981	5	36	40	345	489	857	943	961	731	277	95	5	4784
1982	0	21	24	234	481	697	899	897	658	272	12	0	4195
1983	2	1	38	112	489	715	951	861	787	388	85	0	4429
1984	0	2	107	203	688	724	836	821	681	208	41	0	4311
1985	0	17	40	316	603	826	934	920	525	319	47	0	4547
1986	3	52	209	282	543	844	853	921	582	307	51	1	4648
1987	3	30	51	396	553	846	879	850	665	499	48	0	4820
1988	10	31	108	265	520	851	972	904	678	543	124	3	5009
1989	1	49	210	459	566	820	1013	897	751	392	87	0	5245
1990	5	25	150	339	506	873	895	806	683	431	101	0	4814
1991	0	61	22	227	465	691	937	920	712	514	70	0	4619
1992	0	13	54	373	567	762	868	851	771	464	30	0	4753
1993	1	1	89	271	585	746	871	832	695	369	24	0	4484

See Reference Notes on Page 6B.

SNOWFALL (inches)

PHOENIX. ARIZONA

SEASON	JULY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	TOTAL
1964-65	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1965-66	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1966-67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1967-68	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	0.0	0.0	0.0	T
1968-69	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	0.0	0.0	0.0	T
1969-70	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1970-71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1971-72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1972-73	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1973-74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1974-75	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	0.0	0.0	0.0	T
1975-76	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	T
1976-77	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977-78	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978-79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979-80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980-81	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981-82	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982-83	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983-84	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984-85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	0.0	T
1985-86	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
1986-87	0.0	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	0.0	0.0	T
1987-88	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1988-89	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1989-90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990-91	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	T	0.0	0.0	0.0	0.4
1991-92	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	T	0.0	T
1992-93	0.0	0.0	0.0	T	0.0	0.0	T	0.0	0.0	0.0	0.0	0.0	T
1993-94	0.0	0.0	0.0	0.0	0.0	0.0							
Record Mean	0.0	0.0	0.0	T	0.0	T	T	T	T	T	T	0.0	T

See Reference Notes on Page 6B.

REFERENCE NOTES

PHOENIX. ARIZONA

GENERAL
T - TRACE AMOUNT.
BLANK ENTRIES DENOTE MISSING/UNREPORTED DATA.
# INDICATES A STATION OR INSTRUMENT RELOCATION.
SEE STATION LOCATION TABLE ON PAGE 8.

SPECIFIC
PAGE 2
PM - INCLUDES LAST DAY OF PREVIOUS MONTH
ASOS - AUTOMATED SURFACE OBSERVING SYSTEM IN OPERATION DURING THESE MONTHS.

PAGE 3
(a) - LENGTH OF RECORD IN YEARS, ALTHOUGH INDIVIDUAL MONTHS MAY BE MISSING.
0.* OR * - THE VALUE IS BETWEEN 0.0 AND 0.05
NORMALS - BASED ON THE 1961-1990 RECORD PERIOD.
EXTREMES - DATES ARE THE MOST RECENT OCCURRENCE
WIND DIR.- NUMERALS SHOW TENS OF DEGRESS CLOCKWISE FROM TRUE NORTH. "00" INDICATES CALM.
RESULTANT DIRECTIONS ARE GIVEN TO WHOLE DEGREES.
BOLD VALUES INDICATE EXTREME VALUES WHICH OCCURRED AFTER THE ASOS SYSTEM WAS COMMISSIONED.

PAGE 4B
RECORD = PERIOD OF RECORD
RECORD MEAN PRECIPITATION IS THE MEAN OF ALL DAILY PRECIPITATION AMOUNTS DURING THE PERIOD OF RECORD.
RECORD MAX(MIN) TEMPERATURE IS THE MEAN OF ALL DAILY MAX(MIN) TEMPERATURES DURING THE PERIOD OF RECORD.
RECORD MEAN TEMPERATURE IS THE SUM OF THE RECORD MAX AND RECORD MIN DIVIDED BY 2.
AVERAGE TEMPERATURE IS THE SUM OF THE MEAN DAILY MAX AND MIN TEMPERATURE DIVIDED BY 2.

EXCEPTIONS

PAGE 3
1. PEAK GUST WINDS ARE AS OBSERVED JANUARY 1938 THROUGH OCTOBER 1953 AND FROM RECORDER THEREAFTER.
2. PERCENT OF POSSIBLE SUNSHINE IS FROM CITY OFFICE AUGUST 1895 THROUGH OCTOBER 1953 AND FROM SKY HARBOR AIRPORT THEREAFTER.
3. MEAN SKY COVER IS 1940, 1941, AND 1948 TO DATE.

PAGES 4A, 4B, 6A
RECORD MEANS ARE THROUGH THE CURRENT YEAR,
BEGINNING IN 1896 FOR TEMPERATURE
1896 FOR PRECIPITATION
1938 FOR SNOWFALL

PHOENIX,
ARIZONA

Phoenix is located in the Salt River Valley at an elevation of about 1,100 feet. The valley is oval shaped and flat except for scattered precipitous mountains rising a few hundred to as much as 1,500 feet above the valley floor. Sky Harbor Airport, where the weather observations are taken, is in the southern part of the city. Six miles to the south of the airport are the South Mountains rising to 2,500 feet. Eighteen miles southwest, the Estrella Mountains rise to 4,500 feet, and 30 miles to the west are the White Tank Mountains rising to 4,100 feet. The Superstition Mountains, over 30 miles to the east, rise to as much as 5,000 feet. The valley, though located in the Sonora Desert, supports large acreages of cotton, citrus, and other agriculture along with one of the largest urban populations in the United States. The water supply for this complex desert community is partly from reservoirs on the impounded Salt and Verde Rivers, and partly from a large underground water table.

Temperatures range from very hot in summer to mild in winter. Many winter days reach over 70 degrees and typical high temperatures in the middle of the winter are in the 60s. The climate becomes less attractive in the summer. The normal high temperature is over 90 degrees from early May through early October, and over 100 degrees from early June through early September. Many days each summer will exceed 110 degrees in the afternoon and remain above 85 degrees all night. When temperatures are extremely high, the low humidity does not provide much comfort. Indeed, the climate is very dry. Annual precipitation is only about 7 inches, and afternoon humidities range from about 30 percent in winter to only about 10 percent in June. Rain comes mostly in two seasons. From about Thanksgiving to early April there are periodic rains from Pacific storms. Moisture from the south and southeast results in a summer thunderstorm peak in July and August. Usually the break from extreme dryness in June to the onset of thunderstorms in early July is very abrupt. Afternoon humidities suddenly double to about 20 percent, which with the great heat, gives a feeling of mugginess. Fog is rare, occurring about once per winter, and is unknown in the other seasons.

The valley is characterized by light winds. High winds associated with thunderstorms occur periodically in the summer. These occasionally create duststorms which move large distances across the deserts. Strong thunderstorm winds occur any month of the year, but are rare outside the summer months. Persistent strong winds of 30 mph or more are rare except for two or three events in an average spring due to Pacific storms. Winter storms rarely bring high winds due to the relatively stable air in the valley during that season.

Based on the 1951–1980 period, the average first occurrence of 32 degrees Fahrenheit in the fall is December 13 and the average last occurrence in the spring is February 7

Notice of Correction

Any previously received edition of the "Local Climatological Data Annual Summary for 1993" should be discarded. This revised edition contains updates to the "Normals" based upon the 1961-1990 record period as noted in the "Reference Notes" on Page 6B.

STATION LOCATION

PHOENIX, ARIZONA

LOCATION	OCCUPIED FROM	OCCUPIED TO	AIRLINE DISTANCES AND DIRECTIONS FROM PREVIOUS LOCATION	LATITUDE NORTH	LONGITUDE WEST	ELEVATION ABOVE									AUTOMATIC OBSERVING EQUIPMENT *	* Type M = AMOS T = AUTOB S = ASOS W = AWOS REMARKS
						SEA LEVEL	GROUND									
						GROUND TEMPERATURE SITE	WIND INSTRUMENTS	EXTREME THERMOMETERS	PSYCHROMETER	SUNSHINE SWITCH	TIPPING BUCKET RAIN GAGE	WEIGHING RAIN GAGE	8 INCH RAIN GAGE	HYGROTHERMOMETER		
CITY - - NOTE: For period January 28, 1876 through August 1, 1901, refer to previous editions.																
Talbot Building SW corner First Avenue at Adams	8/1/01	3/24/13	300 ft. NW	33°27'	112°05'	1085	56	50	50	Unk	b41		41			b - Added 6/1/06.
Federal Building 230 N. First Avenue	3/24/13	6/27/16	500 ft.NNW	33°27'	112°05'	1086	81	76	76	Unk	68		68			
Water Users Building 145 W Van Buren Street	6/27/16	9/4/24	100 ft. W	33°27'	112°05'	1086	81	11	11	Unk	68		68			Wind instruments & rain gage equipment left on roof of Federal Building. Thermometer shelter moved to lawn between the buildings.
Ellis Building Basement 137 N Second Avenue	9/4/24	8/22/33	300 ft. S	33°27'	112°05'	1086	82	10	10	Unk	56		56			Thermometer shelter in Ellis Court, exposure poor, moved back to Federal Bldg. lawn on 7/18/25.
Ellis Building 5th Floor 137 N Second Avenue	8/22/33	10/22/36	NA	33°27'	112°05'	1086	107	10	10	Unk	81		81			Ellis Building was raised 2 stories.
Post Office Building 500 N Central Avenue	10/22/36	12/16/36	1200 ft. NNE	33°27'	112°04'	1083	51	39	39	Unk	36		36			Shelter on flat gravelled roof.
Post Office Building 500 N Central Avenue	12/16/36	10/22/53	NA	33°27'	112°04'	1083	87	39	39	Unk	36		36			Psychrometric observations moved to WBAS at Sky Harbor Airport on 7/1/39.
Posts Office Building 500 N Central Avenue	10/22/53	8/15/68	NA	33°27'	112°04'	1083		39				39	36			Combined at Airport 10/22/53. Psychrometer, wind equipment & tipping bucket gage removed 11/1/53.
AIRPORT Administration Building Sky Harbor Airport	5/2/33	12/19/52	3 mi. ESE of P.O.	33°26'	112°02'	1108	29	5	5	NA			3	d		Station closed 7/27/35 to 1/1/38. Cotton Region Shelter moved 110 feet NE & Standard Shelter added 10/1/40.
New Terminal Building Sky Harbor Airport	12/19/52	5/29/58	0.8 mi. SE	33°26'	112°01'	1114	32	5	5	cUnk		c5	3	d		c - Added 11/1/53. d - Telepsychrometer (5') 6/1/49-12/20/60. Hygro. comm. 3900' E of office 12/20/60.
FAA Operations Bldg. Sky Harbor Airport + + Sky Harbor Int'l AP effective 1971.	5/29/58	1/25/78	0.3 mi. NW	33°26'	112°01'	1109 e1117 g1112	41 e18 f36	5	5	35		4	3	d5 f7		e - Effective 12/20/60. f - Moved 2800' SW 9/19/75. g - Effective 9/19/75.
Wea. Svc. Forecast Off. Sky Harbor Int'l AP	1/25/78	Present	3000 ft.SW	33°26'	112°01'	1110	33	5	5	7	5	5	5	5	NA	

SUBSCRIPTION:
Price and ordering information available through: National Climatic Data Center, Federal Building, Asheville, North Carolina 28801.
INQUIRIES/COMMENTS CALL: (704) 271-4800

USCOMM-NOAA-ASHEVILLE, N.C. - 550

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United States Department of Commerce
NOAA Permit No. G - 19

JULY 1994
PHOENIX, AZ
SKY HARBOR INTL AIRPORT

LOCAL CLIMATOLOGICAL DATA

published by: National Climatic Data Center

LATITUDE: 33° 26′ N LONGITUDE: 112° 01′ W ELEVATION (GROUND): 1110 FEET TIME ZONE: MOUNTAIN STANDARD ISSN # 0198-0475 WBAN # 23183

	TEMPERATURE °F						DEG DAYS BASE 65°			SNOW/ICE ON GND(IN)		PRECIPITATION (INCHES)		PRESSURE (INCHES OF HG)		WIND SPEED = MPH DIR = TENS OF DEGREES			MAXIMUM				SUNSHINE		CLOUDINESS			
										0500 LST	1100 LST	0500 LST							5-SEC		2-MIN				SR-SS		MN-MN	
DATE	MAXIMUM	MINIMUM	AVERAGE	DEP FROM NORMAL	AVERAGE DEW PT	AVERAGE WET BULB	HEATING	COOLING	SIGNIFICANT WEATHER	DEPTH	WATER EQUIV	SNOW-FALL	WATER EQUIV	AVERAGE STATION	AVERAGE SEA LEVEL	RESULTANT WIND SPEED	RES DIR	AVERAGE SPEED	SPEED	DIR	SPEED	DIR	TOTAL MINUTES	PERCENT POSSIBLE	CEILOMETER TENTHS	SATELLITE TENTHS	CEILOMETER TENTHS	SATELLITE TENTHS
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
01	110	86	98	6	55	70	0	33		0		0.0	0.00	28.62	29.73	3.6	27	6.2	22	14	20	14	509	59	0		0	
02	111	87	99	7	55	70	0	34		0		0.0	0.00	28.57	29.67	5.0	27	8.0	24	27	20	28	846	98	0	1	0	1
03	109	86	98	6	49	67	0	33		0		0.0	0.00	28.55	29.65	4.4	27	8.1	24	28	20	25	859	100	0	0	0	
04	108	79	94	1	43	64	0	29		0		0.0	0.00	28.58	29.68	5.5	26	8.2	26	24	22	25	859	100	0	0	0	0
05	105	81	93	0	51	67	0	28		0		0.0	0.00	28.65	29.77	3.9	26	7.7	17	28	16	30	857	100	0	1	0	0
06	104	78	91	-2	43	63	0	26		0		0.0	0.00	28.66	29.78	1.3	24	6.5	17	25	14	30	857	100	0	0	0	0
07	109	75	92	-1	43	63	0	27		0		0.0	0.00	28.57	29.67	.7	19	5.2	17	28	13	25	856	100	0		0	1
08	112*	78	95	2	39	63	0	30		0		0.0	0.00	28.58	29.68	.9	12	5.9	20	27	15	27	856	100	0	0	0	0
09	109	82	96	3	44	65	0	31		0		0.0	0.00	28.70	29.81	1.5	1	4.7	15	29	13	29	736	86	0	0	0	0
10	108	83	96	3	51	68	0	31		0		0.0	0.00	28.72	29.83	3.1	28	5.6	20	29	16	29	854	100	0	1	0	1
11	109	84	97	4	50	68	0	32		0		0.0	0.00	28.67	29.78	4.5	27	7.1	21	30	17	27	853	100	0	2	0	1
12	108	81	95	1	44	65	0	30		0		0.0	0.00	28.63	29.74	3.0	27	5.8	21	28	15	28	853	100	0	2	0	1
13	109	78	94	0	42	64	0	29		0		0.0	0.00	28.61	29.72	1.5	6	5.1	14	19	11	17	852	100	0	2	0	1
14	109	82	96	2	44	65	0	31		0		0.0	0.00	28.63	29.73	1.1	11	6.3	18	17	14	19	850	100	0	0	0	0
15	107	80	94	0	45	65	0	29		0		0.0	0.00	28.69	29.80	2.3	1	3.9	11	03	10	03	850	100	0	2	0	1
16	104	81	93	-1	48	66	0	28		0		0.0	0.00	28.71	29.82	4.4	26	6.0	21	25	18	26	638	75	0	3	0	4
17	96	77	87	-7	65	72	0	22	TRH	0		0.0	0.02	28.75	29.87	2.4	22	7.6	30	13	25	13	102	12	2	8	2	8
18	90	73*	82*	-12	67	72	0	17	RFH	0		0.0	0.18	28.78	29.91	3.8	27	4.6	15	24	13	26	440	52	4	4	4	4
19	94	75	85	-9	65	71	0	20	R	0		0.0	T	28.75	29.88	3.1	27	5.5	24	25	21	26	560	66	2	3	2	2
20	102	77	90	-4	61	71	0	25		0		0.0	0.00	28.71	29.83	1.3	16	5.3	30	17	24	16	844	100	0	0	0	1
21	106	83	95	1	58	70	0	30		0		0.0	0.00	28.70	29.81	1.1	19	5.6	15	31	13	25	788	93		1		1
22	108	85	97	3	58	71	0	32		0		0.0	0.00	28.68	29.79	1.9	14	6.2	24	17	21	17	760	90	0	3	0	4
23	108	89	99*	5	60	72	0	34	R	0		0.0	T	28.69	29.79	2.1	27	5.2	17	25	14	26	600	71	0	4	0	
24	108	86	97	3	61	72	0	32		0		0.0	0.00	28.71	29.82	1.3	16	8.6	24	11	20	10	706	84	0	2	0	3
25	108	86	97	3	60	72	0	32		0		0.0	0.00	28.70	29.81	4.2	25	8.2	23	25	20	25	804	96	0	1	0	3
26	103	89	96	2	56	70	0	31	R	0		0.0	T	28.67	29.77	2.2	30	4.5	15	26	13	26	254	30	0	7	0	6
27	106	88	97	3	59	71	0	32		0		0.0	0.00	28.66	29.77	2.4	14	6.3	21	28	17	26	736	88	0	3	0	4
28	109	78	94	0	64	74	0	29	TRH	0		0.0	0.05	28.66	29.76	2.5	15	8.0	48	13	43	13	757	91	0		1	
29	104	79	92	-2	66	74	0	27		0		0.0	0.00	28.66	29.78	3.4	25	5.3	16	28	14	23	775	93	0		0	
30	103	85	94	0	61	72	0	29		0		0.0	0.00	28.68	29.79	2.6	21	9.8	20	12	18	16	753	91	0	1	0	3
31	105	87	96	3	56	70	0	31		0		0.0	0.00	28.70	29.81	4.6	27	5.8	17	26	14	25	762	92	0	0	0	1
	105.8	81.9	93.9	0.4	53.6	68.6	<------- MONTHLY AVERAGES -------->							28.67	29.78	1.9	25	6.3	<- MONTHLY AVERAGES ->						0	2	0	2

DEPARTURE
-.1 0.9

DEGREE DAYS

	MONTHLY TOTAL	MONTHLY DEPARTURE	SEASON TO DATE TOTAL	SEASON TO DATE DEPARTURE
HEATING:	0	0	0	0
COOLING:	904	20	2431	68

TOTAL SNOWFALL: 0.0 TOTAL PRECIPITATION: 0.25
PRECIP. DEPARTURE: -.58

	TOTAL	DATE
GREATEST 24-HR PRECIPITATION:	0.18	18
GREATEST 24-HR SNOWFALL:	0.0	
GREATEST SNOW DEPTH:	0	

SUNSHINE TOTALS: 22626 PERCENT
TOTAL POSSIBLE : 26262 POSSIBLE: 86

WIND	SPEED	DIRECTION	DATE
MAXIMUM 5-SECOND :	48	13	28
MAXIMUM 2-MINUTE :	43	13	28

NUMBER OF DAYS WITH —>

SKY CONDITIONS

CLEAR	PARTLY CLOUDY	CLOUDY
21	3	2

MAXIMUM TEMP ≥ 90 : 31
MAXIMUM TEMP ≤ 32 : 0
THUNDERSTORMS : 2
MINIMUM TEMP ≤ 32 : 0
MINIMUM TEMP ≤ 0 : 0
HEAVY FOG : 0
PRECIPITATION ≥ 0.01 INCH : 3
PRECIPITATION ≥ 0.10 INCH : 1
SNOWFALL ≥ 1.0 INCH : 0

<— NUMBER OF DAYS WITH

HOURLY PRECIPITATION

(WATER EQUIVALENT IN INCHES)

JULY 1994 WBAN #23183
PHOENIX, AZ

DATE	A.M. HOUR (L.S.T.) ENDING AT												DATE	P.M. HOUR (L.S.T.) ENDING AT												DATE	
	1	2	3	4	5	6	7	8	9	10	11	12		1	2	3	4	5	6	7	8	9	10	11	12		
01													01													01	
02													02													02	
03													03													03	
04													04													04	
05													05													05	
06													06													06	
07													07													07	
08													08													08	
09													09													09	
10													10													10	
11													11													11	
12													12													12	
13													13													13	
14													14													14	
15													15													15	
16													16													16	
17													17					T	T	T			0.01	0.01		17	
18						0.14	0.02	0.03		0.03	0.18		18					T	T							18	* 0.40
19								T					19													19	
20													20													20	
21													21													21	
22													22													22	
23			T	T									23													23	
24													24													24	
25													25													25	
26										T			26		T	T										26	
27													27													27	
28													28								0.02	T	0.01	T		28	* 0.03
29													29													29	
30													30													30	
31													31													31	

PUBLISHED BY: NCDC, ASHEVILLE, NC.

MAXIMUM SHORT DURATION PRECIPITATION (MSDP) **

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.06	0.07	0.07	0.08	0.10	0.13	0.18	0.18	0.18			
ENDED: DATE	18	18	18	18	18	18	18	18	18			
ENDED: TIME	0527	0530	0527	0527	0530	0550	1059	1059	1059			

The time indicated is the ending time of the interval. Date and time are not entered for trace amounts.

*The sum of the hourly totals follows the * when it disagrees with the daily total on page 1. NWS does not edit ASOS hourly precipitation but may edit daily and monthly totals. Hourly, daily and monthly totals are printed as reported by the ASOS site.

**NCDC derives MSDP data from one-minute ASOS data. The MSDP data are not printed when inconsistent with ASOS hourly totals.

REFERENCE NOTES :

WFO = WEATHER FORECAST OFFICE.
ASOS = AUTOMATED SURFACE OBSERVING SYSTEM.
* = EXTREME FOR THE MONTH (LAST OCCURRENCE IF MORE THAN ONE).
T = TRACE PRECIPITATION AMOUNT.
\+ = ALSO OCCURS ON EARLIER DATES.
F+ = HEAVY FOG, VISIBILITY .25 MILES OR LESS.

BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

THE HEATING DEGREE DAY SEASON BEGINS JULY 1.

THE COOLING DEGREE DAY SEASON BEGINS JANUARY 1.

CEILOMETER (30-SECOND) DATA ARE USED TO DERIVE CLOUDINESS AT OR BELOW 12,000 FEET. THIS CLOUDINESS IS THE MEAN CLOUD COVER DETECTED DURING THE TIME INTERVAL (HOUR, SUNRISE TO SUNSET, OR MIDNIGHT TO MIDNIGHT).

SATELLITE DATA ARE USED TO DERIVE CLOUDINESS ABOVE 12,000 FEET. EFFECTIVE CLOUD AMOUNT IS BASED ON THE CLOUD COVER AND THE TRANSPARENCY OF THE CLOUDS WITHIN THE SATELLITE FIELD OF VIEW (APPROX. 50 x 50 KM).

SKY CONDITION IS BASED ON THE SUM (NOT TO EXCEED 10) OF THE SUNRISE TO SUNSET CLOUD COVER BELOW AND ABOVE 12,000 FEET. BOTH CEILOMETER AND SATELLITE DATA MUST BE PRESENT TO COMPUTE SKY CONDITION. CLEAR = 0 -3 TENTHS, PARTLY CLOUDY = 4 - 7 TENTHS, AND CLOUDY = 8 - 10 TENTHS.

RESULTANT WIND IS THE VECTOR SUM OF THE WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS.

WIND DIRECTION IS RECRDED IN TENS OF DEGREES (2 DIGITS) CLOCKWISE FROM TRUE NORTH. '00' INDICATES CALM. '36' INDICATES CALM.

SR-SS = SUNRISE TO SUNSET. MN-MN = MIDNIGHT TO MIDNIGHT.

SNOWFALL IS FOR THE 24-HOUR PERIOD ENDING AT THE TIME INDICATED IN COLUMN HEADING.

WATER EQUIVALENT OF SNOW ON THE GROUND IS REPORTED ONLY WHEN THE DEPTH IS 2 OR MORE INCHES.

H, F, F+, P-, R, S, AND ZR ARE REPORTED FROM ASOS AUTOMATED SENSORS. OTHER WEATHER TYPES MAY BE ADDED TO THE REPORT BY STATION PERSONNEL OR BE PROVIDED BY THE WEATHER FORECAST OFFICE (WFO).

A	HAIL	GL	GLAZE	SG	SNOW GRAINS
BD	BLOWING DUST	H	HAZE	SP	SNOW PELLETS
BN	BLOWING SAND	IC	ICE CRYSTALS	T	THUNDER
BS	BLOWING SNOW	IF	ICE FOG	V	VOLCANIC ASH
BY	BLOWING SPRAY	IP	ICE PELLETS	ZL	FREEZING DRIZZLE
D	DUST	K	SMOKE	ZR	FREEZING RAIN
F	FOG	L	DRIZZLE	&	TORNADO
F+	HEAVY FOG	P-	UNKN. PRECIP.	&C	FUNNEL CLOUD
GF	GROUND FOG	R	RAIN	&W	WATERSPOUT
		S	SNOW		

NORMALS ARE FOR THE YEARS 1961 - 1990.

A HEATING (COOLING) DEGREE DAY IS THE DEFERENCE BETWEEN THE AVERAGE DAILY TEMPERATURE AND 65°F.

DEW POINT IS THE TEMPERATURE TO WHICH THE AIR MUST BE COOLED TO ACHIEVE 100% RELATIVE HUMIDITY.

WET BULB IS THE TEMPERATURE THE AIR WOULD HAVE IF THE MOISTURE CONTENT WAS INCREASED TO 100% RELATIVE HUMIDITY.

TEMPERATURE - HUMIDITY INDEX (STEADMAN, 1979)

TEMPERATURE °F	RELATIVE HUMIDITY (PERCENT)										
	0	10	20	30	40	50	60	70	80	90	100
120	107	116	130	148							
115	103	111	120	135	151						
110	99	105	112	123	137	150					
105	95	100	105	113	123	135	149				
100	91	95	99	104	110	120	132	144			
95	87	90	93	96	101	107	114	124	136		
90	83	85	87	90	93	96	100	106	113	122	
85	78	80	82	84	86	88	90	93	97	102	108
80	73	75	77	78	79	81	82	85	86	88	91
75	69	70	72	73	74	75	76	77	78	79	80
70	64	65	66	67	68	69	70	70	71	71	72

APPARENT TEMPERATURE

WIND CHILL EQUIVALENT TEMPERATURE (SIPLE & PASSEL, 1945)

TEMPERATURE °F	WIND VELOCITY (MPH)									
	4	5	10	15	20	25	30	35	40	45
45	45	43	34	29	26	23	21	20	19	18
40	40	37	26	23	19	16	13	12	11	10
35	35	32	22	16	12	8	6	4	3	2
30	30	27	16	9	4	1	-2	-4	-5	-6
25	25	22	10	2	-3	-7	-10	-12	-13	-14
20	20	16	3	-5	-10	-15	-18	-20	-21	-22
15	15	11	-3	-11	-17	-22	-25	-27	-29	-30
10	10	6	-9	-18	-24	-29	-33	-35	-37	-38
5	5	0	-15	-25	-31	-36	-41	-43	-45	-46
0	0	-5	-22	-31	-39	-44	-49	-52	-53	-54
-5	-5	-10	-27	-38	-46	-51	-56	-58	-60	-62
-10	-10	-15	-34	-45	-53	-59	-64	-67	-69	-70
-15	-15	-21	-40	-51	-60	-66	-71	-74	-76	-78
-20	-20	-26	-46	-58	-67	-74	-79	-82	-84	-85
-25	-25	-31	-52	-65	-74	-81	-86	-89	-92	-93
-30	-30	-36	-58	-72	-81	-88	-93	-97	-100	-102

ADDITIONAL INFORMATION :

OBSERVATIONS AT 3-HOURLY INTERVALS

JULY 1994
PHOENIX, AZ

WBAN # 23183

HOUR (LST)	< 12K FEET		SATELLITE > 12K FT				VISIBILITY (MILES)	WEATHER	TEMPERATURE °F			RELATIVE HUMIDITY (PCT)	WIND		PRESSURE (INCHES,HG)	
	CEILOMETER TENTHS	CEILING 100'S OF FT	OBSERVATION TIME(LST)	EFF CLD AMT TENTHS	100'S OF FT LOWEST CLOUD TOP	HIGHEST CLOUD TOP			DRY BULB	DEW POINT	WET BULB		SPEED (MPH)	DIRECTION TENS OF DEG	STATION	SEA LEVEL
SUNRISE: 0522 JUL 01 SUNSET: 1942																
02	0	NC	0124	2	130	440	10.00		93	55	69	28	7	32	28.64	29.74
05	0	NC	0450	3	300	460	10.00		89	56	68	33	6	08	28.68	29.78
08	0	NC	0724	9	310	460	10.00		92	58	70	32	0	00	28.70	29.81
11	0	NC					10.00		98	55	70	24	0	00	28.70	29.80
14	0	NC					10.00		104	54	72	19	7	25	28.62	29.73
17	0	NC					10.00		109	53	72	16	12	25	28.55	29.65
20	0	NC					10.00		106	53	72	17	9	25	28.54	29.63
23	0	NC					10.00		101	53	70	20	0	00	28.57	29.68
SUNRISE: 0522 JUL 02 SUNSET: 1942																
02	0	NC	0124	0	NT	NT	10.00		94	55	69	27	7	20	28.59	29.70
05	0	NC	0450	0	NT	NT	10.00		87	56	68	35	5	11	28.61	29.72
08	0	NC	0724	0	NT	NT	10.00		91	56	69	31	7	09	28.64	29.75
11	0	NC	1050	0	NT	NT	10.00		101	56	72	22	3	24	28.64	29.74
14	0	NC	1324	0	NT	NT	10.00		109	55	73	17	12	27	28.55	29.66
17	0	NC					10.00		110	54	73	16	14	30	28.48	29.58
20	0	NC	1925	0	NT	NT	10.00		105	53	71	18	14	26	28.48	29.58
23	0	NC					10.00		100	53	70	21	12	25	28.52	29.62
SUNRISE: 0523 JUL 03 SUNSET: 1942																
02	0	NC					10.00		94	53	68	25	7	28	28.54	29.64
05	0	NC					10.00		87	56	68	35	3	04	28.57	29.68
08	0	NC	0724	0	NT	NT	10.00		91	56	69	31	5	10	28.62	29.73
11	0	NC	1050	0	NT	NT	10.00		100	45	67	15	7	22	28.62	29.73
14	0	NC	1324	0	NT	NT	10.00		105	49	70	15	12	24	28.57	29.67
17	0	NC					10.00		108	49	71	14	16	23	28.48	29.58
20	0	NC					10.00		103	43	67	13	15	27	28.47	29.57
23	0	NC	2251	0	NT	NT	10.00		95	35	62	12	5	27	28.52	29.62
SUNRISE: 0523 JUL 04 SUNSET: 1942																
02	0	NC	0124	0	NT	NT	10.00		89	35	60	15	6	31	28.54	29.65
05	0	NC	0450	0	NT	NT	10.00		81	40	59	23	6	10	28.57	29.69
08	0	NC	0724	0	NT	NT	10.00		87	43	62	21	3	09	28.64	29.74
11	0	NC	1050	0	NT	NT	10.00		98	39	64	13	3	31	28.64	29.75
14	0	NC	1324	0	NT	NT	10.00		102	47	68	16	5	26	28.59	29.69
17	0	NC					10.00		106	50	70	15	20	24	28.53	29.63
20	0	NC	1925	0	NT	NT	10.00		100	45	67	15	12	25	28.54	29.64
23	0	NC	2251	0	NT	NT	10.00		95	42	64	16	8	22	28.59	29.69
SUNRISE: 0524 JUL 05 SUNSET: 1941																
02	0	NC	0124	0	NT	NT	10.00		85	50	64	30	0	00	28.61	29.72
05	0	NC	0428	0	NT	NT	10.00		81	50	63	34	5	05	28.64	29.75
08	0	NC	0724	0	NT	NT	10.00		86	59	69	40	6	13	28.70	29.82
11	0	NC	1050	0	NT	NT	10.00		95	57	70	28	3	25	28.72	29.83
14	0	NC	1324	0	NT	NT	10.00		102	55	71	21	13	23	28.68	29.78
17	0	NC					10.00		104	48	69	15	10	29	28.61	29.73
20	0	NC	1925	0	NT	NT	10.00		100	46	67	16	10	27	28.61	29.72
23	0	NC	2251	0	NT	NT	10.00		94	47	66	20	10	27	28.66	29.76
SUNRISE: 0524 JUL 06 SUNSET: 1941																
02	0	NC	0124	0	NT	NT	10.00		85	45	62	25	3	09	28.68	29.79
05	0	NC	0428	0	NT	NT	10.00		79	41	58	26	5	10	28.71	29.83
08	0	NC	0724	0	NT	NT	10.00		86	41	61	21	10	13	28.74	29.86
11	0	NC	1050	0	NT	NT	10.00		94	42	64	17	7	14	28.73	29.85
14	0	NC	1324	0	NT	NT	10.00		102	45	68	14	8	22	28.66	29.77
17	0	NC					10.00		102	47	68	16	10	28	28.59	29.70
20	0	NC					10.00		99	42	66	14	9	27	28.59	29.70
23	0	NC	2251	0	NT	NT	10.00		88	36	60	16	3	34	28.61	29.72

HOUR (LST)	< 12K FEET		SATELLITE > 12K FT				VISIBILITY (MILES)	WEATHER	TEMPERATURE °F			RELATIVE HUMIDITY (PCT)	WIND		PRESSURE (INCHES,HG)	
	CEILOMETER TENTHS	CEILING 100'S OF FT	OBSERVATION TIME(LST)	EFF CLD AMT TENTHS	100'S OF FT LOWEST CLOUD TOP	HIGHEST CLOUD TOP			DRY BULB	DEW POINT	WET BULB		SPEED (MPH)	DIRECTION TENS OF DEG	STATION	SEA LEVEL
SUNRISE: 0525 JUL 07 SUNSET: 1941																
02	0	NC	0124	0	NT	NT	10.00		83	32	57	16	0	00	28.59	29.70
05	0	NC	0428	2	190	190	10.00		78	39	57	25	5	08	28.61	29.72
08	0	NC					10.00		85	38	59	19	8	09	28.64	29.76
11	0	NC	1050	8	190	190	10.00		97	42	65	15	5	17	28.62	29.73
14	0	NC	1325	5	190	190	10.00		105	49	70	15	6	17	28.55	29.65
17	0	NC					10.00		107	53	72	17	6	24	28.49	29.59
20	0	NC	1925	0	NT	NT	10.00		102	47	68	16	5	27	28.49	29.59
23	0	NC	2251	0	NT	NT	10.00		92	42	63	18	5	03	28.52	29.62
SUNRISE: 0525 JUL 08 SUNSET: 1941																
02	0	NC	0124	0	NT	NT	10.00		85	42	61	22	3	13	28.53	29.64
05	0	NC	0428	0	NT	NT	10.00		79	39	58	24	7	07	28.55	29.66
08	0	NC					10.00		88	35	60	15	9	10	28.61	29.71
11	0	NC	1050	0	NT	NT	10.00		100	47	68	17	7	17	28.61	29.72
14	0	NC	1325	0	NT	NT	10.00		111	32	67	7	5	35	28.57	29.69
17	0	NC					10.00		111	32	67	7	10	28	28.55	29.65
20	0	NC	1925	0	NT	NT	10.00		103	34	64	9	0	00	28.55	29.66
23	0	NC	2251	0	NT	NT	10.00		95	38	63	14	3	31	28.61	29.72
SUNRISE: 0526 JUL 09 SUNSET: 1941																
02	0	NC	0124	0	NT	NT	10.00		90	41	62	18	8	33	28.64	29.74
05	0	NC	0427	0	NT	NT	10.00		84	43	61	24	3	11	28.68	29.79
08	0	NC	0724	2	180	380	10.00		88	43	62	21	6	08	28.78	29.89
11	0	NC	1050	0	NT	NT	10.00		98	42	65	15	5	17	28.79	29.90
14	0	NC	1325	0	NT	NT	10.00		105	43	68	12	5	34	28.72	29.84
17	0	NC					10.00		108	43	69	11	8	32	28.66	29.76
20	0	NC	1925	0	NT	NT	10.00		103	46	68	15	3	31	28.64	29.74
23	0	NC	2251	0	NT	NT	10.00		94	53	68	25	5	29	28.68	29.79
SUNRISE: 0526 JUL 10 SUNSET: 1940																
02	0	NC	0124	0	NT	NT	10.00		90	51	66	26	3	34	28.70	29.82
05	0	NC	0427	0	NT	NT	10.00		87	48	64	26	0	00	28.76	29.88
08	0	NC					10.00		90	50	66	25	5	09	28.83	29.94
11	0	NC	1050	0	NT	NT	10.00		97	49	68	20	3	14	28.81	29.92
14	0	NC	1325	6	190	190	10.00		106	49	70	15	12	27	28.74	29.85
17	0	NC					10.00		107	54	72	17	12	29	28.66	29.76
20	0	NC	1925	0	NT	NT	10.00		104	51	70	17	7	26	28.62	29.74
23	0	NC	2251	0	NT	NT	10.00		97	52	69	22	5	29	28.66	29.78
SUNRISE: 0527 JUL 11 SUNSET: 1940																
02	0	NC	0124	0	NT	NT	10.00		91	48	65	23	3	31	28.66	29.77
05	0	NC	0427	0	NT	NT	10.00		85	51	65	31	0	00	28.70	29.81
08	0	NC	0724	0	NT	NT	10.00		90	53	67	28	3	06	28.76	29.88
11	0	NC	1050	0	NT	NT	10.00		100	51	69	19	8	21	28.75	29.86
14	0	NC	1325	7	190	190	10.00		106	50	71	15	9	29	28.68	29.79
17	0	NC					10.00		108	52	72	16	12	25	28.61	29.72
20	0	NC	1925	0	NT	NT	10.00		104	52	71	18	9	25	28.59	29.69
23	0	NC	2251	0	NT	NT	10.00		99	49	68	18	7	26	28.64	29.73
SUNRISE: 0527 JUL 12 SUNSET: 1940																
02	0	NC	0124	0	NT	NT	10.00		89	44	63	21	0	00	28.61	29.72
05	0	NC	0427	0	NT	NT	10.00		85	46	62	26	3	11	28.64	29.75
08	0	NC	0723	0	NT	NT	10.00		90	50	66	25	6	13	28.70	29.81
11	0	NC	1050	0	NT	NT	10.00		99	48	68	18	8	18	28.70	29.81
14	0	NC	1325	0	NT	NT	10.00		106	48	70	14	6	26	28.64	29.75
17	0	NC					10.00		106	45	69	13	10	30	28.57	29.68
20	0	NC	1925	0	NT	NT	10.00		101	32	63	9	8	27	28.57	29.67
23	0	NC	2251	0	NT	NT	10.00		90	36	61	15	0	00	28.59	29.70

OBSERVATIONS AT 3-HOURLY INTERVALS

JULY 1994
PHOENIX, AZ

WBAN # 23183

HOUR (LST)	< 12K FEET		SATELLITE > 12K FT				VISIBILITY (MILES)	WEATHER	TEMPERATURE °F			RELATIVE HUMIDITY (PCT)	WIND		PRESSURE (INCHES,HG)	
					100'S OF FT											
	CEILOMETER TENTHS	CEILING 100'S OF FT	OBSERVATION TIME(LST)	EFF CLD AMT TENTHS	LOWEST CLOUD TOP	HIGHEST CLOUD TOP			DRY BULB	DEW POINT	WET BULB		SPEED (MPH)	DIRECTION TENS OF DEG	STATION	SEA LEVEL
SUNRISE: 0528								JUL 13		SUNSET: 1940						
02	0	NC	0124	0	NT	NT	10.00		83	37	58	19	6	07	28.59	29.71
05	0	NC	0427	0	NT	NT	10.00		79	35	56	20	5	10	28.64	29.75
08	0	NC	0723	0	NT	NT	10.00		87	35	59	16	7	10	28.68	29.80
11	0	NC	1050	0	NT	NT	10.00		99	41	65	14	6	16	28.68	29.78
14	0	NC	1325	0	NT	NT	10.00		105	43	68	12	6	06	28.61	29.72
17	0	NC					10.00		108	47	70	13	5	35	28.54	29.64
20	0	NC					10.00		101	49	69	17	0	00	28.54	29.64
23	0	NC	2251	0	NT	NT	10.00		95	51	68	23	5	30	28.57	29.68
SUNRISE: 0529								JUL 14		SUNSET: 1939						
02	0	NC	0124	0	NT	NT	10.00		88	48	64	25	5	10	28.59	29.70
05	0	NC	0427	0	NT	NT	10.00		83	47	62	29	5	07	28.62	29.74
08	0	NC	0723	0	NT	NT	10.00		87	48	64	26	10	10	28.68	29.80
11	0	NC	1050	0	NT	NT	10.00		98	42	65	15	8	12	28.70	29.80
14	0	NC	1325	0	NT	NT	10.00		104	40	67	11	6	05	28.64	29.75
17	0	NC					10.00		109	41	68	10	5	32	28.57	29.68
20	0	NC	1925	0	NT	NT	10.00		102	42	67	13	6	32	28.57	29.68
23	0	NC	2250	0	NT	NT	10.00		95	40	64	15	6	28	28.61	29.72
SUNRISE: 0529								JUL 15		SUNSET: 1939						
02	0	NC	0124	0	NT	NT	10.00		86	40	61	20	0	00	28.64	29.75
05	0	NC	0427	0	NT	NT	10.00		82	41	59	23	5	13	28.68	29.78
08	0	NC	0723	0	NT	NT	10.00		86	47	63	26	5	06	28.76	29.88
11	0	NC	1050	0	NT	NT	10.00		96	40	64	14	5	36	28.77	29.88
14	0	NC	1325	5	190	190	10.00		103	45	68	14	7	06	28.71	29.82
17	0	NC					10.00		106	48	70	14	3	34	28.64	29.75
20	0	NC	1925	0	NT	NT	10.00		101	48	68	17	3	01	28.62	29.74
23	0	NC	2250	4	260	460	10.00		97	44	66	16	5	32	28.66	29.78
SUNRISE: 0530								JUL 16		SUNSET: 1938						
02	0	NC	0124	0	NT	NT	10.00		89	38	61	17	5	33	28.68	29.79
05	0	NC	0427	1	200	330	10.00		84	39	59	20	0	00	28.74	29.85
08	0	NC	0723	1	200	460	10.00		90	41	62	18	3	09	28.79	29.90
11	0	NC	1050	7	150	380	10.00		99	45	67	16	5	25	28.79	29.90
14	0	NC	1325	5	150	440	10.00		101	52	70	19	9	27	28.74	29.85
17	0	NC					10.00		102	52	70	19	16	26	28.66	29.77
20	0	NC	1925	4	200	380	10.00		100	56	71	23	12	26	28.62	29.73
23	0	NC	2250	8	260	330	10.00		95	56	70	27	5	13	28.68	29.79
SUNRISE: 0530								JUL 17		SUNSET: 1938						
02	0	NC	0124	4	140	460	10.00		93	58	70	31	7	25	28.66	29.78
05	0	NC	0427	7	190	440	10.00		88	61	70	40	5	15	28.72	29.84
08	0	NC	0723	7	230	440	10.00		86	64	71	48	12	29	28.78	29.90
11	0	NC	1050	9	240	300	10.00		91	63	72	39	8	27	28.79	29.91
14	2	NC	1325	9	230	330	10.00		94	63	73	36	3	16	28.75	29.86
17	7	80					10.00	TR	81	71	74	72	14	12	28.77	29.90
20	0	NC	1925	8	180	330	10.00		79	71	74	77	6	07	28.78	29.91
23	8	90	2250	9	130	190	10.00		79	71	74	77	3	11	28.80	29.93
SUNRISE: 0531								JUL 18		SUNSET: 1937						
02	4	65	0124	8	130	260	10.00		79	70	73	74	0	00	28.80	29.92
05	4	90	0427	6	130	380	10.00		77	65	69	67	0	00	28.80	29.93
08	6	75	0723	8	160	330	7.00		76	72	73	88	3	31	28.82	29.96
11	2	75	1050	8	130	300	7.00		79	72	74	79	9	24	28.84	29.97
14	0	NC	1325	1	210	210	10.00		88	66	73	48	7	28	28.79	29.91
17	3	NC					10.00		87	65	72	48	5	26	28.73	29.86
20	0	NC	1925	0	NT	NT	10.00		86	64	71	48	6	29	28.73	29.86
23	5	NC	2250	0	NT	NT	10.00		84	67	73	57	0	00	28.75	29.88
SUNRISE: 0532								JUL 19		SUNSET: 1937						
02	6	95	0124	0	NT	NT	10.00		81	66	71	60	0	00	28.74	29.87
05	4	60	0427	0	NT	NT	10.00		80	66	71	63	7	11	28.76	29.88
08	1	60	0723	7	150	380	10.00		76	68	71	76	6	30	28.80	29.93
11	1	NC	1050	2	200	380	10.00		85	66	72	53	7	18	28.81	29.93
14	0	NC	1325	3	160	440	10.00		90	65	73	44	6	27	28.76	29.88
17	0	NC					10.00		93	59	71	32	9	26	28.71	29.84
20	0	NC	1925	0	NT	NT	10.00		86	65	72	50	8	33	28.70	29.83
23	0	NC	2250	0	NT	NT	10.00		85	64	71	50	0	00	28.73	29.85
SUNRISE: 0532								JUL 20		SUNSET: 1936						
02	0	NC	0124	0	NT	NT	10.00		80	66	71	63	0	00	28.72	29.85
05	0	NC	0427	0	NT	NT	10.00		78	66	70	67	6	11	28.73	29.85
08	0	NC	0723	0	NT	NT	10.00		85	65	72	51	6	11	28.77	29.89
11	0	NC	1050	0	NT	NT	10.00		94	59	71	31	0	00	28.76	29.88
14	0	NC	1325	1	210	210	10.00		99	56	71	24	6	28	28.70	29.82
17	0	NC					10.00		101	55	71	22	9	27	28.64	29.76
20	0	NC	1925	2	220	460	10.00		92	62	72	37	17	16	28.68	29.80
23	0	NC	2250	5	180	380	10.00		89	63	72	42	5	08	28.70	29.82
SUNRISE:, 0533								JUL 21		SUNSET: 1936						
02	0	NC	0124	2	130	440	10.00		86	62	70	45	5	07	28.72	29.83
05	0	NC	0427	0	NT	NT	10.00		84	62	70	48	5	10	28.73	29.84
08	0	NC	0723	0	NT	NT	10.00		87	61	70	42	7	13	28.77	29.89
11	0	NC	1050	0	NT	NT	10.00		96	59	72	29	5	13	28.76	29.88
14	0	NC	1325	0	NT	NT	10.00		103	56	72	21	5	24	28.70	29.80
17		NC					10.00		106	56	73	19	8	29	28.61	29.72
20		NC	1925	2	180	440	10.00		101	54	71	21	9	27	28.64	29.74
23		NC	2250	3	150	380	10.00		97	56	71	25	6	26	28.68	29.78
SUNRISE: 0534								JUL 22		SUNSET: 1935						
02	0	NC					10.00		91	59	70	34	6	10	28.70	29.80
05	0	NC					10.00		87	59	69	39	6	11	28.70	29.82
08	0	NC	0723	7	140	330	10.00		92	59	71	33	3	11	28.74	29.85
11	0	NC	1050	5	130	460	10.00		100	57	72	24	0	00	28.72	29.83
14	0	NC	1325	0	NT	NT	10.00		105	56	73	20	5	20	28.66	29.77
17	0	NC					10.00		107	57	74	19	6	30	28.59	29.70
20	0	NC					10.00		103	54	71	20	6	28	28.61	29.72
23	0	NC	2250	9	300	440	10.00		95	59	71	30	14	19	28.68	29.80
SUNRISE: 0534								JUL 23		SUNSET: 1935						
02	1	NC					10.00		92	60	71	34	5	02	28.68	29.78
05	0	NC					10.00		90	60	70	37	3	07	28.70	29.80
08	0	NC	0723	9	230	330	10.00		92	61	72	36	3	27	28.74	29.85
11	0	NC	1050	2	180	460	10.00		98	59	72	27	5	18	28.75	29.86
14	0	NC	1325	0	NT	NT	10.00		105	59	74	22	9	33	28.70	29.80
17	0	NC					10.00		106	57	73	20	8	30	28.61	29.72
20	0	NC					10.00		102	57	72	23	7	27	28.62	29.73
23	0	NC	2250	5	130	300	10.00		99	60	73	28	3	22	28.66	29.77
SUNRISE: 0535								JUL 24		SUNSET: 1934						
02	0	NC	0123	5	230	440	10.00		90	63	72	41	15	15	28.71	29.83
05	0	NC	0427	1	130	440	10.00		86	63	71	46	5	10	28.72	29.83
08	0	NC	0723	0	NT	NT	10.00		91	63	72	39	6	11	28.75	29.86
11	0	NC	1050	1	220	440	10.00		99	60	73	28	7	24	28.75	29.86
14	0	NC	1325	1	220	460	10.00		105	61	75	24	6	29	28.70	29.80
17	0	NC					10.00		107	59	75	21	7	29	28.64	29.75
20	0	NC	1925	6	240	440	10.00		99	57	72	25	6	01	28.68	29.78
23	0	NC	2250	9	300	440	10.00		93	62	72	36	6	01	28.72	29.83

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OBSERVATIONS AT 3-HOURLY INTERVALS

JULY 1994
PHOENIX, AZ
WBAN # 23183

HOUR (LST)	≤ 12K FEET		SATELLITE > 12K FT				VISIBILITY (MILES)	WEATHER	TEMPERATURE °F			RELATIVE HUMIDITY (PCT)	WIND		PRESSURE (INCHES,HG)	
	CEILOMETER TENTHS	CEILING 100'S OF FT	OBSERVATION TIME(LST)	EFF CLD AMT TENTHS	100'S OF FT LOWEST CLOUD TOP	HIGHEST CLOUD TOP			DRY BULB	DEW POINT	WET BULB		SPEED (MPH)	DIRECTION TENS OF DEG	STATION	SEA LEVEL
SUNRISE: 0536 JUL 25 SUNSET: 1934																
02	0	NC	0123	6	210	440	10.00		89	60	70	38	5	08	28.70	29.81
05	0	NC	0427	0	NT	NT	10.00		88	61	70	40	6	10	28.72	29.84
08	0	NC	0723	0	NT	NT	10.00		91	63	72	39	5	11	28.76	29.88
11	0	NC	1050	1	220	380	10.00		100	61	74	28	6	26	28.76	29.88
14	0	NC					10.00		105	61	75	24	13	27	28.70	29.81
17	0	NC					10.00		107	60	75	22	15	25	28.62	29.73
20	0	NC	1925	5	210	460	10.00		104	57	73	21	12	26	28.64	29.74
23		NC	2250	9	330	460	10.00		98	58	72	27	3	01	28.68	29.78
SUNRISE: 0536 JUL 26 SUNSET: 1933																
02	0	NC	0123	7	230	460	10.00		94	56	70	28	7	22	28.66	29.76
05	0	NC	0427	0	NT	NT	10.00		90	55	68	31	0	00	28.68	29.78
08	0	NC	0723	7	130	330	10.00		91	60	71	35	6	06	28.71	29.82
11	0	NC	1050	7	150	380	10.00		98	55	70	24	0	00	28.72	29.83
14	1	NC	1325	9	180	300	10.00	R	100	55	71	22	6	30	28.68	29.80
17	0	NC					10.00		103	55	72	20	7	32	28.61	29.72
20	0	NC	1925	4	130	330	10.00		98	55	70	24	6	27	28.61	29.72
23	0	NC	2250	2	140	190	10.00		94	58	71	30	0	00	28.64	29.75
SUNRISE: 0537 JUL 27 SUNSET: 1932																
02	0	NC	0123	4	150	440	10.00		92	60	71	34	6	13	28.64	29.76
05	0	NC	0427	4	130	380	10.00		89	60	70	38	0	00	28.68	29.79
08	0	NC	0723	5	130	460	10.00		93	63	73	37	14	11	28.72	29.84
11	0	NC	1050	6	260	380	10.00		100	55	71	22	7	18	28.73	29.85
14	0	NC	1325	7	260	440	10.00		102	57	72	23	3	21	28.68	29.78
17	0	NC					10.00		105	57	73	21	6	20	28.59	29.70
20		NC	1925	0	NT	NT	10.00		102	57	72	23	3	28	28.57	29.68
23		NC	2250	0	NT	NT	10.00		96	60	72	30	3	03	28.61	29.72
SUNRISE: 0538 JUL 28 SUNSET: 1931																
02	0	NC					10.00		91	60	71	35	0	00	28.64	29.74
05	0	NC	0427	1	130	300	10.00		89	59	70	36	6	07	28.66	29.76
08	0	NC					10.00		93	61	72	35	7	11	28.70	29.81
11	0	NC	1050	4	330	330	10.00		101	62	74	28	8	15	28.70	29.80
14	0	NC					10.00		107	67	78	28	6	23	28.61	29.71
17	0	NC					10.00		108	58	74	20	7	30	28.54	29.63
20	9	45	1924	9	260	380	10.00	TR	82	71	74	69	24	15	28.70	29.82
23	4	NC	2250	9	300	380	10.00		79	71	74	77	9	09	28.75	29.87
SUNRISE: 0538 JUL 29 SUNSET: 1931																
02	0	NC	0124	7	170	380	10.00		81	70	74	69	3	34	28.71	29.83
05	0	NC	0450	3	140	440	10.00		80	70	73	72	6	19	28.70	29.82
08	0	NC					10.00		82	69	73	65	5	12	28.75	29.87
11	0															
14	0	NC					10.00		101	62	74	28	8	31	28.64	29.76
17	0	NC					10.00		102	64	76	29	10	26	28.57	29.68
20	0	NC	1924	0	NT	NT	10.00		100	65	76	32	9	25	28.59	29.70
23	0	NC	2250	1	220	440	10.00		96	59	72	29	8	26	28.62	
SUNRISE: 0539 JUL 30 SUNSET: 1930																
02	0	NC	0124	6	130	440	10.00		91	58	70	33	6	32	28.66	29.78
05	0	NC	0450	9	300	380	10.00		88	64	72	45	17	14	28.70	29.81
08	0	NC	0724	2	130	380	10.00		87	65	72	48	16	11	28.75	29.87
11	0	NC	1050	0	NT	NT	10.00		92	65	74	41	6	16	28.73	29.85
14	0	NC	1324	2	210	300	10.00		100	59	73	26	6	29	28.68	29.78
17	0	NC					10.00		103	64	76	28	10	26	28.61	29.71
20	0	NC	1924	2	130	440	10.00		101	50	69	18	8	27	28.61	29.72
23	0	NC	2250	5	260	380	10.00		95	60	72	31	10	25	28.68	29.79

HOUR (LST)	≤ 12K FEET		SATELLITE > 12K FT				VISIBILITY (MILES)	WEATHER	TEMPERATURE °F			RELATIVE HUMIDITY (PCT)	WIND		PRESSURE (INCHES,HG)	
	CEILOMETER TENTHS	CEILING 100'S OF FT	OBSERVATION TIME(LST)	EFF CLD AMT TENTHS	100'S OF FT LOWEST CLOUD TOP	HIGHEST CLOUD TOP			DRY BULB	DEW POINT	WET BULB		SPEED (MPH)	DIRECTION TENS OF DEG	STATION	SEA LEVEL
SUNRISE: 0540 JUL 31 SUNSET: 1929																
02	0	NC	0124	5	130	380	10.00		91	59	70	34	5	01	28.70	29.80
05	0	NC	0450	1	130	300	10.00		89	54	67	30	7	22	28.72	29.83
08	0	NC	0724	0	NT	NT	10.00		90	54	68	29	0	00	28.77	29.88
11	0	NC					10.00		96	54	69	24	6	28	28.76	29.88
14	0	NC	1324	0	NT	NT	10.00		102	60	74	25	10	26	28.70	29.81
17	0	NC					10.00		103	54	71	20	8	28	28.64	29.74
20	0	NC	1924	0	NT	NT	10.00		100	57	72	24	8	27	28.64	29.74
23	0	NC	2250	4	130	380	10.00		96	56	70	26	3	32	28.68	29.78

HOURLY SUMMARY NOTES

CEILING IS REPORTED IN HUNDREDS OF FEET (ABOVE GROUND LEVEL) FOR CLOUDS AT OR BELOW 12,000 FEET.
CLOUD TOPS ARE REPORTED IN HUNDREDS OF FEET (ABOVE MEAN SEA LEVEL) FOR CLOUDS ABOVE 12,000 FEET.
NC = A CEILING WAS NOT DETECTED AT OR BELOW 12,000 FEET.
NT = CLOUD TOPS WERE NOT DETECTED ABOVE 12,000 FEET.
SEE PAGE 3 FOR ADDITIONAL NOTES.

SUMMARY BY HOURS

HOUR (LST)	AVERAGES										RESULTANT WIND (MPH)	
	CEILOMETER	EFF CLD AMT	DRY BULB	DEW POINT	WET BULB	RELATIVE HUMIDITY	PRESSURE (INCHES,HG) STATION	SEA LEVEL	VISIBILITY (MILES)	WIND SPEED (MPH)	SPEED	DIRECTION
01	0	3	90	53	67	31	28.65	29.76	10.00	5	1	29
02	0	2	88	53	67	33	28.65	29.76	10.00	4	0	0
03	1	2	87	53	66	34	28.66	29.77	10.00	5	2	9
04	0	2	85	53	66	35	28.67	29.78	10.00	4	3	9
05	0	1	84	53	66	37	28.68	29.79	10.00	4	4	11
06	0	2	83	54	66	39	28.70	29.81	9.77	5	3	11
07	1	2	85	67	55	38	28.72	29.83	9.79	6	4	10
08	0	2	88	55	68	35	28.73	29.85	9.90	6	4	10
09	0	2	91	54	68	32	28.74	29.85	9.90	6	4	11
10	0	2	94	54	69	29	28.73	29.85	9.81	6	2	14
11	0	2	97	53	69	25	28.73	29.84	9.90	5	3	20
12	0	2	99	54	70	24	28.71	29.82	10.00	5	2	24
13	0	2	101	54	71	22	28.69	29.80	10.00	7	4	26
14	0	2	103	54	71	21	28.67	29.78	10.00	7	5	27
15	0	2	104	54	72	20	28.64	29.75	10.00	9	8	27
16	0	3	104	53	72	20	28.62	29.73	10.00	9	8	27
17	0		104	54	72	21	28.60	29.71	10.00	10	8	27
18	0	1	103	53	71	21	28.59	29.70	10.00	10	8	27
19	0	1	102	53	71	22	28.60	29.71	9.70	10	7	27
20	0	2	99	53	70	24	28.61	29.72	10.00	8	5	26
21	0	2	97	53	69	24	28.63	29.74	10.00	6	5	26
22	1	3	95	54	69	28	28.64	29.75	10.00	6	4	25
23	1	3	93	53	69	29	28.65	29.76	10.00	5	2	27
24	0	3	91	53	68	30	28.65	29.76	10.00	5	1	33

PUBLISHED BY: NCDC, ASHEVILLE, NC.

SUPPLEMENTARY HOURLY PRECIPITATION
UNIVERSAL RAIN GAUGE (WATER EQUIVALENT IN INCHES)

JULY 1994
PHOENIX, AZ

LATITUDE 33° 26'N
LONGITUDE 112° 01'W

DATE	A.M. HOUR (L.S.T.) ENDING AT												DATE	P.M. HOUR (L.S.T.) ENDING AT												DATE	DAILY TOTAL
	1	2	3	4	5	6	7	8	9	10	11	12		1	2	3	4	5	6	7	8	9	10	11	12		
01													01													01	0.00
02													02													02	0.00
03													03													03	0.00
04													04													04	0.00
05													05													05	0.00
06													06													06	0.00
07													07													07	0.00
08													08													08	0.00
09													09													09	0.00
10													10													10	0.00
11													11													11	0.00
12													12													12	0.00
13													13													13	0.00
14													14													14	0.00
15													15													15	0.00
16													16													16	0.00
17													17					T	0.01	T			0.01	T		17	0.02
18						0.08	0.01	0.01		0.06	0.02		18													18	0.18
19								T					19													19	T
20													20													20	0.00
21													21													21	0.00
22													22													22	0.00
23			T	T									23													23	T
24													24													24	0.00
25													25													25	0.00
26										T			26													26	T
27													27													27	0.00
28													28								0.01	0.01	0.03	T		28	0.05
29													29													29	0.00
30													30													30	0.00
31													31													31	0.00

PUBLISHED BY: NCDC, ASHEVILLE, NC.

MONTHLY TOTAL 0.25

SUPPLEMENTARY MAXIMUM SHORT DURATION PRECIPITATION (MSDP)

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.05	0.06	0.06	0.06	0.07	0.07	0.08	0.08	0.09	0.09	0.10	0.10
ENDED: DATE	18	18	18	18	18	18	18	18	18	18	18	18
ENDED: TIME	1005	1006	1006	1006	1025	1025	0617	0650	0650	0729	0729	0729

The time indicated is the ending time of the interval.
Date and time are not entered for trace amounts.

The National Weather Service has determined that the ASOS Heated Tipping-Bucket (HTB) rain gauge may not measure water equivalent precipitation accurately during frozen precipitation events. Precipitation data from a nearby site is provided on this page to supplement the ASOS HTB data.

AUGUST 1994
PHOENIX, AZ
SKY HARBOR INTL AIRPORT

LOCAL CLIMATOLOGICAL DATA

published by: National Climatic Data Center

LATITUDE: 33° 26′ N LONGITUDE: 112° 01′ W ELEVATION (GROUND): 1110 FEET TIME ZONE: MOUNTAIN STANDARD ISSN # 0198-0475 WBAN # 23183

DATE	TEMPERATURE °F						DEG DAYS BASE 65°		SIGNIFICANT WEATHER	SNOW/ICE ON GND(IN)		PRECIPITATION (INCHES)		PRESSURE (INCHES OF HG)		WIND SPEED = MPH DIR = TENS OF DEGREES							SUNSHINE		CLOUDINESS			
										0500 LST	1100 LST	0500 LST							MAXIMUM 5-SEC		2-MIN				SR-SS		MN-MN	
	MAXIMUM	MINIMUM	AVERAGE	DEP FROM NORMAL	AVERAGE DEW PT	AVERAGE WET BULB	HEATING	COOLING		DEPTH	WATER EQUIV	SNOW-FALL	WATER EQUIV	AVERAGE STATION	AVERAGE SEA LEVEL	RESULTANT WIND SPEED	RES DIR	AVERAGE SPEED	SPEED	DIR	SPEED	DIR	TOTAL MINUTES	PERCENT POSSIBLE	CEILOMETER TENTHS	SATELLITE TENTHS	CEILOMETER TENTHS	SATELLITE TENTHS
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
01	108	87	98	5	55	70	0	33	H	0		0.0	0.00	28.66	29.77	5.5	27	5.9	21	26	16	26	747	90	0		0	
02	111	85	98	5	50	68	0	33		0		0.0	0.00	28.58	29.69	4.2	26	5.5	20	25	17	25	812	98	0		0	
03	113	83	98	5	45	66	0	33		0		0.0	0.00	28.57	29.67	4.7	28	7.1	22	25	17	25	825	100	0	1	0	0
04	109	85	97	4	52	68	0	32		0		0.0	0.00	28.64	29.75	.8	9	4.9	20	28	13	25	798	97	0	1	0	1
05	113*	90	102*	9	55	70	0	37	H	0		0.0	0.00	28.69	29.80	5.3	10	9.1	31	10	25	10	744	91	0	1	0	2
06	108	89	99	6	58	72	0	34	T	0		0.0	0.00	28.67	29.78	2.6	32	7.1	21	32	16	32	727	89	0	1	0	3
07	107	87	97	4	59	72	0	32		0		0.0	0.00	28.60	29.71	6.9	25	9.3	22	26	17	25	753	92	0		0	3
08	98	81	90	-3	65	72	0	25	TR	0		0.0	0.01	28.70	29.82	1.1	14	7.9	23	22	17	22	322	39	0	4	2	6
09	100	80	90*	-3	66	73	0	25		0		0.0	0.00	28.76	29.88	3.2	24	5.8	15	15	14	15	439	54	0		0	5
10	108	84	96	4	62	73	0	31		0		0.0	0.00	28.69	29.80	4.2	28	5.1	16	23	14	23	795	98	0	1	0	2
11	112	89	101	9	58	72	0	36	TR	0		0.0	T	28.62	29.72	2.6	12	7.7	23	18	17	15	728	90	0	1	0	2
12	103	83	93	1	65	74	0	28	TRH	0		0.0	T	28.70	29.81	6.6	29	7.2	24	16	22	09	776	96	0	1	0	4
13	107	87	97	5	63	73	0	32		0		0.0	0.00	28.71	29.83	6.0	27	7.6	21	25	17	26	702	87	0	2	0	2
14	101	83	92	0	65	73	0	27	TR	0		0.0	T	28.71	29.83	4.6	31	7.4	26	26	20	26	357	44	1	7	0	5
15	108	86	97	5	60	72	0	32		0		0.0	0.00	28.66	29.76	1.8	8	6.0	18	17	15	14	751	93	0	0	0	1
16	106	83	95	3	65	74	0	30	H	0		0.0	0.00	28.66	29.77	4.5	24	8.2	37	15	31	15	693	86	0	1	0	3
17	102	80*	91	0	65	73	0	26	TR	0		0.0	0.01	28.74	29.85	2.2	22	6.6	18	27	15	27	629	79	0	4	0	4
18	106	86	96	5	64	74	0	31		0		0.0	0.00	28.70	29.82	4.9	28	5.5	18	25	14	25	751	94	0	1	0	0
19	107	86	97	6	64	73	0	32	H	0		0.0	0.00	28.67	29.78	1.0	31	9.4	37	14	31	13	760	95	0	0	0	0
20	105	81	93	2	63	72	0	28		0		0.0	0.00	28.64	29.75	1.8	18	4.8	15	26	13	27	795	100	0	1	0	0
21	106	86	96	5	62	72	0	31		0		0.0	0.00	28.64	29.75	2.9	15	7.1	28	16	24	16	774	97	0	1	0	1
22	102	81	92	1	61	71	0	27		0		0.0	0.00	28.68	29.80	2.2	18	6.0	14	29	13	13	750	95	0	2	0	2
23	106	84	95	4	58	70	0	30		0		0.0	0.00	28.69	29.80	3.9	27	4.5	17	23	11	30	747	95	0	1	0	1
24	107	83	95	5	59	71	0	30		0		0.0	0.00	28.70	29.81	2.5	13	5.0	16	13	14	14	763	97		1		1
25	105	88	97	7	62	73	0	32		0		0.0	0.00	28.74	29.85	5.5	27	7.8	20	26	17	25	683	87		1		3
26	102	85	94	4	66	74	0	29		0		0.0	0.00	28.72	29.84	3.8	26	7.9	25	29	20	25	683	87		1		2
27	103	83	93	3	65	73	0	28	R	0		0.0	T	28.69	29.80	1.1	10	5.2	16	23	14	23				2		2
28	106	83	95	5	63	73	0	30		0		0.0	0.00	28.68	29.79	2.7	26	4.5	17	22	15	23	746	96		0		1
29	106	85	96	6	63	73	0	31		0		0.0	0.00	28.64	29.75	3.9	26	6.4	17	25	14	26	725	93		1		1
30	104	86	95	5	63	73	0	30		0		0.0	0.00	28.60	29.71	4.2	23	7.2	23	27	18	17	756	97	0			0
31	103	83	93	4	64	73	0	28		0		0.0	0.00	28.64	29.75	2.3	15	6.3	21	20	18	20	760	98		0		0
	105.9	84.6	95.3	3.8	60.8	71.9	<------- MONTHLY AVERAGES ------->							28.67	29.78	2.1	26	6.6	<- MONTHLY AVERAGES ->						0	1	0	1
	DEPARTURE 2.2	DEPARTURE 5.4																										

DEGREE DAYS

	MONTHLY TOTAL	MONTHLY DEPARTURE	SEASON TO DATE TOTAL	SEASON TO DATE DEPARTURE
HEATING:	0	0	0	0
COOLING:	943	121	3374	189

TOTAL SNOWFALL: 0.0 TOTAL PRECIPITATION: 0.02
PRECIP. DEPARTURE: -.94

	TOTAL	DATE
GREATEST 24-HR PRECIPITATION:	0.01	17+
GREATEST 24-HR SNOWFALL:	0.0	
GREATEST SNOW DEPTH:	0	

SUNSHINE TOTALS: 21291 PERCENT
TOTAL POSSIBLE : 24871 POSSIBLE: 86

WIND	SPEED	DIRECTION	DATE
MAXIMUM 5-SECOND :	37	14	19+
MAXIMUM 2-MINUTE :	31	13	19+

NUMBER OF DAYS WITH ->

SKY CONDITIONS CLEAR	PARTLY CLOUDY	CLOUDY
16	2	1

MAXIMUM TEMP ≥ 90 : 31
MAXIMUM TEMP ≤ 32 : 0
THUNDERSTORMS : 6

MINIMUM TEMP ≤ 32 : 0
MINIMUM TEMP ≤ 0 : 0
HEAVY FOG : 0

PRECIPITATION ≥ 0.01 INCH : 2
PRECIPITATION ≥ 0.10 INCH : 0
SNOWFALL ≥ 1.0 INCH : 0

<- NUMBER OF DAYS WITH

AUGUST 1994
PHOENIX, AZ

J-101

HOURLY PRECIPITATION
(WATER EQUIVALENT IN INCHES)

AUGUST 1994
PHOENIX, AZ

WBAN #23183

DATE	A.M. HOUR (L.S.T.) ENDING AT												DATE	P.M. HOUR (L.S.T.) ENDING AT												DATE
	1	2	3	4	5	6	7	8	9	10	11	12		1	2	3	4	5	6	7	8	9	10	11	12	
01													01													01
02													02													02
03													03													03
04													04													04
05													05													05
06													06													06
07													07													07
08	T	0.01	T	T									08									T	T			08
09													09													09
10													10													10
11													11												T	11
12	T	T	T										12													12
13													13													13
14							T	T	T		T		14													14
15													15													15
16													16													16
17					0.01								17													17
18													18													18
19													19													19
20													20													20
21													21													21
22													22													22
23													23													23
24													24													24
25													25													25
26													26													26
27													27								T	T				27
28													28													28
29													29													29
30													30													30
31													31													31

PUBLISHED BY: NCDC, ASHEVILLE, NC.

MAXIMUM SHORT DURATION PRECIPITATION (MSDP) **

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)												
ENDED: DATE												
ENDED: TIME												

The time indicated is the ending time of the interval. Date and time are not entered for trace amounts.

*The sum of the hourly totals follows the * when it disagrees with the daily total on page 1. NWS does not edit ASOS hourly precipitation but may edit daily and monthly totals. Hourly, daily and monthly totals are printed as reported by the ASOS site.

**NCDC derives MSDP data from one-minute ASOS data. The MSDP data are not printed when inconsistent with ASOS hourly totals.

REFERENCE NOTES :

WFO = WEATHER FORECAST OFFICE.
ASOS = AUTOMATED SURFACE OBSERVING SYSTEM.
* = EXTREME FOR THE MONTH (LAST OCCURRENCE IF MORE THAN ONE).
T = TRACE PRECIPITATION AMOUNT.
\+ = ALSO OCCURS ON EARLIER DATES.
F+ = HEAVY FOG, VISIBILITY .25 MILES OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.
THE HEATING DEGREE DAY SEASON BEGINS JULY 1.
THE COOLING DEGREE DAY SEASON BEGINS JANUARY 1.
CEILOMETER (30-SECOND) DATA ARE USED TO DERIVE CLOUDINESS AT OR BELOW 12,000 FEET. THIS CLOUDINESS IS THE MEAN CLOUD COVER DETECTED DURING THE TIME INTERVAL (HOUR, SUNRISE TO SUNSET, OR MIDNIGHT TO MIDNIGHT).
SATELLITE DATA ARE USED TO DERIVE CLOUDINESS ABOVE 12,000 FEET. EFFECTIVE CLOUD AMOUNT IS BASED ON THE CLOUD COVER AND THE TRANSPARENCY OF THE CLOUDS WITHIN THE SATELLITE FIELD OF VIEW (APPROX. 50 x 50 KM).
SKY CONDITION IS BASED ON THE SUM (NOT TO EXCEED 10) OF THE SUNRISE TO SUNSET CLOUD COVER BELOW AND ABOVE 12,000 FEET. BOTH CEILOMETER AND SATELLITE DATA MUST BE PRESENT TO COMPUTE SKY CONDITION. CLEAR = 0 -3 TENTHS, PARTLY CLOUDY = 4 - 7 TENTHS, AND CLOUDY = 8 - 10 TENTHS.
RESULTANT WIND IS THE VECTOR SUM OF THE WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS.
WIND DIRECTION IS RECRDED IN TENS OF DEGREES (2 DIGITS) CLOCKWISE FROM TRUE NORTH. '00' INDICATES CALM. '36' INDICATES CALM.
SR-SS = SUNRISE TO SUNSET. MN-MN = MIDNIGHT TO MIDNIGHT.
SNOWFALL IS FOR THE 24-HOUR PERIOD ENDING AT THE TIME INDICATED IN COLUMN HEADING.
WATER EQUIVALENT OF SNOW ON THE GROUND IS REPORTED ONLY WHEN THE DEPTH IS 2 OR MORE INCHES.
H, F, F+, P-, R, S, AND ZR ARE REPORTED FROM ASOS AUTOMATED SENSORS. OTHER WEATHER TYPES MAY BE ADDED TO THE REPORT BY STATION PERSONNEL OR BE PROVIDED BY THE WEATHER FORECAST OFFICE (WFO).

A	HAIL	GL	GLAZE	SG	SNOW GRAINS
BD	BLOWING DUST	H	HAZE	SP	SNOW PELLETS
BN	BLOWING SAND	IC	ICE CRYSTALS	T	THUNDER
BS	BLOWING SNOW	IF	ICE FOG	V	VOLCANIC ASH
BY	BLOWING SPRAY	IP	ICE PELLETS	ZL	FREEZING DRIZZLE
D	DUST	K	SMOKE	ZR	FREEZING RAIN
F	FOG	L	DRIZZLE	&	TORNADO
F+	HEAVY FOG	P-	UNKN. PRECIP.	&C	FUNNEL CLOUD
GF	GROUND FOG	R	RAIN	&W	WATERSPOUT
		S	SNOW		

NORMALS ARE FOR THE YEARS 1961 - 1990.
A HEATING (COOLING) DEGREE DAY IS THE DEFERENCE BETWEEN THE AVERAGE DAILY TEMPERATURE AND 65°F.
DEW POINT IS THE TEMPERATURE TO WHICH THE AIR MUST BE COOLED TO ACHIEVE 100% RELATIVE HUMIDITY.
WET BULB IS THE TEMPERATURE THE AIR WOULD HAVE IF THE MOISTURE CONTENT WAS INCREASED TO 100% RELATIVE HUMIDITY.

TEMPERATURE - HUMIDITY INDEX (STEADMAN, 1979)

RELATIVE HUMIDITY (PERCENT)

APPARENT TEMPERATURE

TEMPERATURE °F	0	10	20	30	40	50	60	70	80	90	100
120	107	116	130	148							
115	103	111	120	135	151						
110	99	105	112	123	137	150					
105	95	100	105	113	123	135	149				
100	91	95	99	104	110	120	132	144			
95	87	90	93	96	101	107	114	124	136		
90	83	85	87	90	93	96	100	106	113	122	
85	78	80	82	84	86	88	90	93	97	102	108
80	73	75	77	78	79	81	82	85	86	88	91
75	69	70	72	73	74	75	76	77	78	79	80
70	64	65	66	67	68	69	70	70	71	71	72

WIND CHILL EQUIVALENT TEMPERATURE (SIPLE & PASSEL, 1945)

WIND VELOCITY (MPH)

TEMPERATURE °F	4	5	10	15	20	25	30	35	40	45
45	45	43	34	29	26	23	21	20	19	18
40	40	37	26	23	19	16	13	12	11	10
35	35	32	22	16	12	8	6	4	3	2
30	30	27	16	9	4	1	-2	-4	-5	-6
25	25	22	10	2	-3	-7	-10	-12	-13	-14
20	20	16	3	-5	-10	-15	-18	-20	-21	-22
15	15	11	-3	-11	-17	-22	-25	-27	-29	-30
10	10	6	-9	-18	-24	-29	-33	-35	-37	-38
5	5	0	-15	-25	-31	-36	-41	-43	-45	-46
0	0	-5	-22	-31	-39	-44	-49	-52	-53	-54
-5	-5	-10	-27	-38	-46	-51	-56	-58	-60	-62
-10	-10	-15	-34	-45	-53	-59	-64	-67	-69	-70
-15	-15	-21	-40	-51	-60	-66	-71	-74	-76	-78
-20	-20	-26	-46	-58	-67	-74	-79	-82	-84	-85
-25	-25	-31	-52	-65	-74	-81	-86	-89	-92	-93
-30	-30	-36	-58	-72	-81	-88	-93	-97	-100	-102

ADDITIONAL INFORMATION :

OBSERVATIONS AT 3-HOURLY INTERVALS

AUGUST 1994
PHOENIX, AZ

WBAN # 23183

HOUR (LST)	< 12K FEET		SATELLITE > 12K FT		100'S OF FT		VISIBILITY (MILES)	WEATHER	TEMPERATURE °F			RELATIVE HUMIDITY (PCT)	WIND		PRESSURE (INCHES,HG)	
	CEILOMETER TENTHS	CEILING 100'S OF FT	OBSERVATION TIME(LST)	EFF CLD AMT TENTHS	LOWEST CLOUD TOP	HIGHEST CLOUD TOP			DRY BULB	DEW POINT	WET BULB		SPEED (MPH)	DIRECTION TENS OF DEG	STATION	SEA LEVEL
			SUNRISE: 0540					AUG 01		SUNSET: 1928						
02	0	NC	0124	0	NT	NT	10.00		91	57	69	32	6	32	28.68	29.78
05	0	NC	0450	0	NT	NT	10.00		88	55	67	33	0	00	28.70	29.80
08	0	NC					10.00		92	59	71	33	0	00	28.74	29.85
11	0	NC					10.00		101	52	70	19	3	27	28.73	29.84
14	0	NC					10.00		107	54	72	17	12	28	28.66	29.77
17	0	NC					10.00		107	52	72	16	12	23	28.59	29.70
20	0	NC	1924	0	NT	NT	10.00		104	53	71	18	8	27	28.59	29.69
23	0	NC	2250	0	NT	NT	10.00		97	53	69	23	7	28	28.61	29.71
			SUNRISE: 0541					AUG 02		SUNSET: 1928						
02	0	NC	0124	0	NT	NT	10.00		90	53	67	28	0	00	28.61	29.70
05	0	NC	0450	0	NT	NT	10.00		86	53	66	32	0	00	28.62	29.73
08	0	NC					10.00		92	53	68	27	3	36	28.66	29.77
11	0	NC					10.00		102	51	70	18	5	27	28.66	29.75
14	0	NC					10.00		109	50	71	14	8	24	28.59	29.69
17	0	NC					10.00		110	49	71	13	13	25	28.51	29.61
20	0	NC	1924	0	NT	NT	10.00		107	45	69	12	8	25	28.50	29.60
23	0	NC	2250	0	NT	NT	10.00		98	44	66	16	7	29	28.54	29.63
			SUNRISE: 0542					AUG 03		SUNSET: 1927						
02	0	NC	0124	0	NT	NT	10.00		92	46	65	21	3	29	28.54	29.64
05	0	NC	0450	0	NT	NT	10.00		84	45	62	26	3	12	28.57	29.67
08	0	NC	0724	0	NT	NT	10.00		89	49	65	25	7	11	28.64	29.74
11	0	NC	1050	0	NT	NT	10.00		103	41	67	12	5	31	28.64	29.75
14	0	NC	1324	6	190	190	10.00		111	40	69	9	10	29	28.59	29.69
17	0	NC					10.00		112	41	69	9	13	27	28.52	29.62
20	0	NC	1924	0	NT	NT	10.00		106	45	69	13	12	27	28.52	29.62
23	0	NC	2250	0	NT	NT	10.00		100	45	67	15	7	30	28.55	29.65
			SUNRISE: 0543					AUG 04		SUNSET: 1926						
02	0	NC	0124	0	NT	NT	10.00		91	48	65	23	0	00	28.57	29.68
05	0	NC	0450	0	NT	NT	10.00		88	49	65	26	3	10	28.62	29.72
08	0	NC	0724	1	130	440	10.00		91	51	67	26	8	05	28.72	29.83
11	0	NC	1050	0	NT	NT	10.00		100	55	71	22	8	10	28.73	29.84
14	0	NC	1324	0	NT	NT	10.00		105	49	70	15	0	00	28.66	29.77
17	0	NC					10.00		108	52	72	16	9	27	28.61	29.71
20	0	NC	1924	0	NT	NT	10.00		105	53	71	18	5	29	28.59	29.71
23	0	NC	2250	0	NT	NT	10.00		98	57	71	26	6	09	28.64	29.75
			SUNRISE: 0543					AUG 05		SUNSET: 1925						
02	0	NC	0124	1	200	380	10.00		95	57	70	28	7	14	28.66	29.77
05	0	NC	0450	1	220	330	10.00		90	54	68	29	6	11	28.70	29.80
08	0	NC	0724	5	130	460	10.00		96	58	71	28	7	12	28.76	29.87
11	0	NC	1050	0	NT	NT	10.00		106	54	72	18	14	14	28.77	29.88
14	0	NC	1324	0	NT	NT	10.00		110	53	73	15	5	19	28.70	29.79
17	0	NC					10.00		112	53	73	14	7	31	28.61	29.71
20	0	NC	1924	4	130	440	7.00		98	57	71	26	24	06	28.64	29.75
23	0	NC	2250	6	220	440	10.00		98	55	70	24	7	36	28.70	29.81
			SUNRISE: 0544					AUG 06		SUNSET: 1924						
02	0	NC	0124	8	230	440	10.00		95	56	70	27	8	08	28.70	29.79
05	0	NC	0450	4	130	260	10.00		92	56	69	30	0	00	28.70	29.80
08	0	NC	0724	2	150	330	10.00		92	59	71	33	7	13	28.75	29.86
11	0	NC	1050	1	240	330	10.00		99	62	74	30	8	30	28.74	29.85
14	0	NC	1324	0	NT	NT	10.00		105	61	75	24	8	24	28.66	29.77
17	0	NC					10.00		108	59	75	20	8	28	28.57	29.68
20	0	120	1924	4	150	380	10.00	T	103	57	73	22	13	01	28.59	29.70
23	0	NC	2250	9	350	440	10.00		95	57	70	28	12	34	28.70	29.80

HOUR (LST)	< 12K FEET		SATELLITE > 12K FT		100'S OF FT		VISIBILITY (MILES)	WEATHER	TEMPERATURE °F			RELATIVE HUMIDITY (PCT)	WIND		PRESSURE (INCHES,HG)	
	CEILOMETER TENTHS	CEILING 100'S OF FT	OBSERVATION TIME(LST)	EFF CLD AMT TENTHS	LOWEST CLOUD TOP	HIGHEST CLOUD TOP			DRY BULB	DEW POINT	WET BULB		SPEED (MPH)	DIRECTION TENS OF DEG	STATION	SEA LEVEL
			SUNRISE: 0545					AUG 07		SUNSET: 1923						
02	0	NC	0124	5	160	460	10.00		92	56	69	30	5	08	28.61	29.72
05	0	NC	0450	0	NT	NT	10.00		89	57	69	34	5	29	28.64	29.74
08	0	NC					10.00		92	59	71	33	7	12	28.68	29.78
11	0	NC	1050	1	300	380	10.00		102	58	73	23	8	30	28.66	29.77
14	0	NC	1324	1	220	440	10.00		106	58	74	21	12	28	28.59	29.70
17	0	NC					10.00		107	57	74	19	16	25	28.53	29.63
20	0	NC	1924	5	130	460	10.00		102	61	74	26	10	24	28.53	29.64
23	0	NC	2250	0	NT	NT	10.00		96	63	74	34	13	27	28.59	29.69
			SUNRISE: 0545					AUG 08		SUNSET: 1922						
02	4	NC	0124	9	150	440	10.00	TR	85	66	72	53	14	32	28.61	29.72
05	4	110	0450	1	130	130	10.00		82	67	72	61	7	07	28.70	29.81
08	0	NC	0724	1	130	380	10.00		84	68	73	59	7	10	28.72	29.84
11	0	NC	1006	5	130	440	10.00		90	62	72	39	6	13	28.73	29.85
14	0	NC	1324	9	260	380	10.00		95	59	71	30	5	30	28.70	29.82
17	0	NC					10.00		97	62	73	32	10	28	28.64	29.76
20	7	95	1924	10	300	460	10.00	T	90	65	73	44	14	20	28.73	29.85
23	0	NC					10.00		83	69	73	63	8	10	28.75	29.87
			SUNRISE: 0546					AUG 09		SUNSET: 1921						
02	0	NC	0124	7	260	440	10.00		80	70	73	72	9	14	28.78	29.90
05	0	NC	0450	4	200	300	10.00		81	67	72	63	0	00	28.76	29.88
08	0	NC	0724	5	160	460	10.00		86	68	74	55	8	23	28.80	29.92
11	0	NC	1050	7	200	330	10.00		90	66	74	45	5	16	28.82	29.94
14	0	NC					10.00		94	66	75	40	10	21	28.77	29.89
17	0	NC					10.00		99	63	74	31	7	27	28.71	29.83
20	0	NC					10.00		95	63	73	35	6	27	28.73	29.85
23	0	NC	2250	8	300	440	10.00		92	64	73	40	7	27	28.75	29.86
			SUNRISE: 0547					AUG 10		SUNSET: 1920						
02	0	NC	0124	2	130	440	10.00		88	65	73	47	5	25	28.73	29.85
05	0	NC	0450	5	130	300	10.00		85	65	72	51	3	23	28.73	29.85
08	0	NC	0724	0	NT	NT	10.00		89	65	73	45	3	28	28.77	29.89
11	0	NC	1050	0	NT	NT	10.00		99	62	74	30	6	28	28.75	29.86
14	0	NC	1325	1	210	210	10.00		105	60	75	23	8	32	28.68	29.78
17	0	NC					10.00		106	58	74	21	3	24	28.61	29.71
20	0	NC					10.00		103	60	74	24	6	27	28.59	29.70
23	0	NC	2250	0	NT	NT	10.00		98	61	73	30	3	31	28.62	29.73
			SUNRISE: 0548					AUG 11		SUNSET: 1919						
02	0	NC	0124	2	130	380	10.00		94	60	72	32	8	07	28.62	29.73
05	0	NC	0450	0	NT	NT	10.00		93	58	70	31	6	10	28.64	29.74
08	0	NC	0724	0	NT	NT	10.00		97	59	72	28	6	01	28.68	29.78
11	0	NC	1050	0	NT	NT	10.00		105	57	73	21	6	07	28.66	29.76
14	0	NC	1325	2	130	440	10.00		109	54	73	16	9	15	28.59	29.70
17	0	NC					10.00		108	56	73	18	5	20	28.55	29.66
20	0	NC	1924	2	130	460	10.00		104	64	76	27	8	28	28.57	29.68
23	3	85	2250	8	180	330	10.00	T	96	61	73	31	7	24	28.64	29.75
			SUNRISE: 0548					AUG 12		SUNSET: 1918						
02	0	NC	0124	10	430	520	10.00	T	90	65	73	44	3	28	28.68	29.78
05	1	NC	0450	0	NT	NT	10.00		84	68	73	59	10	31	28.73	29.85
08	0	NC	0724	0	NT	NT	10.00		86	69	74	57	0	00	28.78	29.89
11	0	NC	1051	0	NT	NT	10.00		95	66	75	39	3	31	28.75	29.86
14	0	NC	1325	0	NT	NT	10.00		101	65	76	31	7	28	28.68	29.79
17	0	NC					10.00		102	63	75	28	8	29	28.61	29.72
20	0	NC	1924	9	330	460	10.00		100	64	75	31	9	27	28.66	29.77
23	0	NC	2250	6	300	460	10.00		93	64	73	38	9	28	28.71	29.82

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OBSERVATIONS AT 3-HOURLY INTERVALS

AUGUST 1994
PHOENIX, AZ

WBAN # 23183

HOUR (LST)	< 12K FEET		SATELLITE > 12K FT				VISIBILITY (MILES)	WEATHER	TEMPERATURE °F			RELATIVE HUMIDITY (PCT)	WIND		PRESSURE (INCHES,HG)	
	CEILOMETER TENTHS	CEILING 100'S OF FT	OBSERVATION TIME(LST)	EFF CLD AMT TENTHS	100'S OF FT LOWEST CLOUD TOP	HIGHEST CLOUD TOP			DRY BULB	DEW POINT	WET BULB		SPEED (MPH)	DIRECTION TENS OF DEG	STATION	SEA LEVEL
			SUNRISE: 0549					AUG 13		SUNSET: 1917						
02	0	NC	0124	5	180	460	10.00		90	65	73	44	6	27	28.71	29.82
05	0	NC	0450	0	NT	NT	10.00		89	65	73	45	0	00	28.73	29.84
08	0	NC	0724	3	220	460	10.00		90	65	73	44	6	12	28.77	29.89
11	0	NC	1050	0	NT	NT	10.00		97	64	74	34	7	28	28.78	29.89
14	0	NC	1325	0	NT	NT	10.00		104	62	75	25	9	28	28.71	29.82
17	0	NC					10.00		106	60	75	22	13	25	28.64	29.76
20	0	NC	1924	0	NT	NT	10.00		103	61	74	25	10	27	28.68	29.78
23	0	NC	2250	1	130	440	10.00		98	62	74	31	10	27	28.70	29.81
			SUNRISE: 0550					AUG 14		SUNSET: 1916						
02	0	NC	0124	1	130	440	10.00		92	66	74	42	8	27	28.70	29.81
05	0	NC	0450	9	170	230	10.00		89	65	73	45	7	32	28.73	29.84
08	6	NC	0724	9	230	440	10.00	R	83	73	76	72	7	06	28.78	29.89
11	0	NC	1051	9	190	300	10.00		92	65	74	41	9	28	28.79	29.91
14	0	NC	1325	6	220	330	10.00		95	65	74	37	10	31	28.71	29.83
17	0	NC					10.00		101	61	74	27	6	31	28.64	29.75
20	0	NC	1924	5	220	440	10.00		97	63	74	33	3	30	28.64	29.75
23	0	NC	2250	4	240	440	10.00		95	58	71	29	7	08	28.70	29.80
			SUNRISE: 0550					AUG 15		SUNSET: 1915						
02	0	NC	0124	3	220	380	10.00		90	61	71	38	7	10	28.68	29.80
05	0	NC	0450	1	220	380	10.00		88	60	70	39	5	10	28.68	29.79
08	0	NC	0724	0	NT	NT	10.00		91	61	71	37	10	07	28.72	29.84
11	0	NC	1051	0	NT	NT	10.00		99	60	73	28	10	15	28.72	29.83
14	0	NC	1325	0	NT	NT	10.00		103	58	73	23	7	24	28.66	29.76
17	0	NC					10.00		106	58	74	21	0	00	28.57	29.68
20	0	NC	1924	3	130	440	10.00		101	60	73	26	12	32	28.57	29.69
23	0	NC	2250	0	NT	NT	10.00		95	63	73	35	3	28	28.61	29.72
			SUNRISE: 0551					AUG 16		SUNSET: 1914						
02	0	NC	0124	0	NT	NT	10.00		91	62	72	38	0	00	28.62	29.73
05	0	NC	0428	0	NT	NT	10.00		87	64	72	46	3	34	28.66	29.77
08	0	NC	0724	2	130	440	10.00		91	67	75	45	5	24	28.72	29.84
11	0	NC	1051	0	NT	NT	10.00		98	66	76	35	6	27	28.72	29.83
14	0	NC	1325	0	NT	NT	10.00		103	66	77	30	10	26	28.66	29.76
17	0	NC					10.00		105	64	76	26	12	27	28.57	29.68
20	0	NC	1924	9	220	460	10.00		102	64	76	29	6	29	28.62	29.73
23	2	NC	2250	10	450	490	10.00		83	69	73	63	14	09	28.71	29.83
			SUNRISE: 0552					AUG 17		SUNSET: 1913						
02	0	NC					10.00		83	68	73	61	7	10	28.72	29.83
05	2	NC	0428	9	210	330	10.00	T	80	69	73	69	8	11	28.74	29.85
08	0	95	0724	7	180	380	10.00		84	68	73	59	3	34	28.81	29.93
11	0	NC	1051	3	200	380	10.00		93	65	74	40	5	17	28.80	29.92
14	0	NC	1325	3	130	380	10.00		98	62	74	31	10	26	28.74	29.85
17	0	NC					10.00		100	63	75	30	10	28	28.68	29.80
20	0	NC	1924	0	NT	NT	10.00		99	63	74	31	8	21	28.70	29.80
23	0	NC	2250	0	NT	NT	10.00		95	63	73	35	0	00	28.70	29.82
			SUNRISE: 0552					AUG 18		SUNSET: 1912						
02	0	NC					10.00		91	66	74	44	3	29	28.70	29.82
05	0	NC					10.00		87	66	73	50	0	00	28.72	29.83
08	0	NC	0724	0	NT	NT	10.00		90	66	74	45	3	16	28.77	29.88
11	0	NC	1051	0	NT	NT	10.00		99	65	76	33	5	30	28.77	29.88
14	0	NC	1325	0	NT	NT	10.00		104	63	76	26	9	29	28.71	29.82
17	0	NC					10.00		104	62	75	25	10	27	28.64	29.75
20	0	NC	1924	0	NT	NT	10.00		101	63	75	29	6	27	28.66	29.76
23	0	NC	2250	0	NT	NT	10.00		96	64	74	35	5	23	28.68	29.78

HOUR (LST)	< 12K FEET		SATELLITE > 12K FT				VISIBILITY (MILES)	WEATHER	TEMPERATURE °F			RELATIVE HUMIDITY (PCT)	WIND		PRESSURE (INCHES,HG)	
	CEILOMETER TENTHS	CEILING 100'S OF FT	OBSERVATION TIME(LST)	EFF CLD AMT TENTHS	100'S OF FT LOWEST CLOUD TOP	HIGHEST CLOUD TOP			DRY BULB	DEW POINT	WET BULB		SPEED (MPH)	DIRECTION TENS OF DEG	STATION	SEA LEVEL
			SUNRISE: 0553					AUG 19		SUNSET: 1911						
02	0	NC	0124	0	NT	NT	10.00		93	63	73	37	7	29	28.68	29.78
05	0	NC	0428	0	NT	NT	10.00		89	63	72	42	6	31	28.66	29.78
08	0	NC	0724	0	NT	NT	10.00		93	64	73	38	6	32	28.71	29.82
11	0	NC	1051	0	NT	NT	10.00		100	64	75	31	8	27	28.71	29.83
14	0	NC	1325	0	NT	NT	10.00		106	65	77	27	10	29	28.64	29.74
17	0	NC					10.00		101	64	75	30	8	36	28.59	29.70
20	1	NC	1924	4	130	380	10.00		88	68	74	52	22	12	28.68	29.79
23	4	100	2250	0	NT	NT	10.00		88	64	72	45	5	05	28.73	29.85
			SUNRISE: 0554					AUG 20		SUNSET: 1909						
02	0	NC	0124	0	NT	NT	10.00		86	62	70	45	0	00	28.68	29.79
05	0	NC	0428	0	NT	NT	10.00		82	66	71	59	6	07	28.68	29.78
08	0	NC	0724	0	NT	NT	10.00		85	67	73	55	8	12	28.71	29.83
11	0	NC	1051	0	NT	NT	10.00		94	63	73	36	3	16	28.71	29.83
14	0	NC	1325	0	NT	NT	10.00		103	63	75	27	0	00	28.64	29.74
17	0	NC					10.00		105	61	75	24	7	27	28.55	29.67
20	0	NC	1924	0	NT	NT	10.00		100	61	74	28	0	00	28.57	29.68
23	0	NC	2250	0	NT	NT	10.00		98	62	74	31	9	25	28.61	29.71
			SUNRISE: 0554					AUG 21		SUNSET: 1908						
02	0	NC	0124	0	NT	NT	10.00		91	60	71	35	3	01	28.61	29.72
05	0	NC	0428	0	NT	NT	10.00		87	62	71	43	0	00	28.64	29.75
08	0	NC	0724	0	NT	NT	10.00		90	65	73	44	5	05	28.70	29.80
11	0	NC	1051	0	NT	NT	10.00		97	63	74	33	6	13	28.70	29.81
14	0	NC	1325	7	210	210	10.00		104	62	75	25	9	25	28.61	29.72
17	0	NC					10.00		105	59	74	22	8	28	28.55	29.66
20	3	NC					10.00		95	63	73	35	18	16	28.61	29.72
23	0	NC	2250	8	210	460	10.00		87	64	72	46	10	12	28.68	29.79
			SUNRISE: 0555					AUG 22		SUNSET: 1907						
02	0	NC	0124	4	130	440	10.00		84	62	70	48	6	10	28.68	29.80
05	0	NC	0428	2	150	380	10.00		82	62	69	51	6	10	28.70	29.82
08	0	NC	0724	6	210	460	10.00		85	61	69	45	12	14	28.75	29.87
11	0	NC	1051	2	220	380	10.00		93	62	72	36	6	20	28.75	29.87
14	0	NC	1325	0	NT	NT	10.00		100	60	73	27	3	19	28.68	29.80
17	0	NC					10.00		101	61	74	27	6	26	28.61	29.72
20	0	NC	1924	1	220	330	10.00		97	61	73	30	6	29	28.62	29.73
23	0	NC	2250	0	NT	NT	10.00		94	61	72	33	7	28	28.66	29.77
			SUNRISE: 0556					AUG 23		SUNSET: 1906						
02	0	NC	0124	2	150	440	10.00		89	57	69	34	5	32	28.66	29.78
05	0	NC	0428	0	NT	NT	10.00		86	57	68	37	0	00	28.70	29.80
08	0	NC	0724	0	NT	NT	10.00		89	58	69	35	8	25	28.75	29.87
11	0	NC	1051	0	NT	NT	10.00		96	59	72	29	0	00	28.76	29.87
14	0	NC	1325	0	NT	NT	10.00		102	61	74	26	3	29	28.70	29.80
17	0	NC					10.00		104	59	74	23	9	31	28.64	29.74
20	0	NC	1924	0	NT	NT	10.00		101	55	71	22	5	27	28.64	29.75
23	0	NC	2250	2	220	440	10.00		94	58	71	30	0	00	28.66	29.77
			SUNRISE: 0557					AUG 24		SUNSET: 1905						
02	0	NC	0124	0	NT	NT	10.00		91	59	70	34	5	14	28.68	29.78
05	0	NC	0428	0	NT	NT	10.00		85	61	69	45	6	09	28.68	29.80
08	0	NC	0724	0	NT	NT	10.00		88	60	70	39	5	08	28.74	29.85
11	0	NC	1051	1	180	440	10.00		97	60	72	29	6	13	28.77	29.89
14	0	NC	1325	0	NT	NT	10.00		103	59	74	24	6	06	28.71	29.82
17		NC					10.00		107	60	75	22	7	23	28.66	29.76
20		NC	1924	0	NT	NT	10.00		102	56	72	22	3	19	28.64	29.75
23	0	NC	2250	1	130	330	10.00		96	57	71	27	0	00	28.70	29.80

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OBSERVATIONS AT 3-HOURLY INTERVALS

AUGUST 1994
PHOENIX, AZ

WBAN # 23183

HOUR (LST)	< 12K FEET		SATELLITE > 12K FT			VISIBILITY (MILES)	WEATHER	TEMPERATURE °F			RELATIVE HUMIDITY (PCT)	WIND		PRESSURE (INCHES,HG)	
	CEILOMETER TENTHS	CEILING 100'S OF FT	OBSERVATION TIME(LST)	EFF CLD AMT TENTHS	100'S OF FT LOWEST CLOUD TOP	100'S OF FT HIGHEST CLOUD TOP			DRY BULB	DEW POINT	WET BULB		SPEED (MPH)	DIRECTION TENS OF DEG	STATION	SEA LEVEL
SUNRISE: 0557 AUG 25 SUNSET: 1903																
02	0	NC					10.00		92	62	72	37	3	01	28.71	29.83
05	0	NC	0427	8	140	330	10.00		89	59	70	36	5	07	28.75	29.87
08	0	NC	0724	2	130	440	10.00		90	64	73	42	7	33	28.83	29.94
11		NC	1051	0	NT	NT	10.00		97	64	74	34	12	29	28.83	29.94
14		NC	1325	0	NT	NT	10.00		103	63	75	27	12	28	28.74	29.85
17		NC					10.00		103	61	74	25	10	26	28.66	29.77
20		NC	1924	2	130	460	10.00		101	61	74	27	12	24	28.68	29.78
23		NC	2250	5	210	460	10.00		94	68	76	43	12	26	28.71	29.83
SUNRISE: 0558 AUG 26 SUNSET: 1902																
02	0	NC	0124	5	170	460	10.00		88	67	74	50	13	16	28.76	29.88
05	0	NC	0428	0	NT	NT	10.00		85	67	73	55	3	01	28.77	29.89
08	0	NC	0724	3	130	330	10.00		88	66	73	48	6	28	28.79	29.91
11	0	NC	1051	3	130	330	10.00		93	67	75	43	6	25	28.78	29.90
14	0	NC	1325	0	NT	NT	10.00		100	68	77	35	7	31	28.70	29.81
17		NC					10.00		101	63	75	29	7	26	28.64	29.74
20		NC	1924	0	NT	NT	10.00		97	66	76	36	12	26	28.66	29.77
23		110	2250	4	270	440	10.00		90	63	72	41	9	06	28.71	29.82
SUNRISE: 0559 AUG 27 SUNSET: 1901																
02		NC					10.00		86	67	73	53	7	12	28.70	29.80
05		NC	0428	2	130	330	10.00		84	67	73	57	5	09	28.70	29.82
08		NC	0724	0	NT	NT	10.00		89	65	73	45	3	04	28.74	29.86
11		NC	1051	0	NT	NT	10.00		96	65	75	36	3	08	28.74	29.86
14		NC	1325	0	NT	NT	10.00		102	66	77	31	5	29	28.66	29.77
17		NC					10.00		100	66	76	33	8	23	28.62	29.73
20		100	1924	3	220	440	10.00	R	94	64	74	37	8	35	28.66	29.78
23		NC	2250	0	NT	NT	10.00		91	61	71	37	5	13	28.68	29.79
SUNRISE: 0559 AUG 28 SUNSET: 1860																
02		NC	0124	0	NT	NT	10.00		86	64	71	48	5	30	28.66	29.78
05		NC	0428	0	NT	NT	10.00		83	63	70	51	5	10	28.70	29.81
08		NC	0724	0	NT	NT	10.00		88	63	71	43	3	26	28.74	29.85
11		NC	1051	0	NT	NT	10.00		99	62	74	30	6	31	28.75	29.86
14		NC	1325	0	NT	NT	10.00		103	63	75	27	8	21	28.68	29.79
17		NC					10.00		104	63	76	26	6	30	28.61	29.72
20		NC	1924	3	130	460	10.00		102	62	75	27	7	24	28.62	29.73
23		NC	2250	0	NT	NT	10.00		96	63	74	34	0	00	28.64	29.75
SUNRISE: 0560 AUG 29 SUNSET: 1858																
02		NC	0124	0	NT	NT	10.00		90	65	73	44	5	11	28.66	29.77
05		NC	0428	3	130	460	10.00		87	65	72	48	3	08	28.68	29.79
08		110	0724	5	140	440	10.00		88	65	73	47	5	12	28.72	29.83
11		NC	1051	0	NT	NT	10.00		98	62	74	31	7	30	28.72	29.83
14		NC	1325	0	NT	NT	10.00		103	62	75	26	6	32	28.64	29.74
17		NC					10.00		104	63	76	26	8	24	28.57	29.67
20		NC	1924	0	NT	NT	10.00		100	60	73	27	12	24	28.57	29.68
23		NC	2250	0	NT	NT	10.00		96	61	73	31	7	27	28.59	29.69
SUNRISE: 0601 AUG 30 SUNSET: 1857																
02		NC	0124	0	NT	NT	10.00		91	64	73	41	10	30	28.61	29.72
05		NC	0428	0	NT	NT	10.00		87	63	71	45	0	00	28.62	29.73
08	0	NC					10.00		89	65	73	45	7	14	28.68	29.79
11	0	NC					10.00		97	62	73	32	7	26	28.68	29.78
14	0	NC	1325	0	NT	NT	10.00		101	62	74	28	7	22	28.59	29.70
17	0	NC					10.00		104	63	76	26	10	28	28.53	29.63
20	0	NC	1924	0	NT	NT	10.00		100	60	73	27	6	21	28.54	29.64
23	0	NC	2250	0	NT	NT	10.00		91	65	73	42	10	18	28.59	29.70
SUNRISE: 0601 AUG 31 SUNSET: 1856																
02	1	NC	0123	3	220	380	10.00		86	65	72	50	6	09	28.64	29.76
05	0	NC	0428	0	NT	NT	10.00		84	66	72	55	6	11	28.64	29.75
08	0	NC	0724	0	NT	NT	10.00		87	65	72	48	8	16	28.70	29.80
11	0	NC	1051	0	NT	NT	10.00		94	62	73	35	5	17	28.70	29.81
14	0	NC	1325	0	NT	NT	10.00		100	63	75	30	7	26	28.62	29.74
17		NC					10.00		102	64	76	29	5	02	28.57	29.67
20		NC	1924	0	NT	NT	10.00		98	63	74	32	5	31	28.59	29.69
23		NC	2250	0	NT	NT	10.00		93	63	73	37	8	24	28.62	29.74

HOURLY SUMMARY NOTES

CEILING IS REPORTED IN HUNDREDS OF FEET (ABOVE GROUND LEVEL) FOR CLOUDS AT OR BELOW 12,000 FEET.
CLOUD TOPS ARE REPORTED IN HUNDREDS OF FEET (ABOVE MEAN SEA LEVEL) FOR CLOUDS ABOVE 12,000 FEET.
NC = A CEILING WAS NOT DETECTED AT OR BELOW 12,000 FEET.
NT = CLOUD TOPS WERE NOT DETECTED ABOVE 12,000 FEET.
SEE PAGE 3 FOR ADDITIONAL NOTES.

SUMMARY BY HOURS

HOUR (LST)	AVERAGES										RESULTANT WIND (MPH)	
	CEILOMETER	EFF CLD AMT	DRY BULB	DEW POINT	WET BULB	RELATIVE HUMIDITY	PRESSURE (INCHES,HG) STATION	PRESSURE (INCHES,HG) SEA LEVEL	VISIBILITY (MILES)	WIND SPEED (MPH)	SPEED	DIRECTION
01	0	3	91	61	71	39	28.67	29.78	10.00	6	0	0
02	0	2	89	61	71	41	28.67	29.78	10.00	6	0	0
03	0	3	88	61	71	42	28.67	29.78	10.00	5	0	0
04	0	2	87	61	70	43	28.67	29.79	10.00	4	0	0
05	0	2	86	61	70	45	28.69	29.80	10.00	4	2	7
06	0	2	86	62	70	46	28.70	29.82	10.00	4	1	9
07	0	2	87	71	62	45	28.72	29.83	10.00	4	2	10
08	0	2	89	63	72	43	28.74	29.85	10.00	6	2	11
09	0	2	92	62	72	38	28.74	29.85	10.00	6	2	12
10	0	1	95	61	73	34	28.74	29.86	10.00	6	1	19
11	0	1	97	61	73	31	28.74	29.85	10.00	6	2	25
12	0	2	99	61	74	29	28.72	29.83	10.00	6	3	24
13	0	1	101	60	74	27	28.69	29.80	10.00	7	4	25
14	0	1	103	60	74	25	28.67	29.78	10.00	8	6	27
15	0	1	104	60	74	25	28.64	29.74	9.84	9	6	27
16	0	2	105	59	74	24	28.61	29.72	10.00	9	7	27
17	0		104	59	74	24	28.60	29.71	10.00	8	7	27
18	0	1	104	59	74	24	28.59	29.70	10.00	8	7	27
19	0	1	102	59	73	26	28.60	29.71	9.52	10	6	26
20	0	2	100	60	73	28	28.62	29.73	9.90	9	4	26
21	1	2	97	60	73	31	28.64	29.75	10.00	8	4	22
22	0	3	96	60	72	32	28.65	29.76	10.00	7	3	25
23	0	2	94	61	72	35	28.66	29.77	10.00	7	2	27
24	0	3	92	61	72	37	28.67	29.78	10.00	7	0	0

SUPPLEMENTARY HOURLY PRECIPITATION

UNIVERSAL RAIN GAUGE (WATER EQUIVALENT IN INCHES)

AUGUST 1994
PHOENIX, AZ

LATITUDE 33° 26'N
LONGITUDE 112° 01'W

DATE	A.M. HOUR (L.S.T.) ENDING AT												DATE	P.M. HOUR (L.S.T.) ENDING AT												DATE	DAILY TOTAL
	1	2	3	4	5	6	7	8	9	10	11	12		1	2	3	4	5	6	7	8	9	10	11	12		
01													01													01	0.00
02													02													02	0.00
03													03													03	0.00
04													04													04	0.00
05													05							T	T					05	T
06													06													06	0.00
07													07													07	0.00
08		0.11											08									T	T			08	0.11
09													09													09	0.00
10													10													10	0.00
11													11											T	T	11	T
12	T	T	T										12													12	T
13													13													13	0.00
14													14								T	T				14	T
15													15													15	0.00
16													16													16	0.00
17					T	T	T	T					17													17	T
18													18													18	0.00
19													19													19	0.00
20													20													20	0.00
21													21													21	0.00
22													22													22	0.00
23													23													23	0.00
24													24													24	0.00
25													25													25	0.00
26													26													26	0.00
27													27													27	0.00
28													28													28	0.00
29													29													29	0.00
30													30													30	0.00
31													31													31	0.00

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MONTHLY TOTAL 0.11

SUPPLEMENTARY MAXIMUM SHORT DURATION PRECIPITATION (MSDP)

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.04	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
ENDED: DATE	08	08	08	08	08	08	08	08	08	08	08	08
ENDED: TIME	0206	0206	0206	0206	0206	0206	0206	0206	0206	0206	0206	0206

The time indicated is the ending time of the interval.
Date and time are not entered for trace amounts.

The National Weather Service has determined that the ASOS Heated Tipping-Bucket (HTB) rain gauge may not measure water equivalent precipitation accurately during frozen precipitation events. Precipitation data from a nearby site is provided on this page to supplement the ASOS HTB data.

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER. Kenneth D Hadeen

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MAR 1994
TUCSON, AZ
NAT'L WEA SER OFC
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INTERNATIONAL AIRPORT

ISSN # 0198-0483

LOCAL CLIMATOLOGICAL DATA

MONTHLY SUMMARY

MAR 1994
TUCSON, AZ

LATITUDE 32° 07'N LONGITUDE 110° 56'W ELEVATION (GROUND) 2584 FEET TIME ZONE MOUNTAIN 23160

	TEMPERATURE °F					DEGREE DAYS BASE 65 °F		WEATHER TYPES 1 FOG 2 HEAVY FOG 3 THUNDERSTORMS 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE,HAZE 9 BLOWING SNOW	SNOW/ ICE ON GRD AT 0500 (IN.)	PRECIPITATION (INCHES)		AVERAGE STATION PRESSURE (INCHES OF Hg) ELEV. 2555 (FT.MSL)	WIND (M.P.H.)							SUNSHINE		SKY COVER TENTHS	
																PEAK GUST		FASTEST MILE					
DATE	MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	HEATING	COOLING			WATER EQUIVALENT	SNOW ICE PELLETS		RESULTANT DIR	RESULTANT SPEED	AVERAGE SPEED	SPEED	DIR	SPEED	DIR	MINUTES	PERCENT POSSIBLE	SUNRISE TO SUNSET	MIDNIGHT TO MIDNIGHT
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
01	75	42	59	3	27	6	0		0	0.00	0.0	27.470	15	1.8	7.1	16	SE	7	NW	690	100	0	0
02	82	46	64	8	24	1	0		0	0.00	0.0	27.440	11	10.1	10.8	33	E	16	E	474	69	10	9
03	85	57	71	15	31	0	6		0	0.00	0.0	27.420	19	4.1	8.7	20	SW	10	S	477	69	7	8
04	82	51	67	11	33	0	2		0	0.00	0.0	27.410	23	1.6	7.4	21	W	12	W	685	99	3	3
05	81	48	65	9	28	0	0		0	0.00	0.0	27.340	18	2.4	8.8	24	W	13	W	698	100	0	0
06	82	50	66	9	28	0	1		0	0.00	0.0	27.260	19	9.1	11.8	32	SE	20	S	699	100	4	2
07	62	48	55	-2	41	10	0	3	0	0.18	0.0	27.300	31	3.4	8.4	23	SE	15	W	207	30	9	7
08	64	41	53	-4	39	12	0		0	0.00	0.0	27.370	34	2.3	7.7	20	NW	11	NW	580	83	5	3
09	73	40*	57	0	37	8	0		0	0.00	0.0	27.410	15	0.9	7.5	17	NW	9	NW	706	100	0	0
10	82	44	63	6	30	2	0		0	0.00	0.0	27.360	16	4.6	9.6	26	E	12	E	701	99	4	3
11	78	47	63	5	29	2	0		0	T	0.0	27.260	22	7.4	12.3	36	SW	27	SW	608	86	7	5
12	70	49	60	2	36	5	0		0	0.00	0.0	27.400	36	2.6	8.9	20	NW	13	NW	529	74	5	5
13	65	49	57	-1	36	8	0		0	0.00	0.0	27.490	11	11.7	12.8	33	NE	19	NE	359	50	7	5
14	76	52	64	6	37	1	0		0	0.00	0.0	27.350	12	9.2	11.1	33	E	14	E	683	96	3	3
15	83	49	66	8	37	0	1		0	0.00	0.0	27.360	13	1.9	7.5	18	NW	9	NW	717	100	4	3
16	90*	52	71	12	36	0	6		0	0.00	0.0	27.330	17	2.5	8.7	23	NE	17	NW	679	94	5	5
17	88	55	72*	13	37	0	7		0	0.00	0.0	27.260	24	2.9	7.8	24	W	12	SW	716	99	8	8
18	79	54	67	8	44	0	2		0	0.08	0.0	27.290	14	2.3	8.7	30	SW	17	SW	261	36	10	8
19	76	53	65	6	52	0	0		0	0.54	0.0	27.250	17	5.0	10.1	38	W	26	W	169	23	10	10
20	70	52	61	2	50	4	0		0	0.22	0.0	27.340	21	2.6	8.8	26	W	16	W	327	45	9	9
21	77	49	63	3	46	2	0		0	0.00	0.0	27.350	16	2.2	6.6	20	E	7	W	728	100	0	0
22	81	53	67	7	39	0	2		0	0.00	0.0	27.180	21	5.9	10.6	29	SW	18	SW	648	89	6	7
23	77	51	64	4	38	1	0		0	0.00	0.0	27.190	23	6.6	10.4	35	SW	24	SW	573	78	9	7
24	80	48	64	4	37	1	0		0	0.00	0.0	27.210	20	8.2	11.2	33	SW	25	SW	735	100	1	1
25	71	50	61	0	38	4	0		0	T	0.0	27.200	26	9.3	12.8	36	S	25	S	404	55	10	8
26	60	46	53*	-8	42	12	0		0	0.12	0.0	27.255	33	3.4	8.6	26	N	17	NE	269	36	8	7
27	68	43	56	-5	34	9	0		0	0.00	0.0	27.360	32	4.0	9.2	28	W	20	NE	616	83	2	2
28	74	47	61	0	15	4	0		0	0.00	0.0	27.490	10	5.2	9.1	23	E	11	NE	701	94	1	3
29	81	45	63	2	27	2	0		0	0.00	0.0	27.435	26	0.8	7.1	22	N	11	NW	651	87	3	6
30	86	50	68	6	30	0	3		0	0.00	0.0	27.420	09	1.9	8.4	28	NW	17	NW	672	90	3	3
31	86	51	69	7	31	0	4		0	0.00	0.0	27.380	14	2.5	8.3	24	NW	13	N	748	100	0	0
	SUM	SUM				TOTAL	TOTAL	NUMBER OF DAYS		TOTAL	TOTAL	FOR THE MONTH :								TOTAL	% FOR MONTH	SUM	SUM
	2384	1512				94	34			1.14	0.0	27.340	18	2.1	9.3	38	W	27	SW	17710		153	140
	AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION ≥ .01 INCH	5	DEP.						DATE:19		DATE:11		POSS		AVG	AVG
	76.9	48.8	62.9	4.2	35.1	-135	1			0.42										22306	79	4.9	4.5

NUMBER OF DAYS				SEASON TO DATE TOTAL	TOTAL			GREATEST IN 24 HOURS AND DATES				GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE	
						SNOW, ICE PELLETS ≥ 1.0 INCH	0						
MAXIMUM TEMP.		MINIMUM TEMP.		1257	38	THUNDERSTORMS	1	PRECIPITATION		SNOW. ICE PELLETS			
≥ 90°	≤ 32°	≤ 32°	≤ 0°	DEP.	DEP.	HEAVY FOG	0	0.75	19-20	0.0		0	
1	0	0	0	-317	0	CLEAR 12 PARTLY CLOUDY 10 CLOUDY 9							

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS.
COLS 16 & 17 : PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED.
ONE OF TWO WINDS IS GIVEN UNDER COLS 18 & 19 : FASTEST MILE- HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTIONIN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES).
ERRORS WILL BE CORRECTED IN SUBSEQUENT PUBLICATIONS.

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONALOCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATICDATA CENTER.

Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE
NATIONAL CLIMATIC DATA CENTER ASHEVILLE, NORTH CAROLINA

OBSERVATIONS AT 3-HOUR INTERVALS

MAR 1994 23160
TUCSON, AZ

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					MAR 01											MAR 02											MAR 03						
02	0	UNL	30			44	38	29	56	14	8	3	UNL	30			48	39	27	44	13	8	10	250	30			60	45	26	27	19	5
05	0	UNL	30			42	36	28	58	14	8	7	UNL	30			49	39	24	38	14	7	10	220	30			61	46	27	28	14	6
08	0	UNL	60			46	38	28	50	16	10	10	220	50			52	41	25	35	14	12	9	120	50			63	47	28	27	12	11
11	0	UNL	60			64	48	31	29	36	7	10	220	50			71	49	22	16	12	17	8	150	45			78	54	30	17	16	6
14	0	UNL	60			72	49	22	15	01	4	10	220	50			78	52	23	13	11	14	3	UNL	50			85	58	35	17	21	10
17	0	UNL	60			74	50	22	14	32	7	10	UNL	45			78	52	23	13	09	11	8	110	50			81	56	34	18	28	10
20	0	UNL	30			65	47	26	23	32	7	10	250	30			64	47	26	24	09	6	8	110	30			74	54	34	23	30	10
23	0	UNL	30			52	41	27	38	12	6	10	250	30			64	46	25	23	08	7	4	UNL	30			65	49	33	30	19	4
					MAR 04											MAR 05											MAR 06						
02	7	95	30			58	47	36	44	16	5	0	UNL	30			54	44	31	42	14	7	0	UNL	30			53	43	32	45	12	8
05	5	UNL	30			54	44	33	45	15	5	0	UNL	30			50	42	31	48	13	5	0	UNL	30			51	42	31	47	13	5
08	6	UNL	50			56	46	34	44	13	8	1	UNL	50			54	44	31	42	13	11	1	UNL	50			54	44	33	45	16	5
11	4	UNL	50			72	52	32	23	34	3	2	UNL	60			71	52	34	26	25	4	10	140	50			73	53	33	23	19	17
14	2	UNL	50			80	56	33	18	29	6	0	UNL	60			81	54	25	13	26	9	2	UNL	50			79	54	28	15	22	12
17	1	UNL	70			80	55	32	18	32	12	0	UNL	50			80	52	21	11	29	10	0	UNL	50			78	51	20	11	20	18
20	0	UNL	30			70	51	32	25	33	5	0	UNL	30			67	48	25	20	23	3	0	UNL	30			69	47	20	15	20	12
23	0	UNL	30			63	47	30	29	20	6	0	UNL	30			58	44	26	29	15	7	0	UNL	30			61	45	24	24	23	5
					MAR 07											MAR 08											MAR 09						
02	0	UNL	30			52	42	30	43	04	5	8	48	30			45	43	41	86	19	5	0	UNL	30			44	41	38	80	15	8
05	5	UNL	30			50	42	31	48	00	0	0	UNL	30			44	43	41	89	12	6	0	UNL	30			41	39	37	86	16	6
08	10	75	30			53	47	40	62	31	9	7	85	50			44	43	41	89	17	3	0	UNL	50			44	40	36	74	15	9
11	10	35	30		RW	53	50	47	80	29	16	3	UNL	50			56	48	40	55	28	5	0	UNL	50			60	50	40	48	02	3
14	9	35	15			61	52	45	56	20	10	7	75	50			61	49	37	41	30	7	0	UNL	50			69	53	38	32	32	6
17	7	45	50			59	51	44	58	01	6	6	85	50			61	49	37	41	31	10	0	UNL	40			72	52	31	22	01	8
20	7	55	30			56	48	40	55	31	12	0	UNL	30			56	48	39	53	34	8	4	UNL	30			63	50	36	37	33	7
23	10	45	25		RW	49	48	46	90	20	10	0	UNL	30			49	45	40	71	16	4	0	UNL	30			55	46	37	51	13	8
					MAR 10											MAR 11											MAR 12						
02	0	UNL	30			47	43	39	74	13	6	2	UNL	30			52	42	29	41	14	8	2	UNL	30			51	44	36	57	16	8
05	0	UNL	30			47	42	36	66	15	8	5	UNL	30			47	39	29	50	15	7	10	90	30			53	46	38	57	19	10
08	9	UNL	50			51	44	35	55	16	7	9	250	50			53	42	27	37	14	9	4	UNL	40			51	45	39	64	13	8
11	3	UNL	50			73	52	30	20	13	13	9	UNL	50			70	50	29	22	20	14	5	UNL	40			62	49	35	37	36	4
14	2	UNL	50			80	53	22	12	19	7	5	UNL	50			76	52	28	17	25	17	4	UNL	40			69	51	34	28	35	12
17	3	UNL	50			81	52	19	10	28	8	5	UNL	50			72	50	24	17	24	14	7	UNL	30			68	50	31	25	35	8
20	0	UNL	30			69	50	30	23	30	7	0	UNL	15			63	47	30	29	24	14	5	UNL	30			61	48	35	38	01	8
23	4	UNL	30			62	46	28	28	18	5	9	65	15		RW	57	48	38	49	31	5	1	UNL	30			55	46	35	47	01	3
					MAR 13											MAR 14											MAR 15						
02	2	UNL	30			50	43	35	57	18	3	0	UNL	30			54	46	37	53	08	8	2	UNL	30			55	48	42	62	15	6
05	3	UNL	30			55	45	33	44	11	9	0	UNL	30			56	46	36	47	14	15	0	UNL	30			52	46	40	64	13	9
08	8	200	40			55	46	35	47	12	20	2	UNL	50			56	47	37	49	12	8	0	UNL	50			53	47	40	62	13	10
11	9	100	40			57	47	37	47	12	20	6	UNL	50			68	52	38	33	13	18	1	UNL	50			73	55	38	28	00	0
14	10	55	40			60	48	35	39	10	17	4	UNL	50			74	55	38	27	05	11	7	UNL	50			80	56	35	20	30	6
17	1	UNL	30			62	50	37	40	09	14	1	UNL	50			75	55	36	24	06	9	8	UNL	60			81	56	34	18	30	6
20	1	UNL	30			57	46	35	44	07	9	7	100	30			67	51	35	31	12	7	6	UNL	30			72	53	34	25	34	5
23	2	UNL	30			56	46	36	47	09	6	8	100	30			64	51	39	40	15	8	2	UNL	30			61	48	34	37	15	8
					MAR 16											MAR 17											MAR 18						
02	0	UNL	30			56	46	34	44	13	8	10	UNL	30			62	50	38	41	14	6	0	UNL	30			62	50	38	41	14	8
05	0	UNL	30			54	45	35	49	15	8	10	UNL	30			57	47	36	46	14	7	10	UNL	30			59	49	38	46	13	9
08	5	UNL	50			58	48	37	46	13	11	4	UNL	40			60	49	38	44	15	7	10	250	50			60	49	39	46	15	6
11	4	UNL	40			80	57	38	22	15	7	6	UNL	40			79	56	35	20	34	5	10	150	40			76	56	39	26	33	7
14	2	UNL	40			88	59	35	15	22	10	9	UNL	45			85	58	36	17	35	10	10	140	35		R	75	55	38	26	34	10
17	7	UNL	60			88	59	33	14	05	5	10	UNL	60			86	59	37	18	27	10	10	70	10		R	63	57	52	68	28	9
20	10	UNL	30			77	56	37	24	33	10	8	UNL	30			76	56	38	25	25	7	6	130	30			57	55	54	90	13	5
23	9	UNL	30			67	52	37	33	21	6	4	UNL	30			66	52	38	36	24	8	10	250	30			55	54	53	93	12	7

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.07	0.13	0.16	0.16	0.18	0.20	0.21	0.23	0.25	0.27	0.27	0.28
ENDED: DATE	19	19	19	19	19	19	19	19	19	19	19	19
ENDED: TIME (LST)	1833	1840	1842	1842	1842	1912	1925	1943	1943	1943	1943	1943

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

MAR 1994
TUCSON, AZ
23160

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDEDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					MAR 19						
02	10	250	30			55	53	51	87	10	6
05	10	250	30			54	51	49	83	14	10
08	10	240	50			56	53	50	80	13	10
11	10	240	50			69	57	48	47	13	10
14	10	70	50			75	59	46	36	20	13
17	10	55	10		RW	60	59	58	93	28	16
20	10	37	15		RW	59	58	58	97	05	5
23	10	33	7		RW	59	59	59	100	21	6
					MAR 22						
02	0	UNL	30			56	51	46	69	15	7
05	9	UNL	30			54	49	45	72	15	6
08	6	UNL	50			57	51	45	64	14	9
11	4	UNL	50			73	56	41	32	33	9
14	8	UNL	50			80	54	29	16	28	15
17	9	UNL	50			79	54	31	17	24	16
20	10	250	30			69	52	37	31	22	9
23	10	UNL	30			64	51	39	40	16	5
					MAR 25						
02	0	UNL	30			58	50	43	58	30	5
05	6	UNL	30			52	46	39	61	34	9
08	10	250	50			53	47	41	64	33	5
11	10	220	30			65	52	40	40	05	4
14	10	220	30			71	49	24	17	22	14
17	10	220	50			68	49	28	22	22	16
20	10	140	30			62	50	39	43	25	16
23	10	37	15		R	57	51	45	64	25	17
					MAR 28						
02	0	UNL	30			47	37	22	37	12	6
05	0	UNL	30			50	36	10	20	13	11
08	0	UNL	60			54	38	12	19	12	13
11	0	UNL	60			66	44	10	11	15	12
14	0	UNL	60			71	47	12	10	03	6
17	5	UNL	50			73	47	12	9	31	4
20	10	UNL	30			64	44	15	15	33	5
23	10	UNL	30			55	42	24	30	32	7
					MAR 31						
02	0	UNL	30			53	45	37	55	14	6
05	0	UNL	30			52	44	35	53	14	7
08	0	UNL	50			60	47	34	38	15	8
11	0	UNL	50			80	54	28	15	18	6
14	0	UNL	50			85	55	24	11	32	8
17	0	UNL	40			85	56	26	12	32	10
20	0	UNL	30			74	52	29	19	36	8
23	0	UNL	30			62	48	34	35	18	5

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDEDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					MAR 20						
02	10	70	7		RW	56	55	55	97	20	11
05	10	75	15			53	52	51	93	11	4
08	10	60	50			56	53	51	83	31	4
11	9	45	50			66	54	44	45	22	9
14	9	60	45			68	55	44	42	28	12
17	9	55	40			64	56	50	61	35	9
20	10	50	30		RW	59	56	54	84	15	7
23	8	50	30			57	55	53	87	02	4
					MAR 23						
02	7	UNL	30			60	49	38	44	07	5
05	3	UNL	30			56	48	39	53	30	5
08	10	UNL	50			58	49	41	53	10	7
11	10	UNL	50			71	54	40	33	21	14
14	10	UNL	50			75	54	35	23	22	16
17	10	250	40			73	54	37	27	22	17
20	9	220	30			65	53	42	43	23	8
23	3	UNL	30			60	48	36	41	33	4
					MAR 26						
02	10	20	10		R	46	46	45	96	36	5
05	6	90	30			47	47	46	96	18	6
08	8	70	50			48	47	45	89	14	6
11	10	70	30		RW	56	49	42	60	21	7
14	10	70	30			57	48	39	51	35	9
17	8	55	40			56	48	41	57	03	6
20	2	UNL	30			53	46	39	59	33	11
23	1	UNL	30			50	45	39	66	29	7
					MAR 29						
02	10	UNL	30			49	43	36	61	15	5
05	10	UNL	30			46	41	36	68	14	3
08	3	UNL	50			51	43	34	52	16	5
11	1	UNL	50			71	48	21	15	31	3
14	0	UNL	50			80	52	18	10	26	5
17	2	UNL	50			80	53	22	12	30	10
20	10	UNL	30			69	48	23	18	33	9
23	10	UNL	30			59	46	31	35	17	7

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDEDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					MAR 21						
02	0	UNL	30			53	52	51	93	15	4
05	0	UNL	30			51	50	49	93	13	6
08	0	UNL	50			54	51	49	83	15	8
11	1	UNL	50			70	56	44	39	15	8
14	0	UNL	50			75	58	44	33	29	5
17	0	UNL	50			77	58	42	29	09	6
20	0	UNL	50			68	55	45	44	35	4
23	0	UNL	30			60	54	49	67	15	5
					MAR 24						
02	6	45	30			55	46	37	51	14	4
05	2	UNL	30			51	47	42	72	10	7
08	4	UNL	50			57	51	46	67	15	10
11	0	UNL	50			71	54	38	30	18	9
14	0	UNL	50			79	54	28	15	23	15
17	1	UNL	60			78	54	32	19	21	18
20	0	UNL	30			70	51	32	25	22	9
23	0	UNL	30			63	52	43	48	18	9
					MAR 27						
02	0	UNL	30			45	43	40	83	22	6
05	2	UNL	30			43	42	40	89	18	4
08	0	UNL	60			48	45	41	77	18	5
11	0	UNL	60			59	49	39	48	29	6
14	2	UNL	60			67	51	34	30	33	16
17	2	UNL	60			68	48	25	20	33	15
20	3	UNL	30			61	46	29	30	34	5
23	1	UNL	30			52	42	29	41	11	8
					MAR 30						
02	3	UNL	30			51	44	35	55	12	6
05	8	UNL	30			51	42	32	48	11	9
08	10	250	45			56	45	31	39	15	8
11	2	UNL	50			75	54	33	22	17	5
14	0	UNL	50			85	55	24	11	33	4
17	2	UNL	50			82	54	23	11	33	13
20	0	UNL	30			73	52	29	20	33	9
23	0	UNL	30			61	48	35	38	11	6

WEATHER CODES AND NOTES

*	TORNADO
T	THUNDERSTORM
Q	SQUALL
R	RAIN
RW	RAIN SHOWERS
ZR	FREEZING RAIN
L	DRIZZLE
ZL	FREEZING DRIZZLE
S	SNOW
SW	SNOW SHOWERS
SG	SNOW GRAINS
SP	SNOW PELLETS
IC	ICE CRYSTALS
IP	ICE PELLETS
IPW	ICE PELLET SHOWERS
A	HAIL
F	FOG
IF	ICE FOG
GF	GROUND FOG
BD	BLOWING DUST
BN	BLOWING SAND
BS	BLOWING SNOW
BY	BLOWING SPRAY
K	SMOKE
H	HAZE
D	DUST

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND IS BLOWING, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E. 09 FOR EAST, 18 FOR SOUTH, 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE (MPH=KNOTS X 1.15).

SUMMARY BY HOURS

HOUR L.S.T.	AVERAGES							RESULTANT WIND	
	SKY COVER (TENTHS)	STATION PRESSURE (INCHES)	TEMPERATURE			REL. HUMIDITY %	SPEED (MPH)	DIRECTION	SPEED (MPH)
			AIR °F	WET BULB °F	DEW POINT °F				
02	3	27.350	53	45	37	59	7.3	14	5.4
05	4	27.340	51	44	36	60	8.0	14	6.6
08	5	27.380	54	46	37	56	9.7	14	8.0
11	5	27.380	69	52	35	33	9.9	17	3.8
14	5	27.320	75	53	32	23	11.7	27	4.6
17	5	27.290	74	53	32	27	12.3	29	5.3
20	5	27.320	66	51	35	37	9.2	30	3.8
23	4	27.350	59	48	37	48	7.5	18	3.5

NATIONAL CLIMATIC DATA CENTER
ROOM 120
151 PATTON AVENUE
ASHEVILLE, NORTH CAROLINA 28801-5001

OFFICIAL BUSINESS
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FIRST CLASS
POSTAGE AND FEES PAID
NOAA
PERMIT G-19

MAR 1994 23160
TUCSON, AZ
USCOM - NOAA - ASHEVILLE, NC 175

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

DATE	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												DATE
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
01																									01
02																									02
03																									03
04																									04
05																									05
06																									06
07											T	0.11	0.01		0.05	0.01	T	T					T	T	07
08																									08
09																									09
10																									10
11																							T	T	11
12																									12
13																									13
14																									14
15																									15
16																									16
17																									17
18														T	T	T	0.02	0.05	0.01	T					18
19																	0.07	0.02	0.18	0.07	0.01	0.03	0.09	0.07	19
20	0.07	0.03	0.09	0.02												T	0.01			T	T				20
21																									21
22																									22
23																									23
24																									24
25																							T	T	25
26	0.01	0.05	0.02	0.03	T						T	T			0.01	T									26
27																									27
28																									28
29																									29
30																									30
31																									31

APR 1994
TUCSON, AZ
NAT'L WEA SER OFC
INTERNATIONAL AIRPORT

INQUIRIES/COMMENTS CALL
(704) 271-4800 VOICE
271-4010 TDD/271-4876 FAX

INTERNATIONAL AIRPORT

ISSN # 0198-0483

LOCAL CLIMATOLOGICAL DATA

MONTHLY SUMMARY

TUCSON, AZ

LATITUDE 32° 07'N LONGITUDE 110° 56'W ELEVATION (GROUND) 2584 FEET TIME ZONE MOUNTAIN 23160

DATE 1	TEMPERATURE °F MAXIMUM 2	MINIMUM 3	AVERAGE 4	DEPARTURE FROM NORMAL 5	AVERAGE DEW POINT 6	DEGREE DAYS BASE 65 °F HEATING 7A	COOLING 7B	WEATHER TYPES 1 FOG 2 HEAVY FOG 3 THUNDERSTORMS 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW 8	SNOW/ICE ON GRD AT 0500 (IN.) 9	PRECIPITATION (INCHES) WATER EQUIVALENT 10	SNOW ICE PELLETS 11	AVERAGE STATION PRESSURE (INCHES OF Hg) ELEV. 2555 (FT.MSL) 12	WIND (M.P.H.) RESULTANT DIR 13	RESULTANT SPEED 14	AVERAGE SPEED 15	PEAK GUST SPEED 16	PEAK GUST DIR 17	FASTEST MILE SPEED 18	FASTEST MILE DIR 19	SUNSHINE MINUTES 20	PERCENT POSSIBLE 21	SKY COVER TENTHS SUNRISE TO SUNSET 22	MIDNIGHT TO MIDNIGHT 23
01	88	54	71	9	28	0	6		0	0.00	0.0	27.360	20	2.9	10.2	32	W	14	W	749	100	5	4
02	86	50	68	6	27	0	3		0	0.00	0.0	27.400	15	1.4	8.0	25	NW	14	W	752	100	0	0
03	88	52	70	7	26	0	5		0	0.00	0.0	27.350	19	6.7	10.3	26	SW	18	SW	680	90	8	6
04	82	54	68	5	24	0	3		0	0.00	0.0	27.190	26	8.2	10.5	33	W	22	W	757	100	6	6
05	74	48	61	-2	14	4	0		0	0.00	0.0	27.290	31	5.8	11.1	29	W	17	W	759	100	0	0
06	81	44	63	0	13	2	0		0	0.00	0.0	27.350	17	1.6	9.3	25	W	14	W	749	99	6	4
07	84	49	67	3	24	0	2		0	0.00	0.0	27.285	27	5.1	10.6	38	W	19	W	762	100	8	7
08	82	51	67	3	28	0	2		0	0.00	0.0	27.230	20	12.0	14.6	37	SW	26	SW	758	99	10	9
09	78	52	65	1	29	0	0		0	0.00	0.0	27.220	27	9.3	12.4	36	W	19	W	760	99	3	4
10	70	48	59	-6	28	6	0		0	0.00	0.0	27.240	29	7.9	11.7	32	W	18	W	747	97	3	2
11	78	42	60	-5	29	5	0		0	0.00	0.0	27.380	27	1.9	7.9	20	NW	11	NW	770	100	0	0
12	85	48	67	2	24	0	2		0	0.00	0.0	27.400	09	2.2	7.5	18	SE	9	NW	750	97	.9	7
13	89	52	71	6	23	0	6		0	0.00	0.0	27.300	16	1.0	7.7	23	N	14	N	770	99	7	6
14	88	52	70	4	23	0	5		0	0.00	0.0	27.230	22	4.4	8.7	25	SW	17	SW	776	100	1	1
15	91	52	72	6	25	0	7		0	0.00	0.0	27.350	03	1.5	8.2	17	NW	11	NW	777	100	0	0
16	96	56	76	10	25	0	11		0	0.00	0.0	27.440	11	11.9	12.6	32	E	17	E	759	97	1	2
17	95	69	82*	16	18	0	17		0	0.00	0.0	27.400	12	13.6	13.9	36	E	19	SE	739	95	9	9
18	97	58	78	12	20	0	13		0	0.00	0.0	27.320	12	1.5	8.6	24	NW	17	W	727	93	10	9
19	97	59	78	11	30	0	13		0	0.00	0.0	27.290	17	3.7	8.1	18	W	14	W	785	100	1	2
20	97*	64	81	14	38	0	16	3	0	0.01	0.0	27.270	17	6.5	9.5	41	SW	23	SW	574	73	5	5
21	95	63	79	12	44	0	14	3	0	0.00	0.0	27.260	15	4.5	10.7	36	SE	15	W	739	94	3	4
22	94	62	78	11	42	0	13	3	0	0.00	0.0	27.225	20	2.4	10.3	31	W	19	W	790	100	2	2
23	92	66	79	11	42	0	14		0	0.00	0.0	27.170	21	7.8	12.3	36	S	25	SW	730	92	4	3
24	82	49	66	-2	30	0	1		0	T	0.0	27.165	23	10.7	15.6	48	NW	32	NW	773	97	4	4
25	77	43	60	-8	27	5	0		0	0.00	0.0	27.240	25	5.3	9.8	29	W	18	W	795	100	6	4
26	74	47	61	-7	30	4	0		0	0.00	0.0	27.180	23	12.1	14.7	38	SW	30	SW	788	99	5	4
27	67	46	57*	-12	35	8	0		0	0.03	0.0	27.270	30	5.8	8.6	33	W	22	W	745	93	6	5
28	79	42*	61	-8	25	4	0		0	0.00	0.0	27.260	23	5.4	11.1	32	W	20	W	801	100	0	2
29	76	46	61	-8	31	4	0		0	0.00	0.0	27.370	28	3.8	8.9	26	W	13	W	802	100	0	0
30	88	48	68	-1	26	0	3		0	0.00	0.0	27.340	24	0.9	8.0	21	NW	15	NW	801	100	0	1

SUM	SUM				TOTAL	TOTAL	NUMBER OF DAYS	TOTAL	TOTAL	FOR THE MONTH :							TOTAL	% FOR MONTH	SUM	SUM
2550	1566				42	156		0.04	0.0	27.290	22	3.1	10.4	48	NW	32 NW	22664		122	112
AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION	DEP.						DATE:24		DATE:24	POSS		AVG	AVG
85.0	52.2	68.6	2.8	27.5	-55	35	≥ .01 INCH 2	-0.26									23349	97	4.1	3.7

NUMBER OF DAYS				SEASON TO DATE TOTAL	SEASON TO DATE TOTAL		
						SNOW, ICE PELLETS ≥ 1.0 INCH	0
MAXIMUM TEMP.		MINIMUM TEMP.		1299	194	THUNDERSTORMS	3
≥ 90°	≤ 32°	≤ 32°	≤ 0°	DEP.	DEP.	HEAVY FOG	0
9	0	0	0	-372	35	CLEAR 14 PARTLY CLOUDY 10 CLOUDY 6	

GREATEST IN 24 HOURS AND DATES			
PRECIPITATION		SNOW, ICE PELLETS	
0.03	27	0.0	

GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE	
0	

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
\+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS.
COLS 16 & 17 : PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED.
ONE OF TWO WINDS IS GIVEN UNDER COLS 18 & 19 : FASTEST MILE- HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTIONIN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES).
ERRORS WILL BE CORRECTED IN SUBSEQUENT PUBLICATIONS.

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONALOCEANIC AND ATMOSPHERIC ADMINISTRATION AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATICDATA CENTER.

Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE
NATIONAL CLIMATIC DATA CENTER ASHEVILLE, NORTH CAROLINA

OBSERVATIONS AT 3-HOUR INTERVALS

APR 1994
TUCSON, AZ
23160

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY%	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY%	WIND		SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					APR 01											APR 02											APR 03						
02	0	UNL	30			55	46	36	49	15	7	2	UNL	30			56	45	32	40	10	6	0	UNL	30			56	45	33	42	13	7
05	0	UNL	30			55	44	32	42	14	10	0	UNL	30			54	43	30	40	15	7	0	UNL	30			52	43	31	45	13	5
08	0	UNL	50			62	47	31	31	14	13	0	UNL	50			61	46	27	28	13	9	3	UNL	50			63	48	31	30	15	11
11	0	UNL	50			81	55	30	16	18	4	0	UNL	50			78	52	24	13	18	4	7	UNL	50			81	55	29	15	21	7
14	6	UNL	50			86	56	27	12	28	10	0	UNL	45			84	54	21	10	23	10	10	UNL	50			87	56	25	10	23	10
17	10	UNL	50			86	55	21	9	28	12	0	UNL	60			84	55	24	11	30	10	10	UNL	50			84	54	23	11	22	14
20	10	UNL	30			76	50	19	12	28	5	0	UNL	30			74	51	27	17	35	8	10	250	30			76	49	14	9	28	5
23	8	UNL	30			65	48	28	25	15	9	0	UNL	30			62	48	33	34	15	6	10	250	30			67	48	26	21	14	5
					APR 04											APR 05											APR 06						
02	10	250	30			66	48	27	23	15	8	2	UNL	30			57	44	28	33	23	7	0	UNL	30			47	35	15	28	16	7
05	10	250	30			62	46	26	25	24	4	0	UNL	30			49	40	29	46	14	8	7	UNL	30			47	34	12	24	13	12
08	1	UNL	50			64	48	30	28	00	0	0	UNL	50			58	44	26	29	32	4	9	UNL	50			52	37	11	19	13	11
11	1	UNL	50			77	52	24	14	28	10	0	UNL	50			67	43	4	8	30	15	0	UNL	50			73	47	11	9	21	4
14	10	250	50			78	52	24	13	26	18	0	UNL	60			72	46	4	7	31	17	3	UNL	50			79	50	8	6	34	9
17	10	250	50			76	50	17	11	26	15	0	UNL	70			73	46	2	6	32	16	9	UNL	70			79	50	8	6	30	12
20	4	UNL	30			70	47	19	14	29	14	0	UNL	30			63	42	7	11	36	5	2	UNL	30			71	47	15	12	27	7
23	8	100	30			63	45	22	21	29	8	0	UNL	30			52	38	14	22	15	6	1	UNL	30			60	43	21	22	11	7
					APR 07											APR 08											APR 09						
02	5	UNL	30			59	43	21	23	16	8	10	UNL	30			55	44	31	40	13	3	10	250	30			60	45	27	29	20	13
05	3	UNL	30			52	39	21	30	00	0	6	UNL	30			56	45	32	40	12	7	0	UNL	30			56	44	31	39	24	8
08	6	UNL	60			61	44	23	23	13	4	10	UNL	50			63	48	33	33	15	7	0	UNL	50			59	47	34	39	13	4
11	10	UNL	50			75	50	21	13	34	7	10	UNL	50			77	53	28	16	22	18	2	UNL	50			69	50	29	23	30	12
14	7	UNL	45			83	54	24	11	26	16	10	230	45			79	53	27	15	21	20	3	UNL	45			76	52	27	16	24	18
17	10	UNL	45			80	52	22	12	29	20	9	UNL	40			79	54	29	16	23	19	9	250	45			74	52	28	18	25	18
20	7	UNL	30			70	50	28	21	31	11	7	UNL	30			69	48	22	17	23	13	7	UNL	30			66	49	30	26	28	18
23	6	UNL	30			62	47	30	30	21	6	9	UNL	30			63	44	19	18	22	6	3	UNL	30			61	46	30	31	33	6
					APR 10											APR 11											APR 12						
02	0	UNL	30			55	44	30	39	17	5	0	UNL	30			48	39	28	46	18	5	0	UNL	30			51	42	30	45	13	7
05	0	UNL	30			51	43	34	52	20	6	0	UNL	30			46	38	28	50	17	7	8	UNL	30			51	42	31	47	14	7
08	1	UNL	50			56	47	37	49	33	6	0	UNL	50			54	43	30	40	19	5	9	UNL	50			60	47	33	36	12	4
11	0	UNL	50			65	46	24	21	29	10	0	UNL	50			68	50	32	26	13	3	10	UNL	50			79	53	27	15	17	8
14	5	UNL	50			67	48	26	21	28	16	0	UNL	50			75	53	30	19	34	7	10	UNL	50			84	53	16	8	36	9
17	2	UNL	40			69	47	20	15	30	16	0	UNL	50			77	52	26	15	34	12	10	UNL	50			83	52	15	8	01	7
20	0	UNL	30			62	45	25	24	34	12	0	UNL	30			69	50	30	23	31	9	7	UNL	30			74	50	20	13	33	6
23	0	UNL	30			57	45	31	37	30	7	0	UNL	30			61	46	29	30	24	4	6	UNL	30			63	45	22	21	16	5
					APR 13											APR 14											APR 15						
02	7	UNL	30			54	41	24	31	14	6	3	UNL	30			62	46	27	27	00	0	0	UNL	30			58	42	20	23	14	6
05	4	UNL	30			54	41	24	31	14	9	2	UNL	30			53	42	27	37	13	5	0	UNL	30			53	40	22	30	13	8
08	1	UNL	40			63	46	24	23	14	11	2	UNL	50			66	48	26	22	12	6	0	UNL	50			64	46	23	21	15	9
11	10	UNL	50			82	53	22	11	25	3	1	UNL	50			81	53	24	12	31	8	0	UNL	50			79	52	21	11	36	4
14	10	UNL	50			88	55	19	8	33	8	1	UNL	45			86	55	21	9	20	13	0	UNL	50			88	57	27	11	01	7
17	9	UNL	50			86	54	20	9	29	11	0	UNL	45			86	54	15	7	24	14	0	UNL	30			90	58	28	11	34	10
20	4	UNL	30			74	50	23	15	33	4	0	UNL	30			77	50	14	9	28	10	0	UNL	30			81	55	29	15	33	8
23	2	UNL	30			69	48	24	18	30	3	0	UNL	30			67	48	27	22	16	3	0	UNL	30			72	52	32	23	26	3
					APR 16											APR 17											APR 18						
02	0	UNL	30			60	46	31	34	13	6	6	UNL	30			75	50	22	14	11	16	10	UNL	30			70	46	12	11	11	5
05	0	UNL	30			59	46	31	35	12	10	6	UNL	30			72	48	19	13	11	16	10	UNL	30			65	44	13	13	12	6
08	0	UNL	40			73	52	30	20	14	12	8	UNL	40			78	52	21	12	12	16	10	250	50			74	50	20	13	16	10
11	0	UNL	25			90	58	28	11	10	16	10	UNL	40			89	56	19	8	12	19	10	250	50			87	55	21	9	07	3
14	0	UNL	25			94	59	25	8	09	13	10	250	40			94	57	17	6	12	14	10	250	35			95	58	18	6	31	12
17	3	UNL	25			94	57	19	6	12	6	10	250	40			93	57	18	6	12	10	10	150	40			90	57	22	8	33	17
20	5	UNL	30			81	52	18	9	10	7	10	250	30			80	51	13	8	10	6	10	UNL	30			81	54	26	13	23	4
23	10	UNL	30			78	52	21	12	12	15	10	250	30			77	49	11	8	12	11	4	UNL	30			72	51	29	20	00	0

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
ENDED: DATE	27	27	27	27	27	27	27	27	27	27	27	27
ENDED: TIME (LST)	1053	1053	1053	1053	1053	1053	1053	1053	1053	1053	1053	1053

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

OBSERVATIONS AT 3-HOUR INTERVALS

APR 1994
TUCSON, AZ

23160

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDEREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					APR 19						
02	10	UNL	30			67	49	29	24	16	6
05	1	UNL	30			61	47	31	32	12	7
08	0	UNL	50			76	54	32	20	15	8
11	0	UNL	40			90	58	29	11	10	4
14	0	UNL	40			96	60	28	9	27	8
17	3	UNL	40			96	60	28	9	27	9
20	0	UNL	30			84	56	31	15	27	4
23	5	UNL	30			79	56	35	20	15	10
					APR 22						
02	1	UNL	30			69	57	47	46	13	8
05	0	UNL	30			63	54	47	56	12	10
08	0	UNL	50			75	60	49	40	15	10
11	1	UNL	50			89	62	43	20	21	6
14	6	80	50			92	63	42	18	07	6
17	2	UNL	45			93	61	35	13	26	10
20	5	UNL	30			84	59	38	20	27	12
23	1	UNL	30			77	56	39	26	34	5
					APR 25						
02	0	UNL	30			48	45	41	77	17	6
05	0	UNL	30			45	42	39	80	11	7
08	0	UNL	30			56	46	36	47	19	5
11	10	UNL	40			66	49	32	28	33	3
14	10	UNL	40			75	49	16	11	25	12
17	4	UNL	40			76	49	12	9	27	16
20	2	UNL	30			65	45	17	16	29	7
23	0	UNL	30			59	42	17	19	23	12
					APR 28						
02	2	UNL	30			46	40	33	61	16	6
05	1	UNL	30			44	38	31	60	12	6
08	0	UNL	50			57	45	31	37	14	9
11	0	UNL	50			71	49	22	16	22	7
14	0	UNL	50			78	50	15	9	23	11
17	1	UNL	50			76	49	12	9	25	16
20	6	90	30			65	46	24	21	28	17
23	6	90	30			61	46	27	28	28	8

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDEREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					APR 20						
02	1	UNL	30			69	52	35	29	12	5
05	5	UNL	30			65	50	35	33	16	7
08	3	UNL	50			75	55	38	26	16	7
11	3	UNL	50			92	61	36	14	34	4
14	5	UNL	50			92	61	35	13	20	5
17	10	80	40		TRW	85	60	42	22	23	15
20	10	80	30			83	59	39	21	17	10
23	6	120	30			76	57	42	30	13	10
					APR 23						
02	4	UNL	30			69	53	39	34	15	7
05	7	120	30			68	55	44	42	12	9
08	7	95	40			74	60	49	41	11	5
11	3	UNL	40			87	64	48	26	16	10
14	6	85	40			91	63	44	20	23	16
17	1	UNL	45			89	59	32	13	22	17
20	0	UNL	30			79	59	43	28	25	15
23	0	UNL	30			70	54	39	32	23	7
					APR 26						
02	0	UNL	30			54	42	25	33	18	3
05	0	UNL	30			49	39	25	39	15	7
08	4	UNL	50			61	46	29	30	17	14
11	4	UNL	40			68	50	31	25	22	14
14	9	70	40			69	52	36	30	24	14
17	3	UNL	40			72	50	25	17	25	20
20	2	UNL	30			62	49	35	37	25	15
23	6	55	30			57	47	36	46	25	19
					APR 29						
02	0	UNL	30			51	43	34	52	18	6
05	0	UNL	30			48	42	35	61	15	6
08	0	UNL	50			59	48	37	44	20	8
11	0	UNL	50			69	49	28	22	29	6
14	0	UNL	50			74	52	28	18	31	13
17	0	UNL	50			75	51	25	16	30	16
20	0	UNL	50			69	49	28	22	32	8
23	0	UNL	30			63	48	31	30	34	5

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDEREDS OF FEET	VISIBILITY		WEATHER	TEMPERATURE			REL HUMIDITY %	WIND	
			WHOLE MILES	16THS MILE		AIR °F	WET BULB °F	DEW POINT °F		DIRECTION	SPEED (KNOTS)
					APR 21						
02	10	UNL	30			69	54	42	38	13	5
05	3	UNL	30			65	55	46	50	13	9
08	0	UNL	50			75	58	45	34	15	10
11	0	UNL	50			88	62	42	20	32	7
14	2	UNL	50			93	62	40	16	22	8
17	8	80	40			93	62	39	15	29	14
20	8	120	30			79	60	45	30	12	9
23	2	UNL	30			73	58	47	40	00	0
					APR 24						
02	0	UNL	30			65	48	30	27	18	6
05	3	UNL	30			60	47	33	36	17	6
08	4	UNL	40			68	50	32	26	20	12
11	0	UNL	30			78	50	15	9	23	16
14	5	UNL	30			80	52	18	10	22	20
17	9	UNL	20			75	51	26	16	25	22
20	7	65	20			64	51	39	40	25	18
23	9	60	25			50	45	40	69	32	11
					APR 27						
02	9	50	30			49	47	44	83	32	10
05	8	45	30			48	44	40	74	31	10
08	3	UNL	50			54	47	39	57	07	3
11	10	55	30		RW	63	52	41	45	27	10
14	8	55	30			63	50	37	38	15	4
17	5	UNL	30			67	48	26	21	30	10
20	0	UNL	30			60	45	26	27	31	6
23	0	UNL	30			49	42	33	54	14	4
					APR 30						
02	0	UNL	30			54	43	28	37	16	6
05	0	UNL	30			48	39	28	46	13	6
08	0	UNL	50			61	47	31	32	13	6
11	0	UNL	50			78	52	25	14	24	5
14	0	UNL	50			84	54	23	11	20	3
17	1	UNL	50			86	55	21	9	31	10
20	5	UNL	30			77	52	24	14	34	12
23	3	UNL	30			67	49	28	23	25	6

WEATHER CODES AND NOTES

*	TORNADO	SW	SNOW SHOWERS	GF	GROUND FOG
T	THUNDERSTORM	SG	SNOW GRAINS	BD	BLOWING DUST
Q	SQUALL	SP	SNOW PELLETS	BN	BLOWING SAND
R	RAIN	IC	ICE CRYSTALS	BS	BLOWING SNOW
RW	RAIN SHOWERS	IP	ICE PELLETS	BY	BLOWING SPRAY
ZR	FREEZING RAIN	IPW	ICE PELLET SHOWERS	K	SMOKE
L	DRIZZLE	A	HAIL	H	HAZE
ZL	FREEZING DRIZZLE	F	FOG	D	DUST
S	SNOW	IF	ICE FOG		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND IS BLOWING, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E. 09 FOR EAST, 18 FOR SOUTH, 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM.
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE (MPH=KNOTS X 1.15).

SUMMARY BY HOURS

HOUR L.S.T.	AVERAGES							RESULTANT WIND	
	SKY COVER (TENTHS)	STATION PRESSURE (INCHES)	TEMPERATURE			REL HUMIDITY %	SPEED (MPH)	DIRECTION	SPEED (MPH)
			AIR °F	WET BULB °F	DEW POINT °F				
02	3	27.310	58	45	30	37	7.5	15	5.8
05	3	27.305	55	44	30	42	8.6	14	6.8
08	3	27.330	64	48	31	31	9.2	15	7.6
11	3	27.330	78	53	27	17	9.5	24	3.6
14	5	27.270	83	54	25	13	13.3	25	7.4
17	5	27.230	82	54	23	12	15.9	27	11.8
20	4	27.260	73	51	26	19	10.9	28	7.0
23	4	27.300	65	48	29	28	7.9	20	2.7

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APR 1994 23160
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HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

DATE	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												DATE
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
01																									01
02																									02
03																									03
04																									04
05																									05
06																									06
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19																									19
20																T	0.01	T							20
21																									21
22																									22
23																									23
24																					T	T	T		24
25																									25
26																									26
27		T									0.03	T													27
28																									28
29																									29
30																									30

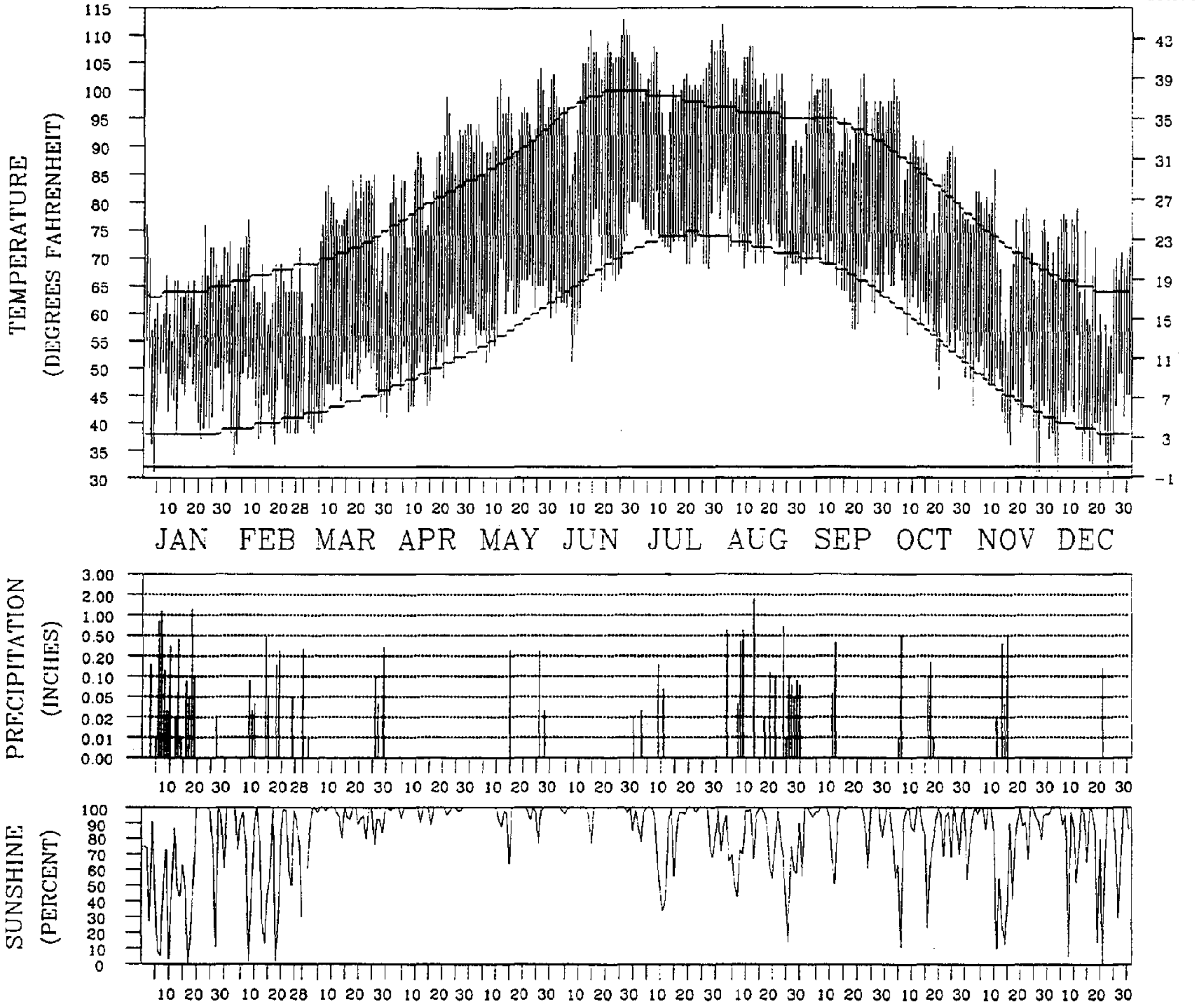
ISSN 0198-0580

1993 LOCAL CLIMATOLOGICAL DATA
ANNUAL SUMMARY WITH COMPARATIVE DATA

TUCSON,
ARIZONA

DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA

Daily Data



TEMPERATURE DEPICTS NORMAL MAXIMUM, NORMAL MINIMUM AND ACTUAL DAILY HIGH AND LOW VALUES (FAHRENHEIT)
PRECIPITATION IS MEASURED IN INCHES, SCALE IS NON-LINEAR
SUNSHINE IS PERCENT OF THE POSSIBLE SUNSHINE

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER, ASHEVILLE, NORTH CAROLINA, 28801

Kenneth D Hadeen
DIRECTOR
NATIONAL CLIMATIC DATA CENTER

noaa

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ATMOSPHERIC ADMINISTRATION

NATIONAL
ENVIRONMENTAL SATELLITE, DATA
AND INFORMATION SERVICE

NATIONAL
CLIMATIC DATA CENTER
ASHEVILLE NORTH CAROLINA

METEOROLOGICAL DATA FOR 1993

TUCSON, ARIZONA

LATITUDE: 32 °07' N LONGITUDE: 110 °56' W ELEVATION: FT. GRND 2584 BARO 2589 TIME ZONE: MOUNTAIN WBAN: 23160

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F:													
Averages													
-Daily Maximum	65.5	65.8	76.5	85.8	94.8	102.6	101.5	98.6	96.4	86.0	72.9	67.3	84.5
-Daily Minimum	44.8	42.2	46.1	51.3	61.4	67.3	74.4	72.4	66.4	59.1	44.7	39.5	55.8
-Monthly	55.2	54.0	61.3	68.6	78.1	85.0	88.0	85.5	81.4	72.6	58.8	53.4	70.2
-Monthly Dewpt.	41.9	37.3	38.0	27.7	40.1	35.3	53.4	62.1	49.7	42.8	33.6	29.3	40.9
Extremes													
-Highest	76	77	85	99	104	113	109	112	103	102	86	79	113
-Date	22	7	25	21	26	26	31	1	22	3	10	11	JUN 26
-Lowest	31	34	38	42	51	51	68	65	57	46	31	30	30
-Date	4	2	3	7	6	7	27	24	19	20	27	23	DEC 23
DEGREE DAYS BASE 65 °F:													
Heating	298	299	129	28	0	0	0	0	0	5	186	355	1300
Cooling	1	0	22	142	413	604	721	641	500	250	11	3	3308
% OF POSSIBLE SUNSHINE	62	67	94	99	97	98	87	75	94	82	79	80	85
AVG. SKY COVER (tenths)													
Sunrise - Sunset	7.9	6.7	4.3	3.4	2.5	1.3	5.0	5.6	1.7	4.4	5.1	4.2	4.3
Midnight - Midnight	7.0	6.1	3.6	2.9	2.2	1.3	4.3	6.2	1.6	3.8	4.2	4.1	3.9
NUMBER OF DAYS:													
Sunrise to Sunset													
-Clear	3	6	15	19	21	27	11	8	23	15	11	16	175
-Partly Cloudy	8	7	10	6	8	2	10	13	7	10	6	6	93
-Cloudy	20	15	6	5	2	1	10	10	0	6	13	9	97
Precipitation .01 inches or more	15	9	4	0	3	1	3	15	2	5	4	1	62
Snow, Ice pellets, hail 1.0 inches or more	0	0	0	0	0	0	0	0	0	0	0	0	0
Thunderstorms	1	2	4	0	4	1	4	19	3	2	0	0	40
Heavy Fog, visibility 1/4 mile or less	0	0	0	0	0	0	0	0	0	0	0	1	1
Temperature °F													
-Maximum													
90° and above	0	0	0	9	25	27	30	27	26	9	0	0	153
32° and below	0	0	0	0	0	0	0	0	0	0	0	0	0
-Minimum													
32° and below	1	0	0	0	0	0	0	0	0	0	2	4	7
0° and below	0	0	0	0	0	0	0	0	0	0	0	0	0
AVG. STATION PRESS. (mb)	926.9	926.5	927.2	923.5	922.8	921.3	924.1	924.8	924.8	925.8	927.5	928.5	925.3
RELATIVE HUMIDITY (%)													
Hour 05	80	77	74	43	49	31	52	71	57	56	63	60	59
Hour 11 (Local Time)	62	50	37	17	21	14	28	40	31	32	37	41	34
Hour 17	52	42	26	11	18	10	24	41	20	26	31	30	28
Hour 23	77	70	57	28	31	19	39	62	44	47	54	53	48
PRECIPITATION (inches):													
Water Equivalent													
-Total	4.81	1.50	0.49	0.00	0.59	0.02	0.26	4.93	0.46	0.81	0.98	0.14	14.99
-Greatest (24 hrs)	1.46	0.49	0.34	0.00	0.29	0.02	0.16	1.81	0.46	0.53	0.57	0.14	1.81
-Date	6- 7	14	29		15	30	9	13	11-12	5- 6	14-15	21	AUG 13
Snow, Ice pellets, hail													
-Total	0.0	0.0	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	0.0	T
-Greatest (24 hrs)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	0.0	T
-Date								9					AUG 9
WIND:													
Resultant													
-Direction (!!)	148	159	210	236	217	239	210	157	164	150	156	140	179
-Speed (mph)	4.2	2.7	1.4	2.5	2.2	3.0	4.5	3.5	3.4	3.1	2.6	2.5	2.4
Average Speed (mph)	8.5	8.5	8.4	8.8	9.2	9.6	9.5	8.9	8.9	9.2	8.2	8.1	8.8
Fastest Mile													
-Direction (!!)	SW	SW	W	SW	SW	S	NW	S	S	SE	S	S	S
-Speed (mph)	29	25	30	25	27	30	23	34	29	25	28	25	34
-Date	8	24	26	22	4	17	9	19	11	27	11	12	AUG 19
Peak Gust													
-Direction (!!)	SW	SW	SE	W	S	NW	S	E	S	SE	W	SE	E
-Speed (mph)	37	39	48	36	45	43	39	60	43	46	43	39	60
-Date	8	20	23	6	11	30	2	9	11	27	13	25	AUG 9

(!!) See Reference Notes on Page 6B

NORMALS, MEANS, AND EXTREMES

TUCSON, ARIZONA

LATITUDE: 32 °07'N LONGITUDE: 110 °56' W ELEVATION: FT. GRND 2584 BARO 2589 TIME ZONE: MOUNTAIN WBAN: 23160

	(a)	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F:														
Normals														
-Daily Maximum		63.9	67.8	72.8	81.2	89.9	99.6	99.4	96.8	93.3	84.3	72.7	64.3	82.2
-Daily Minimum		38.6	41.0	44.6	50.4	58.0	67.9	73.6	72.1	67.5	56.6	45.6	39.8	54.6
-Monthly		51.3	54.4	58.7	65.8	74.0	83.8	86.6	84.5	80.4	70.4	59.2	52.0	68.4
Extremes														
-Record Highest	53	87	92	99	104	107	117	114	112	107	102	90	84	117
-Year		1953	1957	1988	1989	1958	1990	1989	1993	1990	1993	1988	1954	JUN 1990
-Record Lowest	53	16	20	20	27	38	47	59	61	44	26	24	16	16
-Year		1949	1955	1965	1945	1950	1955	1992	1956	1965	1971	1979	1974	DEC 1974
NORMAL DEGREE DAYS:														
Heating (base 65°F)		425	302	229	97	7	0	0	0	0	27	188	403	1678
Cooling (base 65°F)		0	5	33	121	286	564	670	605	462	194	14	0	2954
% OF POSSIBLE SUNSHINE	46	80	82	86	92	93	93	78	80	87	88	85	79	85
MEAN SKY COVER (tenths)														
Sunrise - Sunset	52	4.7	4.6	4.5	3.4	2.8	2.3	5.2	4.6	3.0	2.9	3.5	4.5	3.8
MEAN NUMBER OF DAYS:														
Sunrise to Sunset														
-Clear	53	13.7	12.8	14.7	17.2	20.1	21.5	10.2	12.3	19.3	19.9	17.6	14.8	194.0
-Partly Cloudy	53	7.1	6.4	6.8	7.3	6.8	6.0	12.2	12.1	6.9	6.4	6.1	6.1	90.3
-Cloudy	53	10.3	9.0	9.4	5.5	4.1	2.5	8.6	6.6	3.8	4.8	6.3	10.1	81.0
Precipitation														
.01 inches or more	53	4.7	3.8	4.3	2.0	1.5	1.7	10.3	9.5	4.7	3.4	2.9	4.6	53.3
Snow,Ice pellets,hail														
1.0 inches or more	53	0.2	0.2	0.1	0.*	0.0	0.0	0.0	0.0	0.0	0.0	0.*	0.1	0.5
Thunderstorms	53	0.4	0.3	0.5	0.7	1.6	2.5	13.7	13.6	5.4	2.0	0.5	0.3	41.4
Heavy Fog Visibility														
1/4 mile or less	53	0.3	0.2	0.*	0.0	0.0	0.0	0.0	0.0	0.*	0.0	0.2	0.4	1.0
Temperature °F														
-Maximum														
90° and above	53	0.0	0.*	0.5	4.7	17.7	28.2	29.3	28.6	23.9	9.1	0.*	0.0	142.0
32° and below	53	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-Minimum														
32° and below	53	6.2	4.0	1.1	0.*	0.0	0.0	0.0	0.0	0.0	0.*	1.5	5.0	17.8
0° and below	53	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AVG. STATION PRESS.(mb)	21	927.8	927.1	925.0	924.0	922.8	922.7	924.7	925.0	924.4	925.7	926.9	927.9	925.3
RELATIVE HUMIDITY (%)														
Hour 05	53	63	59	54	42	35	32	57	65	55	52	54	62	53
Hour 11 (Local Time)	53	41	35	29	21	17	16	32	38	32	30	32	40	30
Hour 17	53	33	27	23	16	13	13	28	33	26	25	28	35	25
Hour 23	53	58	50	43	31	24	23	47	53	44	43	48	57	43
PRECIPITATION (inches):														
Water Equivalent														
-Normal		0.87	0.70	0.72	0.30	0.18	0.20	2.37	2.19	1.67	1.06	0.67	1.07	12.00
-Maximum Monthly	53	4.81	2.90	2.26	1.66	1.11	1.46	6.17	7.93	5.11	4.98	1.90	5.02	7.93
-Year		1993	1980	1952	1951	1992	1954	1981	1955	1964	1983	1952	1965	AUG 1955
-Minimum Monthly	53	T	0.00	0.00	0.00	0.00	0.00	0.26	0.23	0.00	0.00	0.00	0.00	0.00
-Year		1970	1972	1956	1972	1974	1983	1993	1976	1953	1982	1980	1981	JUN 1983
-Maximum in 24 hrs	53	1.46	1.49	1.19	0.91	0.89	1.27	3.93	2.48	3.05	3.58	1.86	1.54	3.93
-Year		1993	1942	1952	1988	1943	1954	1958	1961	1964	1983	1968	1967	JUL 1958
Snow,Ice pellets,hail														
-Maximum Monthly	53	4.7	3.9	5.7	2.0	T	0.0	0.0	T	T	T	6.4	6.8	6.8
-Year		1987	1965	1964	1976	1992			1993	1990	1991	1958	1971	DEC 1971
-Maximum in 24 hrs	52	4.3	3.9	5.7	2.0	T	0.0	0.0	T	T	T	6.4	6.8	6.8
-Year		1987	1965	1964	1976	1992			1993	1990	1991	1958	1971	DEC 1971
WIND:														
Mean Speed (mph)	48	7.9	8.1	8.5	8.9	8.8	8.7	8.4	7.9	8.3	8.2	8.1	7.8	8.3
Prevailing Direction through 1963		SE	SE	SE	SE	SE	SSE	SE	SE	SE	SE	SE	SE	SE
Fastest Mile														
-Direction (!!)	45	E	E	SE	SW	SE	SE	SE	NE	SE	SE	E	W	SE
-Speed (MPH)	45	40	59	41	46	43	50	71	54	54	47	55	44	71
-Year		1962	1952	1955	1986	1984	1961	1971	1969	1960	1948	1951	1949	JUL 1971
Peak Gust														
-Direction (!!)	10	SW	E	SE	SW	SE	SW	SE	SE	SE	NW	E	SE	SE
-Speed (mph)	10	45	46	53	55	55	47	66	71	71	47	46	47	71
-Date		1988	1987	1986	1984	1984	1991	1985	1988	1990	1988	1990	1988	SEP 1990

(!!!) See Reference Notes on Page 68.

PRECIPITATION (inches) TUCSON, ARIZONA

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1964	0.14	0.13	0.81	0.67	0.00	0.01	4.82	3.90	5.11	0.91	0.68	0.81	17.99
1965	0.45	0.64	0.27	0.23	T	0.01	2.13	1.12	0.82	0.07	0.77	5.02	11.53
1966	1.74	2.25	0.19	0.12	0.11	0.02	2.57	3.31	3.53	0.32	0.06	0.19	14.41
1967	0.04	0.13	0.41	0.29	0.62	0.42	2.72	2.00	1.35	1.03	0.48	3.44	12.93
1968	0.18	0.99	1.79	0.62	T	0.00	1.97	1.12	T	0.09	1.86	0.32	8.94
1969	0.74	0.50	0.34	0.60	0.46	0.00	1.51	2.57	1.31	0.03	1.06	0.82	9.94
1970	T	0.34	1.13	0.45	0.03	0.33	2.53	1.43	3.58	1.73	0.00	0.43	11.98
1971	0.04	0.50	T	0.56	0.01	T	2.18	3.29	1.75	1.18	0.69	1.97	12.17
1972	0.00	0.00	0.01	0.00	0.24	0.68	3.49	2.93	1.09	4.51	1.30	0.61	14.86
1973	0.06	1.60	2.20	0.02	0.09	0.50	1.74	0.54	T	0.00	0.47	0.00	7.22
1974	0.93	T	0.55	T	0.00	0.01	4.44	1.04	1.69	2.12	0.81	0.33	11.92
1975	0.36	0.13	0.95	0.27	0.11	0.00	2.38	0.32	1.26	T	0.34	0.52	6.64
1976	0.06	0.53	0.38	0.57	0.23	0.10	1.18	0.23	1.68	0.37	0.48	0.47	6.28
1977	1.83	0.04	0.74	0.43	0.08	0.06	0.76	0.80	1.41	2.36	0.33	1.33	10.17
1978	2.05	1.75	0.89	0.01	0.61	0.22	0.78	1.59	1.66	1.86	1.58	2.73	15.73
1979	2.94	0.42	0.64	0.04	0.67	0.53	2.04	2.60	0.02	0.33	0.01	0.15	10.39
1980	0.73	2.90	1.22	0.08	T	0.23	1.78	1.95	2.93	0.22	0.00	0.19	12.23
1981	1.29	0.71	1.98	0.56	0.26	0.16	6.17	0.80	1.10	0.06	0.61	0.00	13.70
1982	1.56	0.06	1.26	0.05	0.51	0.13	2.13	2.51	2.69	0.00	1.30	1.59	13.79
1983	1.70	0.94	1.28	0.14	T	0.00	1.99	4.24	4.28	4.98	1.71	0.61	21.86
1984	0.62	0.00	0.00	0.36	0.06	1.05	2.92	4.19	1.81	0.77	0.45	3.30	15.53
1985	1.71	1.08	0.20	0.45	T	0.07	3.14	1.97	1.13	2.03	0.95	0.15	12.88
1986	0.98	1.13	1.30	T	0.44	0.06	1.82	3.56	0.31	0.50	0.42	1.28	11.80
1987	0.59	1.64	0.83	0.80	0.74	0.16	0.37	2.79	2.30	0.34	0.44	1.50	12.50
1988	0.41	0.53	0.35	1.15	0.02	0.15	1.69	3.64	0.80	2.09	0.75	0.05	11.63
1989	0.96	0.23	0.62	0.00	0.13	0.06	1.42	0.90	0.02	1.84	0.12	0.18	6.48
1990	0.96	0.71	0.38	0.10	0.03	0.64	5.45	2.70	1.63	0.58	0.23	1.54	14.95
1991	1.15	0.91	1.40	0.00	0.00	0.20	0.44	2.17	1.54	0.73	0.80	1.44	10.78
1992	1.21	1.80	2.12	0.19	1.11	0.07	0.93	4.55	0.94	0.03	T	3.47	16.42
1993	4.81	1.50	0.49	0.00	0.59	0.02	0.26	4.93	0.46	0.81	0.98	0.14	14.99
Record Mean	0.90	0.83	0.74	0.34	0.21	0.25	2.20	2.22	1.31	0.72	0.74	1.03	11.49

See Reference Notes on Page 6B.
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AVERAGE TEMPERATURE (deg. F) TUCSON, ARIZONA

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1964	47.5	47.7	54.8	63.2	73.2	82.0	86.2	81.6	76.3	72.1	55.2	52.4	65.0
1965	53.6	51.1	55.1	64.5	70.1	77.6	85.0	84.0	76.8	71.9	62.6	52.1	67.1
1966	47.7	47.8	60.1	66.8	76.1	82.8	85.3	82.9	78.3	68.1	61.1	52.4	67.4
1967	51.4	55.6	62.1	62.1	71.9	80.7	85.4	84.6	80.7	71.6	62.9	48.6	68.1
1968	52.4	59.1	58.7	63.2	73.3	83.5	84.9	81.3	80.7	71.7	58.3	50.6	68.1
1969	55.5	53.1	54.3	66.6	74.9	80.7	86.1	86.3	81.2	66.8	58.6	52.4	68.0
1970	50.0	57.0	55.9	61.1	75.2	83.4	87.2	84.8	76.4	65.1	60.1	51.8	67.3
1971	50.5	52.3	59.8	62.8	69.3	81.2	87.5	81.3	79.1	64.2	56.8	47.1	66.0
1972	50.4	55.8	65.0	65.8	72.3	81.6	86.6	82.9	78.6	66.5	53.0	49.0	67.3
1973	47.6	53.4	51.6	59.7	73.0	81.4	84.3	84.7	79.6	70.7	58.4	52.3	66.4
1974	50.2	51.9	60.1	66.1	74.3	86.9	83.5	83.0	77.8	69.1	57.5	47.0	67.3
1975	49.8	50.7	55.3	57.9	69.8	80.5	84.2	85.8	80.0	69.5	59.3	53.0	66.3
1976	52.6	58.4	58.2	64.8	74.5	83.4	83.9	85.3	77.7	67.8	60.0	52.2	68.3
1977	50.7	56.9	55.7	67.0	70.8	84.7	87.0	86.4	82.0	73.3	61.7	56.9	69.4
1978	53.1	53.6	61.8	65.2	73.1	85.8	88.1	84.7	80.9	73.8	58.5	49.7	69.0
1979	48.4	53.8	56.4	65.6	72.2	83.1	87.5	83.4	84.2	73.0	56.6	55.0	68.3
1980	54.3	57.9	57.5	65.6	71.5	84.9	88.6	84.6	80.5	69.6	59.5	58.1	69.4
1981	54.8	57.1	57.1	69.1	73.4	86.1	85.2	86.4	80.7	68.1	62.2	55.0	69.6
1982	50.7	54.7	57.7	66.1	72.3	80.5	84.8	83.9	79.2	67.0	57.7	50.1	67.0
1983	52.9	53.8	57.3	60.4	73.8	81.6	86.9	84.0	82.2	69.5	57.4	53.5	67.8
1984	51.8	53.7	60.5	64.0	79.9	83.1	84.2	82.9	81.5	66.3	57.8	51.5	68.1
1985	50.3	53.1	58.7	68.7	75.9	85.8	87.5	86.1	77.4	70.0	58.0	52.9	68.7
1986	58.7	56.9	63.8	69.0	76.8	86.6	85.5	86.0	79.0	69.6	59.8	52.3	70.3
1987	50.9	54.2	57.9	70.1	74.3	86.3	87.4	85.1	79.9	75.1	58.9	50.3	69.2
1988	53.0	59.4	61.4	68.0	76.4	86.8	87.9	85.9	80.4	75.3	59.2	51.9	70.5
1989	49.9	58.2	65.0	73.8	77.4	85.4	90.0	85.6	84.5	71.1	61.7	53.0	71.4
1990	51.8	52.8	61.8	69.7	75.2	88.7	85.0	82.6	82.2	73.1	61.6	51.1	69.6
1991	52.3	59.8	55.4	65.2	73.5	81.5	87.5	86.6	80.7	74.0	58.9	54.3	69.1
1992	51.6	57.3	59.4	70.8	76.7	84.5	86.8	85.1	83.6	74.2	56.1	51.4	69.8
1993	55.2	54.0	61.3	68.6	78.1	85.0	88.0	85.5	81.4	72.6	58.8	53.4	70.2
Record Mean	50.6	53.6	58.0	64.9	73.0	82.4	86.1	84.1	80.1	69.7	58.3	51.5	67.7
Max	64.4	67.8	73.0	81.1	89.7	99.1	99.3	96.8	94.1	84.9	73.1	65.3	82.4
Min	36.8	39.3	43.0	48.8	56.3	65.7	72.9	71.4	66.1	54.5	43.5	37.7	53.0

See Reference Notes on Page 6B.
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HEATING DEGREE DAYS Base 65 deg. F

TUCSON, ARIZONA

SEASON	JULY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	TOTAL
1964-65	0	0	0	5	293	383	348	383	305	114	21	0	1852
1965-66	0	0	8	33	110	396	532	473	166	26	0	0	1744
1966-67	0	0	0	20	126	386	416	256	115	113	20	0	1452
1967-68	0	0	0	14	89	502	384	170	200	91	0	0	1450
1968-69	0	0	0	4	204	440	288	328	339	34	35	0	1672
1969-70	0	0	0	55	188	384	455	224	274	132	8	0	1720
1970-71	0	0	0	58	143	403	445	350	200	111	12	0	1722
1971-72	0	0	0	120	249	548	444	259	73	50	0	0	1743
1972-73	0	0	0	96	358	489	533	320	410	174	19	0	2399
1973-74	0	0	0	23	216	390	451	362	161	49	5	0	1657
1974-75	0	0	0	53	218	552	465	393	299	217	29	0	2226
1975-76	0	0	0	38	191	365	378	180	221	88	5	0	1466
1976-77	0	0	0	45	178	390	435	221	287	65	9	0	1630
1977-78	0	0	0	1	117	242	365	313	144	64	24	0	1270
1978-79	0	0	0	15	213	470	511	311	260	76	20	0	1876
1979-80	0	0	0	26	252	302	323	202	227	84	3	0	1419
1980-81	0	0	0	66	197	210	310	220	244	31	0	0	1278
1981-82	0	0	0	34	106	304	437	291	223	46	10	0	1451
1982-83	0	0	0	41	211	456	371	309	239	168	6	0	1801
1983-84	0	0	0	0	232	348	402	323	140	110	0	0	1555
1984-85	0	0	0	49	221	413	448	328	200	41	0	0	1700
1985-86	0	0	0	9	217	369	193	244	117	22	6	0	1177
1986-87	0	0	0	11	154	387	429	299	225	24	0	0	1529
1987-88	0	0	0	0	188	452	366	171	161	46	12	0	1396
1988-89	0	0	0	0	220	402	461	199	82	9	4	0	1377
1989-90	0	0	0	25	107	361	402	340	156	16	3	0	1410
1990-91	0	0	0	5	152	427	384	140	296	47	3	0	1454
1991-92	0	0	0	56	195	325	408	215	169	24	0	0	1392
1992-93	0	0	0	0	261	418	298	299	129	28	0	0	1433
1993-94	0	0	0	5	186	355							

See Reference Notes on Page 6B.

COOLING DEGREE DAYS Base 65 deg. F

TUCSON, ARIZONA

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	TOTAL
1969	0	0	15	87	348	477	658	669	493	118	1	0	2866
1970	0	5	0	25	333	561	693	620	347	68	4	0	2656
1971	6	0	45	51	152	493	706	514	430	101	12	0	2510
1972	0	1	82	82	236	506	678	563	414	150	1	0	2713
1973	0	0	0	21	272	495	603	615	445	206	26	2	2685
1974	0	0	18	87	301	664	581	564	387	185	1	0	2788
1975	0	0	4	11	184	471	604	651	458	182	27	0	2592
1976	2	0	14	89	306	557	597	636	386	139	34	0	2760
1977	0	0	5	133	198	597	691	669	517	266	23	0	3099
1978	0	0	54	76	283	630	721	616	483	293	28	0	3184
1979	0	0	1	101	249	551	706	576	580	282	6	0	3052
1980	0	4	1	109	211	606	742	615	474	216	37	3	3018
1981	0	8	4	159	267	639	633	670	476	137	27	2	3022
1982	0	4	4	82	244	471	622	594	437	112	0	0	2570
1983	0	0	8	36	288	503	688	600	523	145	10	0	2801
1984	0	0	6	87	469	549	601	562	503	96	12	0	2885
1985	0	1	7	159	345	633	704	660	379	173	14	0	3075
1986	2	23	88	150	378	653	643	657	431	158	3	0	3186
1987	0	2	12	184	297	644	702	630	452	325	12	0	3260
1988	2	13	58	142	374	658	716	657	471	327	51	1	3470
1989	0	16	89	281	397	619	780	676	592	221	16	0	3687
1990	0	6	63	164	327	719	625	553	522	262	56	0	3297
1991	0	1	6	58	274	501	703	675	479	345	21	0	3063
1992	0	0	4	204	372	590	683	627	563	291	1	0	3335
1993	1	0	22	142	413	604	721	641	500	250	11	3	3308

See Reference Notes on Page 6B.

SNOWFALL (inches)

TUCSON, ARIZONA

SEASON	JULY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	TOTAL
1964-65	0.0	0.0	0.0	0.0	0.1	0.0	0.0	3.9	0.0	0.0	0.0	0.0	4.0
1965-66	0.0	0.0	0.0	0.0	0.0	0.3	T	1.2	0.0	0.0	0.0	0.0	1.5
1966-67	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	T	0.0	0.0	T
1967-68	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	1.6
1968-69	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	T	0.0	0.0	0.0	0.4
1969-70	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	T	T	0.0	0.0	T
1970-71	0.0	0.0	0.0	0.0	0.0	0.0	T	T	0.0	0.0	0.0	0.0	T
1971-72	0.0	0.0	0.0	0.0	0.0	6.8	0.0	0.0	0.0	0.0	0.0	0.0	6.8
1972-73	0.0	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	0.0	0.0	T
1973-74	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	T	0.0	0.0	0.0	0.4
1974-75	0.0	0.0	0.0	0.0	0.0	T	0.0	T	0.5	0.0	0.0	0.0	0.5
1975-76	0.0	0.0	0.0	0.0	T	T	0.0	0.0	3.8	2.0	0.0	0.0	5.8
1976-77	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977-78	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978-79	0.0	0.0	0.0	0.0	0.0	T	1.2	0.0	0.0	0.0	0.0	0.0	1.2
1979-80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	T
1980-81	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	T
1981-82	0.0	0.0	0.0	0.0	0.0	0.0	T	0.0	T	0.0	0.0	0.0	T
1982-83	0.0	0.0	0.0	0.0	0.0	T	0.0	0.0	0.0	0.0	0.0	0.0	T
1983-84	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984-85	0.0	0.0	0.0	0.0	0.0	T	0.0	2.2	0.0	0.0	0.0	0.0	2.2
1985-86	0.0	0.0	0.0	0.0	0.0	T	0.0	T	0.0	0.0	0.0	0.0	T
1986-87	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.0	T	0.0	0.0	0.0	4.7
1987-88	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	0.0	0.0	3.6
1988-89	0.0	0.0	0.0	0.0	0.0	T	0.0	T	0.0	0.0	0.0	0.0	T
1989-90	0.0	0.0	0.0	0.0	0.0	0.0	2.7	2.3	0.0	T	0.0	0.0	5.0
1990-91	0.0	T	T	0.0	0.0	0.6	0.0	T	0.3	0.0	0.0	0.0	0.9
1991-92	0.0	0.0	0.0	T	0.0	T	0.0	0.0	T	0.0	T	0.0	T
1992-93	0.0	T	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	T
1993-94	0.0	T	0.0	0.0	0.0	0.0							
Record Mean	0.0	T	T	T	0.1	0.3	0.3	0.2	0.3	0.1	T	0.0	1.3

See Reference Notes on Page 6B.

REFERENCE NOTES

TUCSON, ARIZONA

GENERAL
T - TRACE AMOUNT.
BLANK ENTRIES DENOTE MISSING/UNREPORTED DATA.
# INDICATES A STATION OR INSTRUMENT RELOCATION.
SEE STATION LOCATION TABLE ON PAGE 8.

SPECIFIC
PAGE 2
PM - INCLUDES LAST DAY OF PREVIOUS MONTH
ASOS - AUTOMATED SURFACE OBSERVING SYSTEM IN OPERATION DURING THESE MONTHS.

PAGE 3
(a) - LENGTH OF RECORD IN YEARS, ALTHOUGH INDIVIDUAL MONTHS MAY BE MISSING.
0.* OR * - THE VALUE IS BETWEEN 0.0 AND 0.05
NORMALS - BASED ON THE 1961-1990 RECORD PERIOD.
EXTREMES - DATES ARE THE MOST RECENT OCCURRENCE
WIND DIR.- NUMERALS SHOW TENS OF DEGRESS CLOCKWISE FROM TRUE NORTH. "00" INDICATES CALM.
RESULTANT DIRECTIONS ARE GIVEN TO WHOLE DEGREES.
BOLD VALUES INDICATE EXTREME VALUES WHICH OCCURRED AFTER THE ASOS SYSTEM WAS COMMISSIONED.

PAGE 4B
RECORD = PERIOD OF RECORD
RECORD MEAN PRECIPITATION IS THE MEAN OF ALL DAILY PRECIPITATION AMOUNTS DURING THE PERIOD OF RECORD.
RECORD MAX(MIN) TEMPERATURE IS THE MEAN OF ALL DAILY MAX(MIN) TEMPERATURES DURING THE PERIOD OF RECORD.
RECORD MEAN TEMPERATURE IS THE SUM OF THE RECORD MAX AND RECORD MIN DIVIDED BY 2.
AVERAGE TEMPERATURE IS THE SUM OF THE MEAN DAILY MAX AND MIN TEMPERATURE DIVIDED BY 2.

EXCEPTIONS

PAGES 4A, 4B, 6A
RECORD MEANS ARE THROUGH THE CURRENT YEAR,
BEGINNING IN 1900 FOR TEMPERATURE
1900 FOR PRECIPITATION
1941 FOR SNOWFALL

TUCSON,
ARIZONA

Tucson lies at the foot of the Catalina Mountains, north of the airport. The area within about 15 miles of the airport station is flat or gently rolling, with many dry washes. The soil is sandy, and vegetation is mostly brush, cacti, and small trees. Rugged mountains encircle the valley. The mountains to the north, east, and south rise to over 5,000 feet above the airport. The western hills and mountains range from 500 to 4,000 feet.

The climate of Tucson is characterized by a long hot season, from April to October. Temperatures above 90 degrees prevail from May through September. Temperatures of 100 degrees or higher average 41 days annually, including 14 days each for June and July, but these extreme temperatures are moderated by low relative humidities. The temperature range is large, averaging 30 degrees or more a day.

More than 50 percent of the annual precipitation falls between July 1 and September 15, and over 20 percent falls from December through March. During the summer, scattered convective or orographic showers and thunderstorms often fill dry washes to overflowing. On occasion, brief, torrential downpours cause destructive flash floods in the Tucson area. Hail rarely occurs in thunderstorms. The December through March precipitation occurs as prolonged rainstorms that replenish the ground water. During these storms, snow often falls on the higher mountains, but snow in Tucson is infrequent, particularly in accumulations exceeding an inch in depth.

From the first of the year, the humidity decreases steadily until the summer thunderstorm season, when it shows a marked increase. From mid-September, the end of the thunderstorm season, the humidity decreases again until late November. Occasionally during the summer, humidities are high enough to produce discomfort, but only for short periods. During the hot season, humidity values sometimes fall below 5 percent.

Tucson lies in the zone receiving more sunshine than any other section of the United States. Cloudless days are commonplace, and average cloudiness is low.

Surface winds are generally light, with no major seasonal changes in velocity or direction. Occasional duststorms occur in areas where the ground has been disturbed. During the spring, winds may briefly be strong enough to cause some damage to trees and buildings. Wind velocities and directions are influenced by the surrounding mountains, and the general slope of the terrain. Usually local winds tend to be in the southeast quadrant during the night and early morning hours, veering to northwest during the day. Highest velocities usually occur with winds from the southwest and east to south.

While dust and haze are frequently visible, their effect on the general clarity of the atmosphere is not great. Visibility is normally high.

Based on the 1951-1980 period, the average first occurrence of 32 degrees Fahrenheit in the fall is November 29 and the average last occurrence in the spring is February 28.

Notice of Correction

Any previously received edition of the "Local Climatological Data Annual Summary for 1993" should be discarded. This revised edition contains updates to the "Normals" based upon the 1961-1990 record period as noted in the "Reference Notes" on Page 6B.

APPENDIX K.

FORTRAN DATA ANALYSIS PROGRAMS

Listings of the FORTRAN programs used to analyze the detector output data are given in this appendix. The programs, described in Section 10.4, are:

- COUNT.FOR
- INT_CNT.FOR
- DENSITY.FOR
- OVF.FOR
- DENS_TOD.FOR
- DENS_232.FOR
- GP_COUNT.FOR
- OCC.FOR
- SVF.FOR

K.1 COUNT.FOR

```
C*****************************************
C*   THIS PROGRAM OUTPUTS VEHICLE COUNTS VS.  *
C*   TIME OF DAY                              *
C*****************************************
C
        INTEGER TIME
C
        DIMENSION TIME(15000,4), DECTIME(15000)
C
        CALL OPEN
C
C****INITIALIZE COUNTER TO DETERMINE # OF ROWS****
C
        KOUNT=0
C
C****READ IN ARRAY VALUES FROM THE PARADOX DATA****
C
  100   KOUNT=KOUNT+1
        READ(1,*,END=999) (TIME(KOUNT,J),J=1,4)
        GO TO 100
C
  999   KOUNT=KOUNT-1
C
C****COMPUTE DECIMAL TIME FROM THE FOUR TIME FIELDS****
C
        DO 150 I=1,KOUNT
          DECTIME(I)=TIME(I,1)+(TIME(I,2)/60.)+(TIME(I,3)/3600.)
     &              +(TIME(I,4)/3600000.)
          WRITE(2,10) DECTIME(I),I
  150   CONTINUE
C
  10    FORMAT(1X,F7.4,2X,I5)
C
        STOP
        END

        SUBROUTINE OPEN

        CHARACTER*11 FNO
        CHARACTER*11 FNI
        CHARACTER FILENAME(8)

        WRITE(6,*) 'ENTER THE 8 DIGIT NUMERICAL FILENAME: '
        READ(5,225) (FILENAME(J),J=1,8)
  225   FORMAT(8A1)

        FNI=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
     &    FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.CI'

        FNO=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
     &    FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.CO'

        WRITE(6,230) FNI
        WRITE(6,230) FNO
  230   FORMAT(1X,20A)

        OPEN(1,FILE=FNI,STATUS='OLD')
        OPEN(2,FILE=FNO,STATUS='OLD')

        RETURN
        END
```

K.2 INT_CNT.FOR

```
C*******************************************************
C*   THIS PROGRAM COMPUTES VEHICLE COUNT ACCURACIES AND    *
C*   STATISTICAL MEASURES OF EFFECTIVENESS OVER A          *
C*   USER-DEFINED INTEGRATION INTERVAL                     *
C*******************************************************
C
       INTEGER TIME1, TIME2, SUM1, SUM2, DIFF, DIFSUM, SQSUM
C
       REAL OLD, NEW, MEAN
C
       DIMENSION TIME1(7000,4), DECTIME1(7000), TIME2(7000,4),
     &           DECTIME2(7000), SUM1(500), SUM2(500), DIFF(500),
     &           PDIFF(500), SAMTIM(500)
C
       CALL OPEN
C
C****INITIALIZE COUNTER TO DETERMINE # OF ROWS****
C
       KOUNT1=0
       KOUNT2=0
C
C****READ IN ARRAY VALUES FROM THE PARADOX DATA****
C
  100  KOUNT1=KOUNT1+1
       READ(1,*,END=999) (TIME1(KOUNT1,J),J=1,4)
       GO TO 100
C
  999  KOUNT1=KOUNT1-1
C
  110  KOUNT2=KOUNT2+1
       READ(3,*,END=998) (TIME2(KOUNT2,J),J=1,4)
       GO TO 110
C
  998  KOUNT2=KOUNT2-1
C
C****COMPUTE DECIMAL TIME FROM THE FOUR TIME FIELDS****
C
       DO 150 I=1,KOUNT1
         DECTIME1(I)=TIME1(I,1)+(TIME1(I,2)/60.)+(TIME1(I,3)/3600.)
     &             +(TIME1(I,4)/3600000.)
C         WRITE(2,10) DECTIME(I),I
  150  CONTINUE
C
       DO 160 I=1,KOUNT2
         DECTIME2(I)=TIME2(I,1)+(TIME2(I,2)/60.)+(TIME2(I,3)/3600.)
     &             +(TIME2(I,4)/3600000.)
  160  CONTINUE
C
       WRITE(6,*) 'ENTER THE DESIRED COUNT ACCUMULATION TIME (MINS):
       READ(5,*) TINT

       HSTART=FLOAT((TIME1(1,1)))+((TIME1(1,2)+1)/60.)
       HEND=FLOAT((TIME1(KOUNT1,1)))+(TIME1(KOUNT1,2)/60.)
       DELMIN=(HEND-HSTART)*60.
       NINT=INT(DELMIN/TINT)
       OLD=HSTART
       NEW=HSTART+TINT/60.
C
       J=1
       DO 50 I=1,500
```

```
          SUM1(I)=0
  50    CONTINUE
        DO 51 I=1,500
          SUM2(I)=0
  51    CONTINUE
C
        DO 200 I=1,KOUNT1
          IF(DECTIME1(I).GE.NEW) THEN
            J=J+1
            IF(J.GT.NINT) GO TO 200
            OLD=NEW
            NEW=NEW+TINT/60.
            IF((DECTIME1(I).GE.OLD).AND.(DECTIME1(I).LT.NEW)) THEN
              SUM1(J)=SUM1(J)+1
            ENDIF
          ELSE
            IF((DECTIME1(I).GE.OLD).AND.(DECTIME1(I).LT.NEW)) THEN
              SUM1(J)=SUM1(J)+1
            ENDIF
          ENDIF
  200   CONTINUE
C
        J=1
        OLD=HSTART
        NEW=HSTART+TINT/60.
C
        DO 210 I=1,KOUNT2
          IF(DECTIME2(I).GE.NEW) THEN
            J=J+1
            IF(J.GT.NINT) GO TO 210
            OLD=NEW
            NEW=NEW+TINT/60.
            IF((DECTIME2(I).GE.OLD).AND.(DECTIME2(I).LT.NEW)) THEN
              SUM2(J)=SUM2(J)+1
            ENDIF
          ELSE
            IF((DECTIME2(I).GE.OLD).AND.(DECTIME2(I).LT.NEW)) THEN
              SUM2(J)=SUM2(J)+1
            ENDIF
          ENDIF
  210   CONTINUE
C
        SQSUM=0
        DIFSUM=0
        DO 300 I=1,NINT
          SAMTIM(I)=HSTART+(I-1)*TINT/60.
          DIFF(I)=SUM2(I)-SUM1(I)
          PDIFF(I)=(FLOAT(DIFF(I))/FLOAT(SUM1(I)))*100.
          DIFSUM=DIFSUM+DIFF(I)
          SQSUM=SQSUM+(DIFF(I))**2
          PDSUM=PDSUM+PDIFF(I)
          SQPD=SQPD+(PDIFF(I))**2
  300   CONTINUE
C
        XDIFSM=DIFSUM*1.0
        XINT=NINT*1.0
        MEAN=XDIFSM/XINT
        STDDEV=SQRT(FLOAT((NINT*SQSUM-DIFSUM**2)/(NINT*(NINT-1))))
        SIGMA=SQRT((NINT*SQPD-PDSUM**2)/(NINT*(NINT-1)))
```

```
      WRITE(2,*) 'ACCUMULATION INTERVAL TIME: ',TINT,' MINS'
      WRITE(2,*) 'MEAN DIFFERENCE= ',MEAN
      WRITE(2,*) 'STANDARD DEVIATION OF THE DIFF VALUES= ',STDDEV
      WRITE(2,*) 'STANDARD DEVIATION OF THE % DIFF VALUES= ',SIGMA
      WRITE(2,5)
      WRITE(6,*) 'ACCUMULATION INTERVAL TIME: ',TINT,' MINS'
      WRITE(6,*) 'MEAN DIFFERENCE= ',MEAN
      WRITE(6,*) 'STANDARD DEVIATION OF THE DIFF VALUES= ',STDDEV
      WRITE(6,*) 'STANDARD DEVIATION OF THE % DIFF VALUES= ',SIGMA
      WRITE(6,*)
      WRITE(6,5)
 5    FORMAT(1X,2X,'INT',4X,'TIME',3X,'SUM1',1X,'SUM2',1X,'DIFF',1X,
     & '%DIFF')
C
      DO 400 I=1,NINT
        WRITE(2,10) I,SAMTIM(I),SUM1(I),SUM2(I),DIFF(I),PDIFF(I)
        WRITE(6,10) I,SAMTIM(I),SUM1(I),SUM2(I),DIFF(I),PDIFF(I)
 400  CONTINUE

 10   FORMAT(1X,I4,2X,F8.4,2X,2(I3,2X),I3,2X,F5.1)
C
      STOP
      END

      SUBROUTINE OPEN

      CHARACTER*11 FNO
      CHARACTER*11 FNI
      CHARACTER*12 FNL
      CHARACTER FILENAME(8)

      WRITE(6,*) 'ENTER THE 8 DIGIT NUMERICAL FILENAME: '
      READ(5,225) (FILENAME(J),J=1,8)
 225  FORMAT(8A1)

      FNI=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
     &  FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.CI'

      FNO=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
     &  FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.CO'

      FNL=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
     &  FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.ILI'


      WRITE(6,230) FNI
      WRITE(6,230) FNO
      WRITE(6,230) FNL
 230  FORMAT(1X,20A)

      OPEN(1,FILE=FNL,STATUS='OLD')
      OPEN(2,FILE=FNO,STATUS='OLD')
      OPEN(3,FILE=FNI,STATUS='OLD')

      RETURN

      END
```

K.3 DENSITY.FOR

```
C*******************************************************
C*   THIS PROGRAM COMPUTES DENSITY, SPEED,     *
C*  AND FLOW FOR A USER-DEFINED TIME INTERVAL *
C*******************************************************
C
        INTEGER DETINT1, DETINT2
C
        REAL*8 TIME, FACTOR, TEMP, TIME1, TIME2, DELTAT, NEWTIME,
     &    HOUR1, HOUR2, TMIC1, TMIC2, CONST
C
        DIMENSION SAMPLE(2000), DENS(2000), FLOW(2000),
     &    ICOUNT(2000), SPDSUM(2000), AVESPD(2000), TAG(2000)
C
        CALL OPEN
C
C****INITIALIZE COUNTERS****
C
        KOUNT=0
        NCYCLE=0
        FACTOR=4.294967295E9
C
C****READ IN ARRAY VALUES AND COMPUTE TIMES FROM SPEED TRAP TIME TAGS***
C
        READ(1,*) THOUR,TMIN,TSEC,THSEC,INTNUM1,SPDTRP1
        TIME=SPDTRP1
        TIMTAG=THOUR+TMIN/60.
        WRITE(3) INTNUM1,TIME
        HOUR1=THOUR+TMIN/60.+TSEC/3600.+THSEC/3600000.
        TMIC1=TIME
  100   KOUNT=KOUNT+1
        READ(1,*,END=999) THOUR,TMIN,TSEC,THSEC,INTNUM2,SPDTRP2
        IF(SPDTRP2.LT.SPDTRP1) NCYCLE=NCYCLE+1
        TIME=SPDTRP2+NCYCLE*FACTOR
        WRITE(3) INTNUM2,TIME
        INTNUM1=INTNUM2
        SPDTRP1=SPDTRP2
        GO TO 100
  999   KOUNT=KOUNT-1
        HOUR2=THOUR+TMIN/60.+TSEC/3600.+THSEC/3600000.
        TMIC2=TIME
        CONST=(HOUR2-HOUR1)*3.6E9/(TMIC2-TMIC1)
        WRITE(6,*) 'CONSTANT = ',CONST
C
C****SOLICIT INPUT FOR DESIRED OCCUPANCY TIME INTERVAL****
C
        WRITE(6,*)
        WRITE(6,10)
        READ(5,*) SPACE
        WRITE(6,*)
        WRITE(6,15)
  10    FORMAT(1X,'ENTER THE SPACING BETWEEN DETECTION ZONES (FT) ')
  15    FORMAT(1X,'ENTER THE DESIRED INTEGRATION TIME INTERVAL (MINS) ')
        READ(5,*) DELTAM
        WRITE(6,16) DELTAM
  16    FORMAT(1X,'DELTA M = ',F6.3,1X,'MINUTES')
        HDELT=DELTAM/60.
        WRITE(6,*)
        WRITE(6,*) 'ENTER THE DETECTOR INTERFACE # FOR ZONE 1 '
        READ(5,*) DETINT1
        WRITE(6,*)
```

```
        WRITE(6,*) 'ENTER THE DETECTOR INTERFACE # FOR ZONE 2 '
        READ(5,*) DETINT2
        WRITE(6,*) 'NCYCLE= ',NCYCLE
C
C****THROW OUT "NON-PAIRED" DATA AND COMPUTE SPEED****
C
        KOUNTR=0
        REWIND 3
        READ(3) INTNUM1,TIME1
        DO 500 I=2,KOUNT
          READ(3) INTNUM2,TIME2
          IF((INTNUM1.EQ.DETINT1).AND.(INTNUM2.EQ.DETINT2)) THEN
            KOUNTR=KOUNTR+1
            DELTAT=(TIME2-TIME1)*CONST
            NEWTIME=TIME2*CONST/3.6E9
            SPEED=SPACE/DELTAT*3.6E9/5280.
            WRITE(4) NEWTIME,SPEED
          ENDIF
          INTNUM1=INTNUM2
          TIME1=TIME2
  500   CONTINUE

        WRITE(6,*) 'KOUNTR = ',KOUNTR
C
C****SET UP SAMPLING INTERVAL AND OCCUPANCY ARRAY****
C
        XHOUR2=INT(NEWTIME)
        XMIN2=INT((NEWTIME-INT(NEWTIME))*60.)
        REWIND 4
        READ(4) NEWTIME,SPEED
        XHOUR1=INT(NEWTIME)
        XMIN1=INT((NEWTIME-INT(NEWTIME))*60.)
C
        START=XHOUR1+XMIN1/60.
        END=XHOUR2+XMIN2/60.
        INUM=((END-START)/HDELT)+1
C
        WRITE(6,*) 'START = ',START,'  END = ',END,'  INUM = ',INUM
        WRITE(6,*)
C
        DO 200 K=1,INUM
          SAMPLE(K)=START+(K-1)*HDELT
          TAG(K)=TIMTAG+(K-1)*HDELT
  200   CONTINUE
C
C****COMPUTE VEHICLE FLOWS AND AVERAGE SPEEDS****
C
        DO 400 I=1,INUM
          REWIND 4
          DO 410 J=1,KOUNTR
            READ(4) NEWTIME,SPEED
            IF(NEWTIME.LE.SAMPLE(I)) THEN
              GO TO 410
            ELSE
              IF((NEWTIME.GT.SAMPLE(I)).AND.(NEWTIME.LE.
     &          SAMPLE(I)+HDELT)) THEN
                  ICOUNT(I)=ICOUNT(I)+1
                  SPDSUM(I)=SPDSUM(I)+SPEED
              ELSE
                GO TO 405
```

```
            ENDIF
          ENDIF
410     CONTINUE
405       FLOW(I)=(FLOAT(ICOUNT(I)))/HDELT
          AVESPD(I)=SPDSUM(I)/ICOUNT(I)
          DENS(I)=FLOW(I)/AVESPD(I)
400   CONTINUE

      WRITE(6,17)
      WRITE(6,18)
      WRITE(6,21)
17    FORMAT(1X,1X,'INTRVL',1X,'SAMPLE',6X,'FLOW',8X,'AVG',6X,
   &    'LANE')
18    FORMAT(1X,3X,'NUM',3X,'TIME',7X,'RATE',7X,'SPEED',3X,
   &    'DENSITY')
21    FORMAT(1X,9X,'(HRS)',4X,'(VEH/HR)',5X,'(MPH)',3X,'(VEH/MI)')

      DO 300 I=2,INUM-1
        WRITE(6,19) I,TAG(I),FLOW(I),AVESPD(I),DENS(I)
        WRITE(2,22) TAG(I),FLOW(I),AVESPD(I),DENS(I)
300   CONTINUE

19    FORMAT(1X,I5,2X,F7.4,2X,F9.2,2X,F9.2,2X,F7.2)
22    FORMAT(1X,F7.4,2X,F7.2,2X,F6.2,2X,F7.2)

      STOP
      END

      SUBROUTINE OPEN

      CHARACTER*11 FNO
      CHARACTER*11 FNI
      CHARACTER FILENAME(8)

      WRITE(6,*) 'ENTER THE 8 DIGIT NUMERICAL FILENAME: '
      READ(5,225) (FILENAME(J),J=1,8)
225   FORMAT(8A1)

      FNI=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
   &    FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.DI'

      FNO=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
   &    FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.DO'

      WRITE(6,230) FNI
      WRITE(6,230) FNO
230   FORMAT(1X,20A)

      OPEN(1,FILE=FNI,STATUS='OLD')
      OPEN(2,FILE=FNO,STATUS='OLD')
      OPEN(3,FILE='MICSEC.DAT',STATUS='OLD',ACCESS='SEQUENTIAL',
   &    FORM='UNFORMATTED')
      OPEN(4,FILE='DENS.DAT',STATUS='OLD',ACCESS='SEQUENTIAL',
   &    FORM='UNFORMATTED')

      RETURN

      END
```

K.4 OVF.FOR

```
C*********************************************
C*   THIS PROGRAM COMPUTES OCCUPANCY VERSUS   *
C*   FLOW FOR A USER-DEFINED TIME INTERVAL    *
C*********************************************
C
        INTEGER TIME
C
        DIMENSION TIME(7000,4), PRES(7000), DECTIME(7000),
     &    SAMPLE(7000), SUM(7000), HPRES(7000), OCC(7000),
     &    SEC(7000), FLOW(7000), ICOUNT(7000)
C
        CALL OPEN
C
C****INITIALIZE COUNTER TO DETERMINE # OF ROWS****
C
        KOUNT=0
C
C****READ IN ARRAY VALUES FROM THE PARADOX DATA****
C
  100   KOUNT=KOUNT+1
        READ(1,*,END=999) (TIME(KOUNT,J),J=1,4), PRES(KOUNT)
        HPRES(KOUNT)=PRES(KOUNT)/3.6E9
        GO TO 100
C
  999   KOUNT=KOUNT-1
C
C****COMPUTE DECIMAL TIME FROM THE FOUR TIME FIELDS****
C
        DO 150 I=1,KOUNT
          DECTIME(I)=TIME(I,1)+(TIME(I,2)/60.)+(TIME(I,3)/3600.)
     &              +(TIME(I,4)/3600000.)
  150   CONTINUE
C
C****SOLICIT INPUT FOR DESIRED OCCUPANCY TIME INTERVAL****
C
        WRITE(6,15)
  15    FORMAT(1X,'ENTER THE DESIRED OCCUPANCY TIME INTERVAL (MINS) ')
        READ(5,*) DELTAM
        WRITE(6,16) DELTAM
  16    FORMAT(1X,'DELTA M = ',F6.3,1X,'MINUTES')
        HDELT=DELTAM/60.
        WRITE(6,*)
C
C****SET UP SAMPLING INTERVAL AND OCCUPANCY ARRAY****
C
        XHOUR1=TIME(1,1)
        XMIN1=TIME(1,2)
        XHOUR2=TIME(KOUNT,1)
        XMIN2=TIME(KOUNT,2)
C
        START=XHOUR1+XMIN1/60.
        END=XHOUR2+XMIN2/60.
        INUM=((END-START)/HDELT)+1
C
        WRITE(6,*) 'START = ',START,'  END = ',END,'  INUM = ',INUM
        WRITE(6,*)
C
        DO 200 K=1,INUM
          SAMPLE(K)=START+(K-1)*HDELT
          SUM(K)=0.0
```

```
  200   CONTINUE
C
C****SUM UP THE PRESENCE TIMES FOR EACH SAMPLING PERIOD****
C
        DO 250 I=1,INUM
          DO 260 J=1,KOUNT
            IF(DECTIME(J).LE.SAMPLE(I)) THEN
              GO TO 260
            ELSE
              IF((DECTIME(J).GT.SAMPLE(I)).AND.(DECTIME(J)-HPRES(J).LT.
     &          SAMPLE(I))) THEN
                  SUM(I)=SUM(I)+DECTIME(J)-SAMPLE(I)
              ELSE
                IF(((DECTIME(J)-HPRES(J)).GE.SAMPLE(I)).AND.(DECTIME(J)
     &          .LE.SAMPLE(I)+HDELT)) THEN
                    SUM(I)=SUM(I)+HPRES(J)
                ELSE
                  IF(((DECTIME(J).GT.(SAMPLE(I)+HDELT)).AND.
     &            ((DECTIME(J)-HPRES(J)).LT.(SAMPLE(I)+HDELT)))) THEN
                      SUM(I)=SUM(I)+(HPRES(J)-DECTIME(J)+SAMPLE(I)+
     &                HDELT)
                  ELSE
                    IF(((DECTIME(J)-HPRES(J)).LT.(SAMPLE(I))).AND.
     &              (DECTIME(J).GT.(SAMPLE(I)+HDELT))) THEN
                        SUM(I)=SUM(I)+HDELT
                    ELSE
                      GO TO 250
                    ENDIF
                  ENDIF
                ENDIF
              ENDIF
            ENDIF
  260     CONTINUE
  250   CONTINUE
C
C****COMPUTE OCCUPANCIES AND WRITE OUTPUTS****
C
        DO 265 I=1,INUM
          OCC(I)=SUM(I)*100/HDELT
          SEC(I)=SUM(I)*3600.
  265   CONTINUE
C
C****COMPUTE VEHICLE FLOWS AT SPECIFIED INTEGRATION TIMES****
C
        DO 400 I=1,INUM
          DO 410 J=1,KOUNT
            IF(DECTIME(J).LE.SAMPLE(I)) THEN
              GO TO 410
            ELSE
              IF((DECTIME(J).GT.SAMPLE(I)).AND.(DECTIME(J).LE.
     &          SAMPLE(I)+HDELT)) THEN
                  ICOUNT(I)=ICOUNT(I)+1
              ELSE
                GO TO 405
              ENDIF
            ENDIF
  410     CONTINUE
  405       FLOW(I)=(FLOAT(ICOUNT(I)))/HDELT
  400   CONTINUE
```

```
      WRITE(6,17)
      WRITE(6,18)
      WRITE(6,21)
17    FORMAT(1X,1X,'INTRVL',1X,'SAMPLE',4X,'INTRVL',5X,'INTRVL',13X,
   &    'FLOW')
18    FORMAT(1X,3X,'NUM',3X,'TIME',1X,2(3X,'PRESENCE'),4X,'OCC',5X,
   &    'RATE')
21    FORMAT(1X,9X,'(HRS)',5X,'(HRS)',6X,'(SECS)',4X,'(%)',3X,
   &    '(VEH/HR)')

      DO 300 I=2,INUM-1
        WRITE(6,19) I,SAMPLE(I),SUM(I),SEC(I),OCC(I),FLOW(I)
        WRITE(2,22) SAMPLE(I),OCC(I),FLOW(I)
300   CONTINUE

19    FORMAT(1X,I5,2X,F7.4,2X,E10.4,2X,F7.3,2X,F7.3,2X,F7.2)
22    FORMAT(1X,F7.4,2X,F7.3,2X,F7.2)

      STOP
      END

      SUBROUTINE OPEN

      CHARACTER*12 FNO
      CHARACTER*11 FNI
      CHARACTER FILENAME(8)

      WRITE(6,*) 'ENTER THE 8 DIGIT NUMERICAL FILENAME: '
      READ(5,225) (FILENAME(J),J=1,8)
225   FORMAT(8A1)

      FNI=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
   &    FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.IN'

      FNO=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
   &    FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.OFO'

      WRITE(6,230) FNI
      WRITE(6,230) FNO
230   FORMAT(1X,20A)

      OPEN(1,FILE=FNI,STATUS='OLD')
      OPEN(2,FILE=FNO,STATUS='OLD')

      RETURN

      END
```

K.5 DENS_TOD.FOR

```
C*******************************************
C*   THIS PROGRAM COMPUTES DENSITY, SPEED,    *
C*  AND FLOW FOR A USER-DEFINED TIME INTERVAL *
C*******************************************
C
        INTEGER TIME
C
        REAL NEWTIME

        DIMENSION TIME(13000,4), DECTIME(13000), INTNUM(13000),
     &    SAMPLE(1000), DENS(1000), SPEED(6500), FLOW(1000),
     &    ICOUNT(1000), NEWTIME(6500), SPDSUM(1000), AVESPD(1000),
     &    DELTAT(6500)
C
        CALL OPEN
C
C****INITIALIZE COUNTER TO DETERMINE # OF ROWS****
C
        KOUNT=0
C
C****READ IN ARRAY VALUES FROM THE PARADOX DATA****
C
  100   KOUNT=KOUNT+1
        READ(1,*,END=999) (TIME(KOUNT,J),J=1,4), INTNUM(KOUNT)
        GO TO 100
C
  999   KOUNT=KOUNT-1
C
C****COMPUTE DECIMAL TIME FROM THE FOUR TIME FIELDS****
C
        DO 150 I=1,KOUNT
          DECTIME(I)=TIME(I,1)+(TIME(I,2)/60.)+(TIME(I,3)/3600.)
     &              +(TIME(I,4)/3600000.)
  150   CONTINUE
C
C****SOLICIT INPUT FOR DESIRED OCCUPANCY TIME INTERVAL****
C
        WRITE(6,*)
        WRITE(6,10)
        READ(5,*) SPACE
        WRITE(6,*)
        WRITE(6,15)
  10    FORMAT(1X,'ENTER THE CENTER-TO-CENTER LOOP SPACING (FT) ')
  15    FORMAT(1X,'ENTER THE DESIRED INTEGRATION TIME INTERVAL (MINS) ')
        READ(5,*) DELTAM
        WRITE(6,16) DELTAM
  16    FORMAT(1X,'DELTA M = ',F6.3,1X,'MINUTES')
        HDELT=DELTAM/60.
        WRITE(6,*)
C
C****THROW OUT "NON-PAIRED" DATA AND COMPUTE SPEED****
C
        DO 500 I=1,KOUNT
          IF((INTNUM(I).EQ.1).AND.(INTNUM(I+1).EQ.2)) THEN
            KOUNTR=KOUNTR+1
            NEWTIME(KOUNTR)=DECTIME(I+1)
            DELTAT(KOUNTR)=(DECTIME(I+1)-DECTIME(I))
            SPEED(KOUNTR)=SPACE/DELTAT(KOUNTR)/5280.
          ELSE
          ENDIF
```

```
  500   CONTINUE
        WRITE(6,*) 'KOUNTR = ',KOUNTR,'  NEWTIME(FINAL)= ',
     &    NEWTIME(KOUNTR)
        WRITE(6,*) 'NEWTIME(1)= ',NEWTIME(1)
        WRITE(6,*) 'DECTIME(1)= ',DECTIME(1)
        WRITE(6,*) 'DECTIME(2)= ',DECTIME(2)
        WRITE(6,*) 'DECTIME(3)= ',DECTIME(3)
        WRITE(6,*) 'DELTAT(1)= ',DELTAT(1)
        WRITE(6,*) 'SPEED(1)= ',SPEED(1)
C
C****SET UP SAMPLING INTERVAL AND OCCUPANCY ARRAY****
C
        XHOUR1=INT(NEWTIME(1))
        XMIN1=INT((NEWTIME(1)-INT(NEWTIME(1)))*60.)
        XHOUR2=INT(NEWTIME(KOUNTR))
        XMIN2=INT((NEWTIME(KOUNTR)-INT(NEWTIME(KOUNTR)))*60.)
C
        START=XHOUR1+XMIN1/60.
        END=XHOUR2+XMIN2/60.
        INUM=((END-START)/HDELT)+1
C
        WRITE(6,*) 'XMIN1= ',XMIN1
        WRITE(6,*) 'START = ',START,'  END = ',END,'  INUM = ',INUM
        WRITE(6,*)
C
        DO 200 K=1,INUM
          SAMPLE(K)=START+(K-1)*HDELT
  200   CONTINUE
C
C****COMPUTE VEHICLE FLOWS AND AVERAGE SPEEDS****
C
        DO 400 I=1,INUM
          DO 410 J=1,KOUNTR
            IF(NEWTIME(J).LE.SAMPLE(I)) THEN
              GO TO 410
            ELSE
              IF((NEWTIME(J).GT.SAMPLE(I)).AND.(NEWTIME(J).LE.
     &          SAMPLE(I)+HDELT)) THEN
                  ICOUNT(I)=ICOUNT(I)+1
                  SPDSUM(I)=SPDSUM(I)+SPEED(J)
              ELSE
                GO TO 405
              ENDIF
            ENDIF
  410     CONTINUE
  405       FLOW(I)=(FLOAT(ICOUNT(I)))/HDELT
            AVESPD(I)=SPDSUM(I)/ICOUNT(I)
  400   CONTINUE

        WRITE(6,17)
        WRITE(6,18)
        WRITE(6,21)
  17    FORMAT(1X,1X,'INTRVL',1X,'SAMPLE',6X,'FLOW',8X,'AVG',6X,
     &    'LANE')
  18    FORMAT(1X,3X,'NUM',3X,'TIME',7X,'RATE',7X,'SPEED',3X,
     &    'DENSITY')
  21    FORMAT(1X,9X,'(HRS)',4X,'(VEH/HR)',5X,'(MPH)',3X,'(VEH/MI)')

        DO 300 I=1,INUM
```

```
          WRITE(6,19) I,SAMPLE(I),FLOW(I),AVESPD(I),DENS(I)
          WRITE(2,22) SAMPLE(I),FLOW(I),AVESPD(I),DENS(I)
300     CONTINUE

19      FORMAT(1X,I5,2X,F7.4,2X,F9.2,2X,F9.2,2X,F7.2)
22      FORMAT(1X,F7.4,2X,F7.2,2X,F6.2,2X,F7.2)

        STOP
        END

        SUBROUTINE OPEN

        CHARACTER*11 FNO
        CHARACTER*11 FNI
        CHARACTER FILENAME(8)

        WRITE(6,*) 'ENTER THE 8 DIGIT NUMERICAL FILENAME: '
        READ(5,225) (FILENAME(J),J=1,8)
225     FORMAT(8A1)

        FNI=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
     &    FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.DI'

        FNO=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
     &    FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.DO'

        WRITE(6,230) FNI
        WRITE(6,230) FNO
230     FORMAT(1X,20A)

        OPEN(1,FILE=FNI,STATUS='OLD')
        OPEN(2,FILE=FNO,STATUS='OLD')

        RETURN

        END
```

K.6 DENS_232.FOR

```
C*******************************************
C*   THIS PROGRAM COMPUTES DENSITY, SPEED,    *
C*  AND FLOW FOR A USER-DEFINED TIME INTERVAL *
C*******************************************
C
       INTEGER TIME
C
       DIMENSION TIME(13000,4), DECTIME(13000), SPEED(13000),
     &   SAMPLE(1000), DENS(1000), FLOW(1000),
     &   ICOUNT(1000), SPDSUM(1000), AVESPD(1000)
C
       CALL OPEN
C
C****INITIALIZE COUNTER TO DETERMINE # OF ROWS****
C
       KOUNT=0
C
C****READ IN ARRAY VALUES FROM THE PARADOX DATA****
C
 100   KOUNT=KOUNT+1
       READ(1,*,END=999) (TIME(KOUNT,J),J=1,4), SPEED(KOUNT)
       GO TO 100
C
 999   KOUNT=KOUNT-1
C
C****COMPUTE DECIMAL TIME FROM THE FOUR TIME FIELDS****
C
       DO 150 I=1,KOUNT
         DECTIME(I)=TIME(I,1)+(TIME(I,2)/60.)+(TIME(I,3)/3600.)
     &            +(TIME(I,4)/3600000.)
 150   CONTINUE
C
       WRITE(6,15)
 15    FORMAT(1X,'ENTER THE DESIRED INTEGRATION TIME INTERVAL (MINS) ')
       READ(5,*) DELTAM
       WRITE(6,16) DELTAM
 16    FORMAT(1X,'DELTA M = ',F6.3,1X,'MINUTES')
       HDELT=DELTAM/60.
       WRITE(6,*)
C
C****SET UP SAMPLING INTERVAL AND OCCUPANCY ARRAY****
C
       XHOUR1=INT(DECTIME(1))
       XMIN1=INT((DECTIME(1)-INT(DECTIME(1)))*60.)
       XHOUR2=INT(DECTIME(KOUNT))
       XMIN2=INT((DECTIME(KOUNT)-INT(DECTIME(KOUNT)))*60.)
C
       START=XHOUR1+XMIN1/60.
       END=XHOUR2+XMIN2/60.
       INUM=((END-START)/HDELT)+1
C
       WRITE(6,*) 'XMIN1= ',XMIN1
       WRITE(6,*) 'START = ',START,'  END = ',END,'  INUM = ',INUM
       WRITE(6,*)
C
       DO 200 K=1,INUM
         SAMPLE(K)=START+(K-1)*HDELT
 200   CONTINUE
C
C****COMPUTE VEHICLE FLOWS AND AVERAGE SPEEDS****
```

```
C
       DO 400 I=1,INUM
         DO 410 J=1,KOUNT
           IF(DECTIME(J).LE.SAMPLE(I)) THEN
             GO TO 410
           ELSE
             IF((DECTIME(J).GT.SAMPLE(I)).AND.(DECTIME(J).LE.
     &         SAMPLE(I)+HDELT)) THEN
                 ICOUNT(I)=ICOUNT(I)+1
                 SPDSUM(I)=SPDSUM(I)+SPEED(J)
             ELSE
               GO TO 405
             ENDIF
           ENDIF
 410     CONTINUE
 405       FLOW(I)=(FLOAT(ICOUNT(I)))/HDELT
           AVESPD(I)=SPDSUM(I)/ICOUNT(I)
           DENS(I)=FLOW(I)/AVESPD(I)
 400   CONTINUE

       WRITE(6,17)
       WRITE(6,18)
       WRITE(6,21)
 17    FORMAT(1X,1X,'INTRVL',1X,'SAMPLE',6X,'FLOW',8X,'AVG',6X,
     &   'LANE')
 18    FORMAT(1X,3X,'NUM',3X,'TIME',7X,'RATE',7X,'SPEED',3X,
     &   'DENSITY')
 21    FORMAT(1X,9X,'(HRS)',4X,'(VEH/HR)',5X,'(MPH)',3X,'(VEH/MI)')

       DO 300 I=2,INUM-1
         WRITE(6,19) I,SAMPLE(I),FLOW(I),AVESPD(I),DENS(I)
         WRITE(2,22) SAMPLE(I),FLOW(I),AVESPD(I),DENS(I)
 300   CONTINUE

 19    FORMAT(1X,I5,2X,F7.4,2X,F9.2,2X,F9.2,2X,F7.2)
 22    FORMAT(1X,F7.4,2X,F7.2,2X,F6.2,2X,F7.2)

       STOP
       END

       SUBROUTINE OPEN

       CHARACTER*11 FNO
       CHARACTER*11 FNI
       CHARACTER FILENAME(8)

       WRITE(6,*) 'ENTER THE 8 DIGIT NUMERICAL FILENAME: '
       READ(5,225) (FILENAME(J),J=1,8)
 225   FORMAT(8A1)

       FNI=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
     &   FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.DI'

       FNO=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
     &   FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.DO'

       WRITE(6,230) FNI
       WRITE(6,230) FNO
 230   FORMAT(1X,20A)
```

```
OPEN(1,FILE=FNI,STATUS='OLD')
OPEN(2,FILE=FNO,STATUS='OLD')

RETURN

END
```

K.7 GP_COUNT.FOR

```
C*********************************************
C*   THIS PROGRAM OUTPUTS VEHICLE COUNTS VS.   *
C* TIME OF DAY FOR THE TUCSON SURFACE STREET   *
C* SITE. COUNTS ARE ONLY NOTED FOR THRU-TRAFFIC*
C* i.e. DURING THE SIGNAL GREEN PHASE          *
C*********************************************
C
       INTEGER TIME, GPTIME
C
       REAL NEWTIME
C
       DIMENSION TIME(10000,4), DECTIME(10000), VPRES(10000),
     &          NEWTIME(10000), GPTIME(2000,4), GDECTIME(2000)
C
       CALL OPEN
C
C****INITIALIZE COUNTERS****
C
       KOUNT=0
       KNTGP=1
       NUM=0
       NUMGP=0
C
C****READ IN ARRAY VALUES FROM THE PARADOX DATA****
C
  100  NUM=NUM+1
       READ(1,*,END=999) (TIME(NUM,J),J=1,4)
       GO TO 100
C
  999  NUM=NUM-1
C
  110  NUMGP=NUMGP+1
       READ(3,*,END=499) (GPTIME(NUMGP,J),J=1,4),VPRES(NUMGP)
       GO TO 110
C
  499  NUMGP=NUMGP-1
C
C****COMPUTE DECIMAL TIME FROM THE FOUR TIME FIELDS****
C
       DO 150 I=1,NUM
         DECTIME(I)=(TIME(I,1)+(TIME(I,2)/60.)+(TIME(I,3)/3600.)
     &              +(TIME(I,4)/3600000.))*3600.
  150  CONTINUE
C
       DO 160 I=1,NUMGP
         GDECTIME(I)=(GPTIME(I,1)+(GPTIME(I,2)/60.)+(GPTIME(I,3)/3600.)
     &               +(GPTIME(I,4)/3600000.))*3600.
         VPRES(I)=VPRES(I)/1.0E6
  160  CONTINUE
C
C*********************************************************************
C****TUCSON SURFACE STREET SITE HAD A 4 SECOND YELLOW PHASE FOLLOWED***
C****                BY A 2 SECOND "ALL RED" PHASE                ****
C*********************************************************************

       DO 200 I=1,NUM
         IF((DECTIME(I).GT.(GDECTIME(KNTGP)-VPRES(KNTGP)+1)).AND.
     &     DECTIME(I).LE.(GDECTIME(KNTGP)+6)) THEN
           KOUNT=KOUNT+1
           NEWTIME(KOUNT)=DECTIME(I)
```

```
            ELSE
              IF(DECTIME(I).GT.(GDECTIME(KNTGP)+6)) THEN
                KNTGP=KNTGP+1
              ENDIF
            ENDIF
  200     CONTINUE
C
          WRITE(6,*) 'KOUNT= ',KOUNT,'    NUM= ',NUM
          PERGRN=FLOAT(KOUNT)/FLOAT(NUM)*100.
          WRITE(6,*) 'PERCENTAGE OF COUNT OCCURRING DURING GREEN PHASE = '
     &               ,PERGRN
C
          DO 300 I=1,KOUNT
            NEWTIME(I)=NEWTIME(I)/3600.
            WRITE(6,*) NEWTIME(I),I
            WRITE(2,10) NEWTIME(I),I
  300     CONTINUE
C
  10      FORMAT(1X,F10.7,2X,I5)
C
          STOP
          END

          SUBROUTINE OPEN

          CHARACTER*12 FNO
          CHARACTER*12 FNI
          CHARACTER*11 FNGP
          CHARACTER FILENAME(8)

          WRITE(6,*) 'ENTER THE 8 DIGIT NUMERICAL FILENAME: '
          READ(5,225) (FILENAME(J),J=1,8)
  225     FORMAT(8A1)

          FNI=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
     &      FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.GPI'

          FNO=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
     &      FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.GPO'

          FNGP=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
     &      FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.GP'

          WRITE(6,230) FNI
          WRITE(6,230) FNO
  230     FORMAT(1X,20A)

          OPEN(1,FILE=FNI,STATUS='OLD')
          OPEN(2,FILE=FNO,STATUS='OLD')
          OPEN(3,FILE=FNGP,STATUS='OLD')

          RETURN

          END
```

K.8 OCC.FOR

```
C********************************************
C*   THIS PROGRAM DOES ARRAY MANIPULATION     *
C*   AND COMPUTES OCCUPANCY VALUES FOR A      *
C*   USER-DEFINED TIME INTERVAL               *
C********************************************
C
        INTEGER TIME
C
        DIMENSION TIME(9000,4), PRES(9000), DECTIME(9000),
     &   SAMPLE(9000), SUM(9000), HPRES(9000), OCC(9000),
     &   SEC(9000)
C
        CALL OPEN
C
C****INITIALIZE COUNTER TO DETERMINE # OF ROWS****
C
        KOUNT=0
        FACTOR=0.0
C
C****READ IN ARRAY VALUES FROM THE PARADOX DATA****
C
  100   KOUNT=KOUNT+1
        READ(1,*,END=999) (TIME(KOUNT,J),J=1,4), PRES(KOUNT)
        HPRES(KOUNT)=PRES(KOUNT)/3.6E9
        FACTOR=PRES(KOUNT)+FACTOR
        GO TO 100
C
  999   KOUNT=KOUNT-1
        AVEPRES=FACTOR/KOUNT
C
C****COMPUTE DECIMAL TIME FROM THE FOUR TIME FIELDS****
C
        DO 150 I=1,KOUNT
          DECTIME(I)=TIME(I,1)+(TIME(I,2)/60.)+(TIME(I,3)/3600.)
     &              +(TIME(I,4)/3600000.)
  150   CONTINUE
C
C****SOLICIT INPUT FOR DESIRED OCCUPANCY TIME INTERVAL****
C
        WRITE(6,15)
  15    FORMAT(1X,'ENTER THE DESIRED OCCUPANCY TIME INTERVAL (MINS) ')
        READ(5,*) DELTAM
        WRITE(6,16) DELTAM
  16    FORMAT(1X,'DELTA M = ',F6.3,1X,'MINUTES')
        HDELT=DELTAM/60.
        WRITE(6,*)
C
C****SET UP SAMPLING INTERVAL AND OCCUPANCY ARRAY****
C
        XHOUR1=TIME(1,1)
        XMIN1=TIME(1,2)
        XHOUR2=TIME(KOUNT,1)
        XMIN2=TIME(KOUNT,2)
C
        START=XHOUR1+XMIN1/60.
        END=XHOUR2+XMIN2/60.
        INUM=((END-START)/HDELT)+1
C
        WRITE(6,*) 'START = ',START,'  END = ',END,'  INUM = ',INUM
        WRITE(6,*)
```

```
C
        DO 200 K=1,INUM
          SAMPLE(K)=START+(K-1)*HDELT
          SUM(K)=0.0
  200   CONTINUE
C
C****SUM UP THE PRESENCE TIMES FOR EACH SAMPLING PERIOD****
C
        DO 250 I=1,INUM
          DO 260 J=1,KOUNT
            IF(DECTIME(J).LE.SAMPLE(I)) THEN
              GO TO 260
            ELSE
              IF((DECTIME(J).GT.SAMPLE(I)).AND.(DECTIME(J)-HPRES(J).LT.
     &          SAMPLE(I))) THEN
                  SUM(I)=SUM(I)+DECTIME(J)-SAMPLE(I)
              ELSE
                IF(((DECTIME(J)-HPRES(J)).GE.SAMPLE(I)).AND.(DECTIME(J)
     &          .LE.SAMPLE(I)+HDELT)) THEN
                    SUM(I)=SUM(I)+HPRES(J)
                ELSE
                  IF(((DECTIME(J).GT.(SAMPLE(I)+HDELT)).AND.
     &            ((DECTIME(J)-HPRES(J)).LT.(SAMPLE(I)+HDELT)))) THEN
                      SUM(I)=SUM(I)+(HPRES(J)-DECTIME(J)+SAMPLE(I)+
     &                HDELT)
                  ELSE
                    IF(((DECTIME(J)-HPRES(J)).LT.(SAMPLE(I))).AND.
     &                (DECTIME(J).GT.(SAMPLE(I)+HDELT))) THEN
                        SUM(I)=SUM(I)+HDELT
                    ELSE
                      GO TO 250
                    ENDIF
                  ENDIF
                ENDIF
              ENDIF
            ENDIF
  260     CONTINUE
  250   CONTINUE
C
C****COMPUTE OCCUPANCIES AND WRITE OUTPUTS****
C
        DO 265 I=1,INUM
          OCC(I)=SUM(I)*100/HDELT
          SEC(I)=SUM(I)*3600.
  265   CONTINUE

        WRITE(6,17)
        WRITE(6,18)
        WRITE(6,21)
  17    FORMAT(1X,1X,'INTRVL',1X,'SAMPLE',4X,'INTRVL',5X,'INTRVL')
  18    FORMAT(1X,3X,'NUM',3X,'TIME',1X,2(3X,'PRESENCE'),4X,'OCC')
  21    FORMAT(1X,9X,'(HRS)',5X,'(HRS)',6X,'(SECS)',4X,'(%)')

        DO 300 I=2,INUM-1
          WRITE(6,19) I,SAMPLE(I),SUM(I),SEC(I),OCC(I)
          WRITE(2,22) SAMPLE(I),OCC(I)
  300   CONTINUE
        WRITE(6,*) 'AVERAGE PRESENCE IN MICROSECONDS = ',AVEPRES

  19    FORMAT(1X,I5,2X,F7.4,2X,E10.4,2X,F7.3,2X,F7.3)
```

```
22      FORMAT(1X,F7.4,2X,F7.3)

        STOP
        END

        SUBROUTINE OPEN

        CHARACTER*12 FNO
        CHARACTER*11 FNI
        CHARACTER FILENAME(8)

        WRITE(6,*) 'ENTER THE 8 DIGIT NUMERICAL FILENAME: '
        READ(5,225) (FILENAME(J),J=1,8)
225     FORMAT(8A1)

        FNI=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
     &    FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.IN'

        FNO=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
     &    FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.OUT'

        WRITE(6,230) FNI
        WRITE(6,230) FNO
230     FORMAT(1X,20A)

        OPEN(1,FILE=FNI,STATUS='OLD')
        OPEN(2,FILE=FNO,STATUS='OLD')

        RETURN

        END
```

K.9 SVF.FOR

```
C*********************************************
C*   THIS PROGRAM COMPUTES FLOW RATES AND AVERAGE *
C*   SPEEDS FOR A USER-DEFINED SAMPLING TIME      *
C*********************************************
C
        INTEGER TIME
C
        DIMENSION TIME(9000,4), SPEED(9000), DECTIME(9000),
     &    SAMPLE(9000), SPDSUM(9000), ICOUNT(9000), AVESPD(9000),
     &    FLOW(9000)
C
        CALL OPEN
C
C****INITIALIZE COUNTER TO DETERMINE # OF ROWS****
C
        KOUNT=0
C
C****READ IN ARRAY VALUES FROM THE PARADOX DATA****
C
  100   KOUNT=KOUNT+1
        READ(1,*,END=999) (TIME(KOUNT,J),J=1,4), SPEED(KOUNT)
        GO TO 100
C
  999   KOUNT=KOUNT-1
C
C****COMPUTE DECIMAL TIME FROM THE FOUR TIME FIELDS****
C
        DO 150 I=1,KOUNT
          DECTIME(I)=TIME(I,1)+(TIME(I,2)/60.)+(TIME(I,3)/3600.)
     &               +(TIME(I,4)/3600000.)
  150   CONTINUE
C
C****SOLICIT INPUT FOR DESIRED OCCUPANCY TIME INTERVAL****
C
        WRITE (6,*)
        WRITE(6,15)
  15    FORMAT(1X,'ENTER THE DESIRED SAMPLING TIME INTERVAL (MINS) ')
        READ(5,*) DELTAM
        WRITE(6,16) DELTAM
  16    FORMAT(1X,'DELTA M = ',F6.3,1X,'MINUTES')
        HDELT=DELTAM/60.
        WRITE(6,*)
C
C****SET UP SAMPLING INTERVAL****
C
        XHOUR1=TIME(1,1)
        XMIN1=TIME(1,2)
        XHOUR2=TIME(KOUNT,1)
        XMIN2=TIME(KOUNT,2)
C
        START=XHOUR1+XMIN1/60.
        END=XHOUR2+XMIN2/60.
        INUM=((END-START)/HDELT)+1
C
        WRITE(6,*) 'START = ',START,'  END = ',END,'  INUM = ',INUM
        WRITE(6,*)
C
        DO 200 K=1,INUM
          SAMPLE(K)=START+(K-1)*HDELT
  200   CONTINUE
```

```
C
C****COMPUTE AVERAGE SPEEDS AND FLOW RATES****
C
        DO 250 I=1,INUM
          DO 260 J=1,KOUNT
            IF(DECTIME(J).LE.SAMPLE(I)) THEN
              GO TO 260
            ELSE
              IF((DECTIME(J).GT.SAMPLE(I)).AND.(DECTIME(J).LE.
     &          SAMPLE(I)+HDELT)) THEN
                  SPDSUM(I)=SPDSUM(I)+SPEED(J)
                  ICOUNT(I)=ICOUNT(I)+1
              ELSE
                GO TO 250
              ENDIF
            ENDIF
  260     CONTINUE
  250   CONTINUE
C
        DO 265 I=1,INUM
          AVESPD(I)=SPDSUM(I)/ICOUNT(I)
          FLOW(I)=(FLOAT(ICOUNT(I)))/HDELT
  265   CONTINUE

        WRITE(6,17)
        WRITE(6,18)
        WRITE(6,21)
  17    FORMAT(1X,1X,'INTRVL',1X,'SAMPLE',2X,'INTRVL',2X,'FLOW',5X,
     &    'AVG')
  18    FORMAT(1X,3X,'NUM',3X,'TIME',3X,'COUNT',3X,'RATE',4X,'SPEED')
  21    FORMAT(1X,9X,'(HRS)',8X,'(VEH/HR)',2X,'(MPH)')

        DO 300 I=2,INUM-1
          WRITE(6,19) I,SAMPLE(I),ICOUNT(I),FLOW(I),AVESPD(I)
          WRITE(2,19) I,SAMPLE(I),ICOUNT(I),FLOW(I),AVESPD(I)
  300   CONTINUE

  19    FORMAT(1X,I5,2X,F7.4,2X,I4,2X,F7.2,2X,F7.3)

        STOP
        END

        SUBROUTINE OPEN

        CHARACTER*12 FNO
        CHARACTER*12 FNI
        CHARACTER FILENAME(8)

        WRITE(6,*) 'ENTER THE 8 DIGIT NUMERICAL FILENAME: '
        READ(5,225) (FILENAME(J),J=1,8)
  225   FORMAT(8A1)

        FNI=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
     &    FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.SFI'

        FNO=FILENAME(1)//FILENAME(2)//FILENAME(3)//FILENAME(4)//
     &    FILENAME(5)//FILENAME(6)//FILENAME(7)//FILENAME(8)//'.SFO'

        WRITE(6,230) FNI
        WRITE(6,230) FNO
```