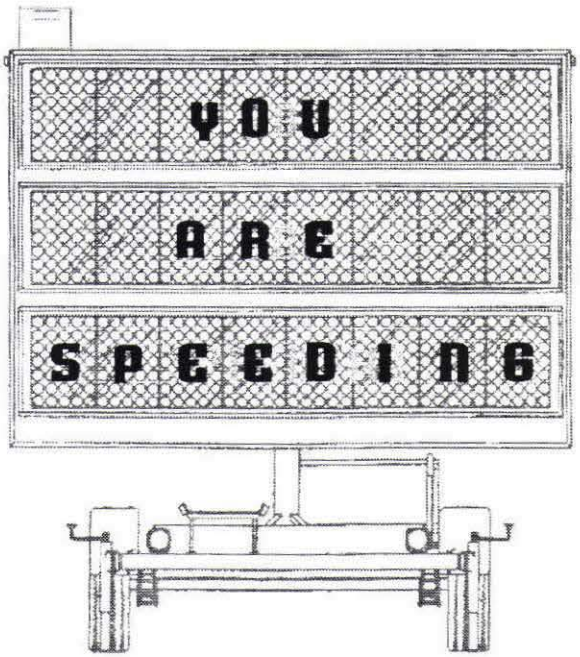
SD95-10-F

SD Department of Transportation
Office of Research



Use of Speed Monitoring and Communications Display for Traffic Control

Study SD 95-10
Final Report

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Jon Becker ..... Office of Research
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An executive summary is located on page 1 of this report.

16. Abstract

The objective of this research was to: 1) identify or develop a speed monitoring display suitable for use in SDDOT interstate highway work zones, and 2) evaluate the display's effectiveness in reducing speeds in interstate work zones. A review of the literature and current practice was conducted to identify product availability and other state DOT's use.

Speed monitoring display alternatives were identified and evaluated according to essential requirements and project evaluation criteria. The SDDOT selected a lidar laser radar device with a changeable message sign (CMS) to be tested. The selected device was installed and field tested. The before and after field data were analyzed to determine the effectiveness of the speed monitoring display in reducing speeds. The speed monitoring display was effective in reducing speeds higher than the lidar laser device setting of 70 mph. However, average travel speeds were not reduced.

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EXECUTIVE SUMMARY

Introduction

The overall purpose of this SDDOT research was to improve traffic safety in construction work zones by reducing vehicle travel speeds. The research is a follow-up to SDDOT 92-10 project which looked at various traffic safety measures for work zones. This project identified, developed, and evaluated a speed monitoring display for interstate work zones.

Contacts and Information

Two important research project items were: 1) to gain sound understanding of current knowledge regarding speed monitoring and communication displays, and 2) to learn of the working experiences with these types of devices. These two items were developed through professional and technical contacts and a product literature search regarding speed monitoring and communication displays.

Candidate Alternatives

The candidate display alternatives were evaluated according to essential requirements and detailed project criteria for an interstate work zone application. The detailed criteria included: Structure and Power Source, Communication Features, Operational Ease, and Cost Effectiveness. Based on the alternative evaluation, the SDDOT selected a lidar laser radar unit with a changeable message sign (CMS) to be field tested.

Display Operation

The laser/CMS display was equipped to measure the speeds of on-coming vehicles. If a speed threshold was reached, a signal was sent to the CMS which would then display a special message to the on-coming vehicles. The CMS's default message was: "RIGHT LANE CLOSED, KEEP LEFT" with advancing arrows right to left below the word text. The CMS message when activated by the lidar laser device was "YOU ARE SPEEDING, SLOW DOWN NOW".

Field Study

A field test was conducted to evaluate whether this device would reduce speed of traffic approaching the work zone. The work zone selected was a pavement joint repair project of short-term duration of three to five days. The field test used a laser speed threshold of 70 mph (113 kph) which activated the special CMS message. This 70 mph (113 kph) threshold was activated for approximately 20 percent of the approaching vehicles.

Findings

The analyses indicated a ten percent reduction in the percentage of vehicles traveling greater than 70 mph (113 kph) Average speeds decrease by 0 to 2 mph (3 kph) and the 85th percentile speeds decreased by 1 to 4 mph (6 kph). Also, it should be noted that the average speeds were not reduced to the 45 mph advisory speed. Statistical analyses indicated that the difference in the before and after average speeds were not significant, but the 85th percentile speed differences were significant. Overall, a reduction in speeds greater than 70 mph (113 kph) was observed, thus providing added safety to the work zone.

Recommendations

The research recommended that further study was needed to gauge the effectiveness of the display and its ability to reduce the average speeds. Also, the display was recommended to be tested in a long-term construction work zone. Finally, additional study was recommended in different environments such as non-freeway conditions and various posted speed limits.

PURPOSE, OBJECTIVES, AND RESEARCH PLAN

Purpose and Background

Principal purpose pertains to safety in interstate highway work zones

The fundamental purpose to which this research project is directed involves safety of workers and the traveling public in highway work zones. As was documented in the final report for Study SD 92-10, "Work Zone Safety Device Evaluation," (1) the rate and severity of traffic accidents in highway work zones are significantly higher than those on normal roadway sections. Study SD 92-10 involved identification and field testing of a variety of measures to improve work zone safety. One of the measures evaluated was a speed monitoring display. The test that was performed regarding the speed monitoring display indicated this device has the potential to reduce traffic speeds and thereby improve work zone safety. However, this test also revealed several issues regarding the design of the display and its installation at the work zone site. Upon review of the procedures and results for this previously described study, SDDOT panel members identified the following three particular issues:

Three issues with speed display study in previous project SD 92-10

- The display was not sufficiently legible
- The display was placed too close to other work zone traffic control devices
- Too much information was presented in the display

The speed reduction results achieved through the prior study have stimulated SDDOT staff to conduct this research project to further investigate the effectiveness of speed monitoring displays in improving safety in work zones. Two important parameters for this current study are:

- To select a design for the speed monitoring display and to develop an installation plan that resolves the issues with the prior project
- To select an interstate highway work zone dedicated to the study of this device

Objectives

The two overall objectives for this project were:

1) To identify or develop a speed monitoring display suitable for use in interstate highway work zones
2) To evaluate the display's effectiveness in reducing speeds in interstate work zones

Three additional objectives which this project accomplished included:

- Evaluation of the display's effectiveness in reducing the variability of traffic speeds in interstate work zones

- Interviews of engineers in adjacent states to gain understanding regarding their use of speed monitoring displays for highway work zones and other measures they have adopted in interstate work zones.

- Monitor and report findings from the "Portable Work Zone Traffic Management System" initiated by the Minnesota DOT.

Research Plan

The research plan consisted of eight tasks. Each of these tasks is summarized below:

Task 1: Initial Meeting with Project Panel

This task included an initial meeting with SDDOT Project Panel to review the work plan and to identify in a preliminary manner the criteria to be used for this research project.

Task 2: Product Literature Search, Survey, and Interviews

Three main steps accomplished under this task were: 1) a search and a review of product literature for speed monitor/communication displays, 2) a national survey of working experiences with speed monitor/communication displays, and 3) interviews with selected individuals regarding their experience with speed monitor/communication displays.

Task 3: Presented Findings and Recommended Specifications for Speed Monitor/Communication Display

This task was accomplished through a meeting with the Project Panel. This meeting focused on presenting the results of the product search, surveys, and interviews and recommending the specifications for a speed monitor/communication display to be studied.

Task 4: Purchase or Develop Speed Monitor/Communication Display

This work task developed the speed monitor/communication display in accordance with the decision, specifications, and procedures established in Task 3.

Task 5: Select Study Site and Outline Field Study Plan

This task included discussions with SDDOT staff regarding the speed monitor/communication display, selection of the interstate work zone field study site, and development of the work plan for the field study.

Task 6: Field Study and Analyses

This task included the before and after field studies in the work zone and the analyses to evaluate these before and after studies.

Task 7: Report Documentation

This task documented the entire study process and findings in a single report.

Task 8: Final Presentation

This task included a presentation to the SDDOT Research Review Board.

RESEARCH CONTACTS AND PRODUCT INFORMATION

Overview

Two important research project items were: 1) to gain sound understanding of current knowledge regarding speed monitoring and communication displays, and 2) to learn of the working experiences with these types of devices. These two items were developed through professional and technical contacts and a product literature search regarding speed monitoring and communication displays.

Contacts, Information, and Survey

Three approaches were used to gain information regarding previous studies and experiences with speed monitoring and communication displays. The three approaches included reviewing previous research studies, phone contacts with several DOTs, and an E-mail survey.

While numerous studies have been conducted to address traffic speeds in work zones, only a few recent studies have been performed regarding speed monitoring and communication displays. The previous South Dakota research study (Work Zone Safety Device Evaluation, SD 92-10), which precipitated this research work, identifies potential benefits of speed monitoring communication display use in work zones.

Virginia Study

In addition to the South Dakota experience, the Virginia Transportation Research Council completed a study documented in a September 1994 report titled "Effectiveness of Changeable Message Signs in Controlling Vehicle Speeds in Work Zones" (2). The Virginia study relates directly to and is a valuable tool for this research work. Key recommendations from this study include:

- CMS with radar unit is recommended as an effective speed control device to be used in work zones on interstate highways. In addition to reducing speeds, it is also effective in reducing speed variance, which could result in overall safer conditions in the work zone.

- This project determined that the CMS is effective in work zones for short-term applications, up to one week at a time. To assess its effectiveness for longer periods, it is recommended that a similar study be repeated as soon as possible, testing the usefulness of CMS on long-term applications and experimenting with various techniques which might expand it potential.

- Further study is also recommended to test the application of CMS in different environments -- type of highway, various reduced speed limits, number of lanes open to traffic, day or night operation, length of work zone, etc.

- Finally, the use of CMS with radar unit in conjunction with technologies such as photo-radar is recommended for future applications. This technology could be quite beneficial if the central processing unit of the CMS could be modified to accept visual information and process it quickly enough for

display. This technique would allow the message to be more personalized, and therefore more threatening, as vehicle license plate numbers could be identified and displayed along with a warning message.

Contacts with Adjacent States

The second approach came from phone contacts with other Departments of Transportation in nearby states. The states that were contacted included Iowa, Minnesota, Nebraska, and North Dakota.

Fred Walker of the Iowa DOT indicated that they use changeable message signs (CMS) in interstate work zones; however, speed reduction is not an issue. Iowa's concern and experience is that there is not a problem with excessive speeds; rather, their concern is to avoid significant speed reductions and stopping. Iowa is focused on providing advanced notice to motorists approaching a work zone of changes in traffic conditions (speed, queue, delay, etc.). Iowa is not presently using speed monitoring and communication display units.

Dan Waddle of the Nebraska DOT indicated that their methods for slowing traffic down in interstate work zones is accomplished with flaggers. They use CMS for information purposes to notify motorists of pending work zone activity (e.g. road work ahead).

Jack Olsen of the North Dakota Traffic Safety Division indicated that enforcement is their current primary method for speed reduction in work zones. Also, recent legislation has increased their minimum traffic fines for a speed violation in a work zone. Similar to Nebraska DOT, North Dakota uses CMS as an information device in work zones.

Dan Brannan of the Minnesota DOT has performed limited studies with speed monitoring and display applications. Mn/DOT has tested a radar and CMS device for a lane closure condition at two locations: a metro interstate freeway and a rural divided highway. The device was operated with radar to identify speeding vehicles, which then activated the CMS to produce alternating messages of "SLOW DOWN" and "YOUR SPEED IS ___." Comments cited from the metro interstate freeway application were:

- If vehicles were speeding, the CMS didn't change quick enough for the motorist to see entire message.
- The metro freeway had high traffic volumes and the radar had trouble locking on specific vehicles. The radar usually locked on semi-trucks, even with cars located directly in front of the truck.
- The CMS message was jumping back and forth because there was no locking feature built into the software.
- No significant speed changes were documented.
- The CMS was an expensive device to place in the field.

The rural divided highway experience was similar to the metro experience. However, the rural Mn/DOT District staff thought the device was beneficial in reducing speeds.

In addition, Dan Brannan indicated that Mn/DOT has conducted a study of two other options. The first being the standard MUTCD orange barrels and signing, which resulted in an approximate three mile per hour reduction. Second, Mn/DOT built an 8 foot by 13 foot orange and black construction sign with flashers instructing motorists to slow down. Results of this option indicated an approximate 5 to 10 mile per hour speed reduction on the interstate freeway.

Finally, Dan Brannan indicated that it is important for construction activity be present in the work zone to achieve reduced speeds.

The last contact approach was the Internet E-mail system. A short survey was developed (see Appendix) to gather information on working experiences with speed monitoring and communication display devices. This survey was sent to approximately 20 DOT representatives plus numerous other transportation professionals via the DOT LIST service based in North Dakota. To date only one response from Tom Notbohm, Wisconsin DOT, was received which indicated that they are not now using a display, but have contemplated the idea.

Smart Work Zone Traffic Management System

This Minnesota project, an ITS Operational Test, was focused on work zone traffic safety. The Smart Work Zone Traffic Management System is an integration of existing traffic management devices and innovative new technologies into a portable, wireless, user friendly system designed to provide transportation professionals with a tool to manage traffic in the construction work zone. Real time traffic images and data are gathered in the construction zone and communicated to a traffic control center. This information is reviewed and messages are sent out to signs that are located outside the work zone and in the construction area itself. The information is also placed on a worldwide web page for people who have access to on-line services.

An operational test of the Smart Work Zone system took place during the summer and fall of 1996. Preliminary results of the test have been positive and the project has achieved the goals set forth by project team members. When the final evaluation and reporting is completed, the project documentation will be transmitted to SDDOT Research staff.

Product Literature Search

The product literature search resulted in three basic types of existing products:

- Speed Message Radar Trailer
- Fixed Message Radar Unit
- Changeable Message Radar Unit

Each of the three existing product types are discussed in further detail next. Also, manufacturer's promotion brochures are provided in the Appendix.

Speed Message Radar Trailer

The speed message radar trailer is similar to the product previously tested in SD 92-10 Research Study. These trailers, made by different manufacturers, use standard radar detectors and flip-disk message boards to present a travel speed to the motorist. Typically, a posted speed limit sign is mounted on the trailer for motorists to correlate with their travel speed. These products are being used mostly as education tools by Cities and Counties to lower speeds on various roadways. In addition, the Minnesota State Patrol just recently began using this product, as an education tool, on rural two lane roadways.

The Minnesota State Patrol units have traffic counters installed in the trailer for data collection of speeds.

Kustom Signal Inc. and the MPH/Might Mover/Mitron group are two such manufacturers. These products cost approximately $9,000-12,000 each depending on the features desired.

Fixed Message Radar Unit

We found one manufacturer making fixed message radar units. This product (Speedminder 200) uses fiber optics for three, ten inch message lines such as "SLOW DOWN NOW". This message is visible at 300 to 400 feet. The message is activated when a speed threshold is reached through use of a standard radar unit. Typical power source is diesel, however, a custom solar supply has been developed by a current user. These signs can be truck, trailer, or sign bridge mounted. Prices range from $5,000-11,000, depending on the mounting location.

Changeable Message Radar Unit

Numerous changeable message sign (CMS) manufacturers have added radar units and software to their products. Three brands are ADDCO, American Signal Company, and American Electronic Sign. Brochures regarding the products from these companies are presented in the Appendix. Flip-disk conventional lamps and LED lamps technology CMS are available. The standard three line 18 inch character CMS has recently been modified to full matrix ability for one line of 53 inches, two lines of 28 inches, or the standard three lines.

Costs range from $20,000-28,000 each depending on power source and lamp types. The add on radar units and software are priced in the $2,000-3,000 range. It should be noted that these radar units can be retrofitted to existing CMS, which was accomplished in the Virginia study.

Another product recently available is the laser speed detector (see Appendix). This laser detector is not detectable by standard radar detectors and has a beam width of approximately three feet at 1000 feet. This tighter beam width allows for exact identification of specific vehicles. Costs for this laser detector are in the $4,000-5,000 range. A number of agencies are using these devices for spot speed detection, speed enforcement by police or patrol, and distance measuring devices.

DEVELOPMENT AND EVALUATION OF ALTERNATIVES

Framework

The identification of potentially viable alternatives for the speed monitoring/communication device involves a four step framework:

1) Identify the essential requirements and conduct a preliminary evaluation based on these essential requirements as a first screen of the alternatives

2) Identify detailed criteria for further evaluation of the alternatives

3) Evaluate the alternatives through input from the Project Panel and the Benshoof firm

4) Determine detailed specifications for the device based on the step three evaluation results

Three key factors which have a major influence on this framework and the alternatives evaluation are:

- The USAGE of the device for only speed monitoring and communication or for multiple purposes.
- The PLACEMENT of the device relative to its identified traffic use.
- The OPERATION of the device in the work zone depending on certain conditions and circumstances.

Four basic alternatives have been identified for further evaluation as follows:

- Speed Message Radar Trailer
- Fixed Message Radar Unit
- Changeable Message Radar Unit
- New Product Development - This fourth alternative would be to develop a new device to specifically meet the needs.

Essential Requirements

The above framework uses essential requirements to adequately identify and evaluate the potential alternatives. The essential requirements were prepared for the device based on:

- Comments received from the Project Panel at the initial meeting
- Review of previous studies, literature, and product information
- Review of pertinent traffic engineering standards for a speed warning device along a freeway

Identification of Essential Requirements

To be considered for further evaluation, the alternatives will be required to have the following essential characteristics:

- The device should be used in conjunction with other conventional signs, pavement markings and lighting.
- The device should not replace any required signing or be used for regulatory messages.
- The device should be placed laterally and vertically to the roadway similar to other traffic signing standards in the shoulder or at a location farther from the travel lanes.
- The message should become legible at 750 feet (0.23 km) in advance of the device for all traffic lanes, and that legibility should be maintained for 650 feet (0.20 km). To meet the 750 foot (0.23 km) legibility, the message characters would need to be 15 inches (375 mm) in height (50 foot distance = 1 inch of character height).
- The device should be placed so that it is visible at approximately one-half mile.
- The device should provide a maximum of three message lines.
- The entire message should be readable twice at the posted speed prior to the desire action requested by the message.
- No more than two display messages should be used in the message cycle.
- Messages should be spelled out when space permits and/or understood abbreviations could be used.
- Scrolling of messages vertically or horizontally is not acceptable.
- The device should employ proven features for the intended traffic purposes.
- The device should be able to operate in a safe manner in the intended environment.
- It should be possible for one person to setup and monitor the device.

Initial Evaluation Based on Essential Requirements

Based on the above essential requirements, the four basic alternatives were screened for their compliance. Each of the four alternatives is reviewed next.

Speed Message Radar Trailer

This alternative does not meet a number of the essential requirements. This device typically provides a regulatory speed sign which is not recommended. A constant fixed sign message such as "SLOW DOWN" could replace the regulatory speed sign, but would not be applicable to all motorists. This alternative would need significant modifications to improve its placement along the road, its visibility, and its legibility. Therefore, this alternative is recommended to be eliminated from further consideration.

Fixed Message Radar Unit

The fixed message radar unit has one major limitation in that it does not meet the 750 foot visibility requirement. The ten inch fiber optic message is only visible at 300 to 400 feet. Modifications to this alternative to increase its visibility would basically create a CMS that has a fixed message. Therefore, this alternative is recommended to be eliminated from further consideration.

Changeable Message Radar Unit

This alternative meets the above essential requirements and should be further evaluated. It should be noted that a number of options are possible for this alternative and will be further evaluated with the detailed criteria.

New Product Development

Since this product does not presently exist, this alternative could be designed to meet the above essential requirements and should be further considered.

Criteria

The above framework indicates that detailed criteria were used to adequately identify and evaluate the potential alternatives. An initial set of criteria was prepared primarily based on comments received from the Project Panel at the initial meeting. In addition, the Benshoof firm fine tuned these criteria based on their research work to date.

The two alternatives which met the essential requirements were evaluated by the Project Panel and the Benshoof firm through use of a set of four detailed criteria. These four criteria, which are discussed next, include: *Structure and Power Source, Communication Features, Operational Ease, and Cost Effectiveness.*

Structure and Power Source

The alternative devices were compared with respect to the qualities of the structure and the power source. The structure should be a portable trailer mounted with leveling and directional aiming. Also, the structure's materials and durability were included in this criterion.

The device should provide a solar power source with appropriate battery back up, recharge, and duration.

Communication Features

This criterion was to encompass all communication features, including:

- Ability of the device to convey the desired message in the appropriate lines and character height. The Virginia Research Study did a detailed analysis of four different types of messages and concluded that "YOU ARE SPEEDING, SLOW DOWN" and "HIGH SPEED, SLOW DOWN" would be the two best messages to use.
- Legibility of message in all lighting conditions such as full sun with possible reflection and night time operations with a dimming feature.
- Legible color of message text.

Alternatives which provide enhanced functions were scored higher in this category.

Operational Ease

This criterion was to evaluate the alternatives based on the two users which would be expected to operate the device. The first user would be a technical staff person capable of setting up the device's operating features (programming, selecting message, etc.) prior to implementation.

The second user would be an individual who would field place and implement the device. The device should be able to be installed and set-up by one individual.

In addition, product support from the manufacturer would be desired for initial training and on-going questions. It is expected that the manufacturer would be responsible for the computer software interfaces between the speed monitoring device and the communication display.

Cost Effectiveness

Equipment, operational, and maintenance costs were considered for each of the alternatives. Cost effectiveness was dependent on the usage for a single application or multi-purposes. The SDDOT had established a $10,000 equipment budget for this study.

Evaluation of Alternatives

Two alternatives, Changeable Message Radar Unit and New Product Development, met the essential requirements. These two alternatives were evaluated separately by the Project Panel and the Benshoof firm. The matrix (Table 1) was established for this evaluation because there are numerous possible options for the Changeable Message Radar Unit alternative. These options are as follows:

- Add a radar device to an existing SDDOT CMS
- Add a laser device to an existing SDDOT CMS

- Purchase a new standard flip-disk CMS with radar device
- Purchase a new standard flip-disk CMS with laser device
- Purchase a new L.E.D. CMS with radar device
- Purchase a new L.E.D. CMS with laser device

TABLE 1

MATRIX EVALUATION OF ALTERNATIVES

ALTERNATIVES	ESTIMATED CAPITOL COSTS	CRITERIA				
		STRUCTURE AND POWER SOURCE	COMMUNICATION FEATURES	OPERATIONAL EASE	COST EFFECTIVENESS	TOTAL
Changeable Message Radar Unit						
Add Radar to Existing CMS	$3-5,000	4	3	5	5	17
Add Laser to Existing CMS	$5-8,000	4	4	5	4	17
New Standard CMS with Radar	$24-26,000	4	3	4	3	14
New Standard CMS with Laser	$26-29,000	4	4	4	3	15
New LED CMS with Radar	$29-31,000	4	3	4	2	13
New LED CMS with Laser	$31-34,000	4	4	4	2	14
New Product Development	???	???	???	???	???	???

Each alternative was given a rating score of 1 to 5 (5 being the best) relative to the criteria description.

Findings and Recommended Specifications

As noted in Table 1, the alternatives were evaluated for each of the four criteria. No differences were discernible in the structure and power source criteria. The communication feature gave a slight nod to the laser over the radar device because of its enhanced characteristic in aiming of the laser beam. The operational ease criteria resulted in a slight advantage to the existing CMS units because SDDOT staff would not have to be trained for their use. The last criterion, cost effectiveness, varied widely due to capital cost of each alternative.

Based on the criteria evaluation and through discussions with the Project Panel, the recommended alternative chosen was adding a laser device to an existing CMS display.

Acquisition of Display

The alternative selected, laser device with existing CMS display, was chosen due to SDDOT's availability of both the laser device and the CMS display. The laser device was SDDOT's existing "Pro Laser II - Infrared Lidar System" which was previously acquired for Kustom Signals, Inc. The CMS, manufactured by ADDCO, was a solar-powered model, with control circuitry capable of interfacing with a serial data device such as the Lidar. DOT personnel consulted with ADDCO, who provided revised firmware and instructions for interfacing the two devices. The lidar laser was mounted to the CMS in an enclosure created and fabricated by SDDOT staff. Installation included bolting a mounting bracket to the CMS frame for the Lidar, and running cables from the Lidar for power and speed violation signal into the housing containing the sign controller.

FIELD STUDY AND ANALYSIS

Study Site

The before and after field studies were conducted on I-90 in McCook County between Mitchell and Sioux Falls. The work zone construction was a concrete pavement joint repair project (Project #0901-256, 0901-254, and 0901-258). This work zone construction created single lane closures in short durations of approximately three to five days. This short work zone duration resulted in the before and after study data to be collected at two different locations.

Before Study Site

The before study site was located on a straight and flat section of eastbound I-90 near mile post 353. The ADT on eastbound I-90 was approximately 4,560 vehicles per day and the posted speed limit was 75 mph (121 kph). The right lane was closed for construction as shown in Figure 1. The traffic control plan followed SDDOT standards for a lane closure on an interstate highway when control devices are left overnight or longer. The traffic road tube counters were located in advance of the "right lane closed ahead" signs, at the beginning of the lane closure taper, and at the end of the lane closure taper (see Figure 1). Also, it should be noted that the exit 353 off ramp was located between "right lane closed ahead" signs and the beginning of the taper. The bridge over I-90 for exit 353 was located at the end of the lane closure taper.

After Study Site

The after study site was located on a straight and flat section of westbound I-90 near mile post 348. Due to time limitations in the work zone construction area and in the CMS availability, the after study site was selected based on a nearby similar segment of I-90. The westbound direction of I-90 was selected because there was not an eastbound I-90 work zone which fit within the time limitations for the CMS. The ADT on westbound I-90 was approximately 5,150 vehicles per day and the posted speed limit was 75 mph (121 kph). The right lane was closed for construction as shown in Figure 2. The same traffic control plan as the before study was used for this after study location. The traffic road tube counters were located in the same three locations as designated in the before study.

The lidar/CMS display was located 500 feet (0.15 km) in advance of the "advance warning arrow panel." The lidar device was aimed 750 feet (0.23 km) in advance of the lidar/CMS display. In setting up the lidar/CMS display, the lidar was initially programmed to activate the CMS display at 62 mph (100 kph). At 62 mph (100 kph), the lidar/CMS display was constantly being activated. Therefore, the lidar setting was further raised to 70 mph (113 kph), which based on the before study data, would be activated by approximately 33 percent of the vehicles. The CMS message, when not activated was:

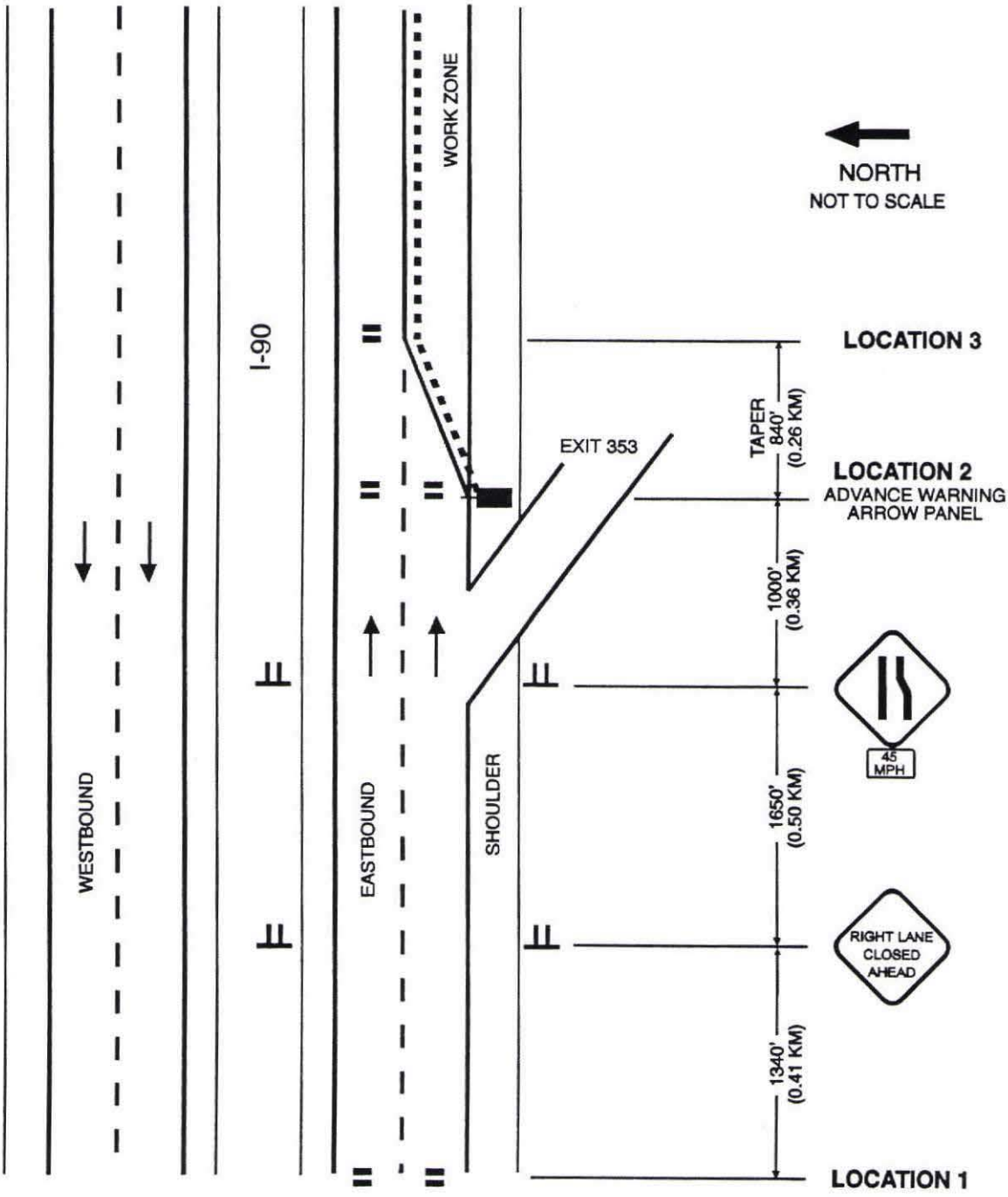
RIGHT LANE CLOSED
KEEP LEFT
← ← ←

The CMS message when activated by the lidar device was:

YOU ARE SPEEDING
SLOW DOWN NOW

FIGURE 1
BEFORE STUDY

I-90 EASTBOUND
NEAR MILEPOST 353

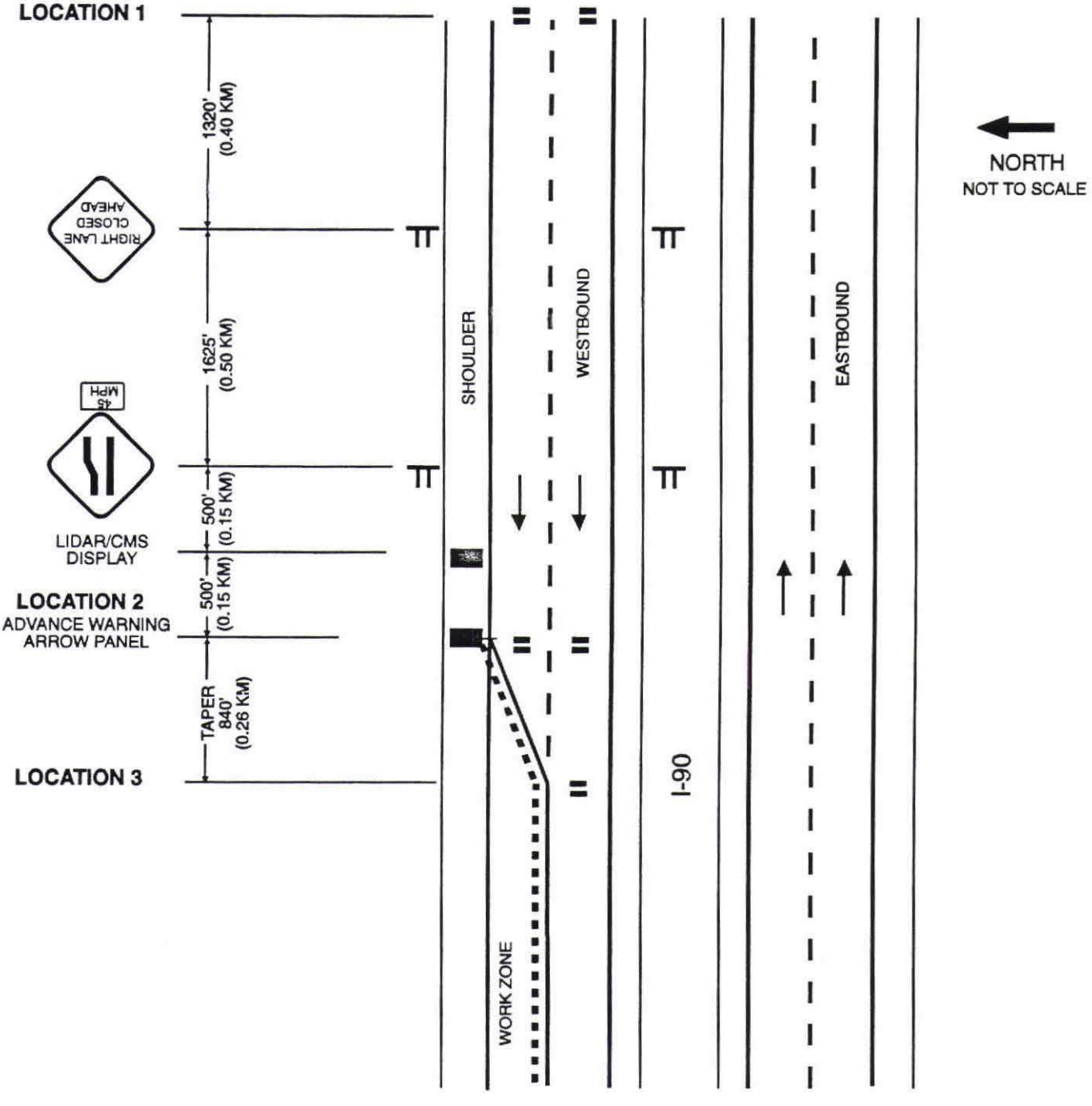


■ ■ ■ ■ REFLECTORIZED DRUMS

〓 TRAFFIC ROAD TUBE COUNTERS

FIGURE 2
AFTER STUDY

I-90 WESTBOUND
NEAR MILEPOST 348



■ ■ ■ ■ REFLECTORIZED DRUMS

〓 TRAFFIC ROAD TUBE COUNTERS

Data Collection

Data were collected before and after the lidar/CMS display was installed. The before study was conducted on Tuesday, July 16, 1996.

Due to the short-term work zone durations, the lidar/CMS display was first installed and placed in operation (message displayed) at a work zone near the after study location from Monday, July 22, 1996 through Friday, July 26, 1996. Thus, the westbound I-90 traffic was exposed to the lidar/CMS display which minimized the chances of simply observing the novelty effects of the display. Subsequently, for the after study, the lidar/CMS display was installed at the after study site on Monday, July 29, 1996 and data was collected on Tuesday, July 30, 1996.

For both the before and after studies, the data was collected for a 24 hour period. The weather on both days was sunny with a few scattered clouds. No precipitation occurred, and the pavement was dry at both study sites.

The data were collected with automatic road tube counters at three locations as shown in Figures 1 and 2. At the first and second locations, the data were collected for both travel lanes. At the third location (end of the work zone taper), data were collected for the single travel lane. The intention had been to collect speed, volume, headway, and vehicle classification data for each travel lane. Due to an equipment malfunction, the vehicle classification data and separate data for each travel lane were not collected for the before study. After discussing this issue with SDDOT staff and because of the limited time frame for using the CMS display, it was determined that the vehicle classification and travel lane data were not vital items and would not be collected for the before or after studies.

In addition, the exit 353 off ramp did not appear to influence the traffic flow operations based on observations conducted during the before study.

Data Analysis

The purpose of the lidar/CMS display was to notify motorists that they were traveling too fast for the work zone. Therefore, the display's effectiveness was measured based on the vehicle speeds approaching the work zone for the before and after studies. The speed data were then analyzed to determine if the speeds were lower after the lidar/CMS display was installed.

Speed Data

The speeds used in the analysis were "free flow" speeds, which were vehicles that were not influenced by other vehicles. Based on the 75 mph (121 kph) posted speed limit, a "free flow" vehicle existed if the headway between it and another vehicle was more than five seconds. The average speeds and the sample sizes are shown in Table 2.

Table 2 - Average Speeds Before and After Speed Monitoring Display

Location	Average Speed (kph)		Sample Size	
	Before	After	Before	After
1: 4,000 ft. in advance of taper	68.2 (110.0)	66.5 (107.3)	3,556	3,740
2: beginning of taper	63.5 (102.4)	61.9 (99.8)	2,882	3,128
3: end of taper	59.3 (95.6)	59.4 (95.8)	2,862	3,105

It should be noted in Table 2, that the sample sizes decreased from Location 1 to 3, because more vehicles were traveling with a headway which was less than five seconds. As expected, the average speeds are highest at Location 1 and lowest at Location 3. This means that the average speeds decreased as motorists approached and traveled into the work zone. At Locations 1 and 2, the after study average speeds were less than the before study. At Location 3, the before and after average speeds were approximately equal.

In addition to the average speed, three other statistics were completed: the 85th percentile speed, the 10 mph (16 kph) pace speed, and the speed percentage greater than 70 mph (113 kph). The 10 mph (16 kph) pace speed is the 10 mph (16 kph) speed range in which the largest volume of traffic is traveling. The speed percentage greater than 70 mph (113 kph) was selected because this is the speed value that the lidar device was set for in the after study. These three analyses are presented in Tables 3, 4, and 5.

Table 3 - 85th Percentile Speeds Before and After Speed Monitoring Display

Location	85th Percentile Speed (kph)	
	Before	After
1: 4,000 ft. in advance of taper	75.9 (122.4)	73.8 (119.0)
2: beginning of taper	72.8 (117.4)	68.9 (111.1)
3: end of taper	68.2 (110.0)	67.0 (108.1)

Table 4 - 10 mph (16 kph) Pace Speeds Before and After Speed Monitoring Display

Location	10 mph (16 kph) Pace Speed (kph)	
	Before	After
1: 4,000 ft. in advance of taper	66-76 (106-122)	60-70 (97-113)
2: beginning of taper	59-69 (95-111)	59-69 (95-111)
3: end of taper	53-63 (85-101)	54-64 (87-103)

Table 5 - Speed Percentage Greater Than 70 mph (113 kph) Before and After Speed Monitoring Display

Location	Speed Percentage > 70 mph	
	Before	After
1: 4,000 ft. in advance of taper	39.7	23.8
2: beginning of taper	20.0	9.9
3: end of taper	7.8	6.1

In Table 3, the 85th percentile speeds are lower in the after study when compared to the before study. In Table 4, the 10 mph pace at Location 1 decreased six mph (10 kph) from the before to the after study. At Locations 2 and 3, the 10 mph (16 kph) paces were approximately equal. In Table 5, the percentage of speeds greater than 70 mph (113 kph) was dramatically different in the before and after studies. If the lidar/CMS display had no effect on travel speeds, then it would be

expected that a comparison of the after to before study would indicate little or no changes in speeds greater than 70 mph (113 kph). However, at Location 1, the after study percentage is approximately 60 percent (23.8/39.7) less than the before study percentage. At Location 2, this after study percentage is approximately 50 percent (9.9/20.0) less than the before study percentage. This ten percent reduction (60-50) indicates that the lidar/CMS display has affected the travel speeds greater than 70 mph (113 kph).

In addition to the above data and analyses, the before and after speed data were tabulated by hour. This information is presented in the Appendix.

Analysis of Variance (ANOVA)

An analysis of variance was performed to understand the statistical significance of the differences in the before and after average and 85th percentile speeds. The null hypothesis developed for the average and 85th percentile speeds was: *The average and 85th percentile speeds were equal before and after the lidar/CMS display was installed.* This analysis used hour of day as a blocking factor and the speed at Location 1 for each hour as a covariant. Therefore, the effect of hour of day and the speed at Location 1 were removed. The results of the analysis of variance are shown in Tables 6 and 7.

Table 6 - Least-Square Mean Speeds Before and After Speed Monitoring Display

Location	Least-Square Mean Speed (kph)		p-value
	Before	After	
2: beginning of taper	62.4 (100.6)	62.4 (100.6)	0.500
3: end of taper	59.7 (96.3)	59.1 (95.3)	0.008

The Table 6 speeds are the average speeds that would result if 1) the average speeds for each hour of day and 2) the average speed at Location 1, were the same in both the before and after studies. This analysis indicated that the after mean speed at Location 2 was the same and was not statistically significant (large p-value). At Location 3, the after mean speed was lower than the before mean speed. The p-value is low, which would indicate statistical significance. However, the difference in mean speeds of 0.6 mph (1 kph) is very low.

Table 7 - Least-Square 85th Percentile Speeds Before and After Speed Monitoring Display

Location	Least-Square 85th Percentile Speed (kph)		p-value
	Before	After	
2: beginning of taper	72.7 (117.3)	69.3 (111.8)	<0.0001
3: end of taper	68.2 (110.0)	67.1 (108.2)	<0.0001

The Table 7 speeds are the 85th percentile speeds that would result if 1) 85th percentile speeds for each hour of day and 2) the 85th percentile speed at Location 1, were the same in both the before and after studies. This analysis indicated that the differences between the after 85th percentile speeds at Locations 2 and 3 were statistically significant (small p-value).

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Specific conclusions from the analyses were:

- Based on the study results, the lidar/CMS display's message was activated for approximately 20 percent of the approaching vehicles.
- It does not appear that the travel directions on I-90 during the before (westbound) and the after (eastbound) studies had any influence on the speed data collected.
- The average speeds at Locations 2 and 3 were 14 to 18 mph (23 to 29 kph) higher than the work zone's 45 mph (73 kph) advisory speed.
- A zero to 1.7 mph (0 to 2.7 kph) decrease was observed in the average speeds from the before to the after studies.
- A 1.2 to 3.9 mph (1.9 to 6.3 kph) decrease was observed in the 85th percentile speeds from the before to the after studies.
- The 10 mph (16 kph) pace speed was only different at Location 1. This indicates that most motorists, as they entered the work zone area (Location 3), were consistently driving 53 to 63 mph (85 to 101 kph).
- There was a dramatic change in the percentage of vehicles traveling greater than 70 mph (113 kph). In comparing the before and after studies at Locations 1 and 2, there was a ten percent reduction in the number of vehicles traveling greater than 70 mph (113 kph). This finding is important because the lidar/CMS display was activated when a vehicle was traveling greater than 70 mph (113 kph).
- The analysis of variance (ANOVA) indicated that the differences in the average speeds were not significant, while the 85th percentile speeds were significant, after the lidar/CMS display was installed. Thus, the analysis results indicate that the lidar/CMS display did influence the higher speed motorists.

Based on the above points, the overall conclusion is that the lidar/CMS display did result in significantly reducing the percentage of vehicles traveling greater than 70 mph (113 kph). This speed reduction would provide added safety to the work zone.

Recommendations

The recommendations for using the lidar/CMS display as a speed control measure in work zones are as follows:

- Further applications of this display should be explored to gauge its effectiveness and ability to reduce the average speeds. This can be accomplished by testing a lower speed setting for the lidar laser device which is closer to the posted advisory speed.

- The placement of the lidar/CMS display in the work zone traffic control plan appeared to provide adequate spacing between traffic control devices. If this lidar/CMS display is used where the quantity of permanent signing is much greater (i.e. urban freeway, etc.), it is recommended that the traffic control plans effectively account for this additional signing.

- The project determined that the lidar/CMS display was effective in a short-term (three to five days) work zone. To assess the display's effectiveness in long-term work zones, it is recommended that a similar study be conducted where a long-term work zone duration can be tested.

- Finally, further study is recommended to test the lidar/CMS display in different environments such as non-freeway conditions and various posted speed limits.

APPENDIX A

RESEARCH REFERENCES

(1) P.T. McCoy, J.A. Bonneson and J.A. Kollbaum, Work Zone Safety Device Evaluation, (SD 92-10-F), South Dakota Department of Transportation, December, 1993.

(2) N.J. Garber and S.T. Patel, Effectiveness of Changeable Message Signs in Controlling Vehicle Speeds in Work Zones (FHWA/VA 95-R4), Virginia Department of Transportation, September, 1994.

(3) J.S. Miller, B.L. Smith, B.R. Newman, and M.J. Demetsky, Development of Manuals for the Effective Use of Variable Message Signs (VTRC 95-R15), Virginia Department of Transportation, January, 1995.

(4) H.D. Robertson, J.E. Hummer, and D.C. Nelson, Manual of Transportation Engineering Studies, Institute of Transportation Engineers, 1994.

(5) E.C. Noel, C.L. Dudek, O.J. Pendleton and Z.A. Sabra, Speed Control Through Freeway Work Zones: Techniques Evaluation, Transportation Research Board 1163, TRB, 1987, pp. 31-42.

APPENDIX B
SURVEY QUESTIONNAIRE

August 21, 1995

E-MAIL MEMORANDUM

TO: DOT LIST
FROM: Jon Micheal Wertjes, Benshoof & Associates, Inc.
RE: Survey Questionnaire for Traffic Speed Monitoring and Communication Devices

The South Dakota Department of Transportation has hired the Benshoof firm to conduct a research study on the use of traffic speed monitoring and communication devices for traffic control in work zones. This short survey questionnaire is intended to gather information regarding current working experiences with traffic speed monitor and communication devices. Please complete the survey and return to me by _____ via the DOT LIST or E-mail (benshoof@bitstream.net) or fax. If you know of any other individuals which I should contact regarding these devices please let me know. Thanks for your assistance.

SURVEY QUESTIONS

1) Name: _____ Organization: _____

Phone & Fax Numbers: _____ E-Mail Number: _____

2) Do you currently use a speed monitor/communication device for traffic control in work zones?
Yes - go to #3 No - go to #2a

2a) Have you contemplated or discussed the possible future use of a speed monitor/communication device? If so, what type?

3) Which speed monitor/communication device(s) do you use? How often?

4) Have you modified or specially designed the speed monitor/communication device? If yes, how?

5) What are the key benefits and disadvantages in the your device's features?

6) How would you characterize your working experiences and satisfaction with the your device?

7) What characteristics have you found to be important relative to the work zone location and installation of your device?

8) Are there any other comments regarding working experiences with your speed monitor/communication device?

APPENDIX C

PRODUCT BROCHURES

KUSTOM SIGNALS, INC.

SMART

Slow them down and keep them alive with the Speed Monitoring Awareness Radar Trailer from Kustom Signals.

SMART System
Speed Monitoring Awareness Radar Trailer

"I didn't realize I was going that fast."

Where there is a speed limit, there are motorists not paying attention. Day-dreaming drivers are a danger in high-risk accident locations. School zones, construction sites and hospital grounds could use some help in promoting voluntary compliance. That's why Kustom Signals offers the SMART system: the gentle reminder for motorists to slow down.

Around-the-Clock Duty

SMART, which stands for Speed Monitoring Awareness Radar Trailer, is just that: a portable, self-contained speed display unit. Designed to promote speed awareness, SMART is towed to a site that has experienced frequent speed-related problems. After quick and easy set-up—less than 10 minutes, SMART is left on the roadside where it quietly performs its job: display the speeds of oncoming vehicles.

Mounted inside the locked, 16 gauge steel trailer is a Kustom radar unit clocking speeds. Motorists see their speeds on the 12-inch tall giant digital display from up to 100 yards away. The speed limit sign mounted above the display reminds them to pay attention and ease up on the gas pedal.

Public Acceptance

Officers have returned to the trailer to find notes taped to it reading: "Please bring this to my neighborhood." Citizens are concerned that speed-related accidents will hit too close to home. SMART brings results. Speed awareness goes up and motorists slow down. Collision rates go down. Citizens feel safer. After all, speed limit compliance *is* about safety.

Built-in Versatility

SMART can be used for public relations and to issue warnings and citations. For public relations, agencies can work with the media to advertise SMART's location. Interested motorists can drive by for a cost-free speedometer check. A positive attitude towards the posted speed limit is created.

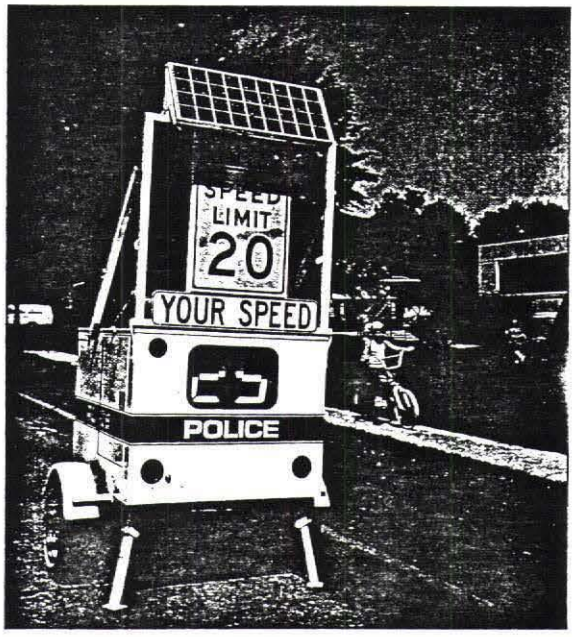
For those who ignore SMART's warning, citations can be issued to get the point across. Speed enforcement can take place from a patrol vehicle down the street, or curbside from the radar trailer. SMART comes equipped with Kustom Signals radar: either a Falcon handheld or a KR-10SP two-piece with remote control. Both are suitable for unattended public awareness campaigns. For enforcement purposes, Kustom recommends the KR-10SP because the readout is mounted just inside the access door, easily seen for safe speed monitoring. Positioned on the curb side of the trailer an officer can monitor and lock speeds, then wave violators over for their citation.

For conducting traffic surveys while promoting speed awareness, hook up the optional *Traffic Statistics Computer.* SMART can record the results of its workday, providing valuable information that can be downloaded to a personal computer for further use.

A Smart Investment

However SMART is used, studies show that the average speed tends to remain lower for a period after SMART moves to another location. In short, SMART provides a greater impact on a greater number of motorists, promoting awareness and good will. Put a SMART system on the payroll. Motorists' comments might start sounding more like this: "Thank you."

Speed Enforcement from the name you trust: Kustom Signals.



System Features

(Trailer shown with optional striping and chrome wheels.)

SOLAR CELLS continuously recharge the maintenance-free batteries. An internal controller regulates the amount of current delivered to the batteries, and prevents overcharging. A fully-charged set of batteries powers the system for 72 hours of continuous operation. A battery charger allows for recharging the batteries from a standard 110 VAC source.

FOLDING RACK supports the solar panel and provides for mounting a standard speed limit sign, which is secured with a single lockable fastener. **QUICK-RELEASE FASTENERS** secure movable parts into place for quick set-up and take-down.

TRAILER CONSTRUCTION is a welded square tubular frame and 16 gauge steel outer panels. All metalwork is finished with a durable, graffiti-resistant powder coat paint. The closed trailer is well-sealed and weatherproof.

INTERIOR provides storage for signs, equipment, and accessories. **SECURITY** is provided by a locking access door on both sides of the trailer and optional alarm.

DIGITAL READOUT displays vehicle speeds on 12" high, reflective digits, readable from a distance of 100 yards. During periods of low light, the speed readout is automatically illuminated by fluorescent lighting.

SAFETY GLASS of the type used for windshields protects the radar and display.

TOWING LIGHTS include rear brake, turn signals, and license plate. A standard connector for vehicle hookup is included.

TORSION-SPRING SUSPENSION system provides for easy towing and minimizes the effects of road shock.

LEVELING JACKS are provided on the front and rear, ensuring a firm standing on uneven terrain.

TRAILER HITCH is removable for safe storage inside the trailer, and prevents an unattended trailer from being towed away.

SMART
System Specifications

SMART Unit

Construction:	Welded square, tubular frame and 16 gauge steel outer panels. All metalwork is finished with a durable, graffiti-resistant powder coat paint.
Battery Power Supply:	Internal bank of three, heavy-duty maintenance-free batteries with a total capacity of 300 amp-hours.
110 VAC Charger:	10.0 amp output.
Solar Panel Output:	3.0 amp.
Display Size:	Two-digit display, 12" high.
Display Lighting:	Fluorescent lighting automatically turns on and off depending on ambient light.
Towing:	Requires Class I hitch with 2" ball. Tongue Weight: 125 lbs.
Physical:	Length: 8' Width: 6' Height: 10'2" with panel up. 6'5" with panel down. Weight: 1050 lbs.

Options

Axle Lock:	Prevents rolling when trailer is parked on an incline.
Tamper Alarm:	Movement-sensitive, sounds a loud, piercing siren for several minutes before resetting. Initially activated via wireless remote control with audible confirmation of alarm status.
Traffic Statistics Computer:	PC compatible computer provides hourly tally of traffic counts and speeds, and an analysis by percentile speed categories in 5-mph or 1-mph groups, for speed surveys. Includes dedicated computer, proprietary software, printer, and pneumatic tube to lay across the roadway.
Speed Sign Rack:	Stores up to six 24" x 30" speed limit signs.
Custom Striping:	Consists of accent striping with either POLICE or SHERIFF nomenclature, and a decal of the agency insignia.
Chrome Wheels:	Replaces white powder coat painted wheels.

Radar Unit

Style:	*Falcon* handheld, stationary; or *KR-10SP* two-piece, moving/stationary with remote control.
Measurement:	Available in miles or kilometers per hour.
Type:	True Doppler Radar.
Operating Frequency:	24.15 GHz (K-Band) ±100 MHz.
Operating Temperature Range:	-22°F to +140°F (-30°C to +60°C); 90% relative humidity at +99°F (+37°C), non-condensing.
Electronic Components:	100% Solid State, integrated circuits and transistors.
Power Requirements:	10.8 to 16.5 VDC, negative ground. 13.6 VDC nominal; 1.0A maximum.
Reverse Polarity Protection:	No damage will result, due to reversal of power supply.
Crystal Error Protection:	No speed is displayed or locked should either crystal fail or drift off frequency.
RFI Protection:	No speed displayed or locked when radio frequency interference is present.
Range Control:	Allows operator to select range for target acquisition.
Accuracy:	Stationary: ±1 mph.
Target Speed Range:	35 to 90 mph (56 to 145 km/h) within 10 dB sensitivity range; typ. readings from 15 to 199 mph (24 to 320 km/h).
Microwave Source:	Gunn-Effect Diode.
Power Output:	15 mW typ., 50 mW max.
Power Density:	.39 mW/cm² typ., 1.30 mW/cm² max. (measured at face of antenna).
Beam Width:	6° from main axis to half power point in any axis.
Side Lobes:	25 dB below main beam.
Receiver:	Low noise Schottky Barrier Diode (100 mW rating).
Antenna Gain:	23 dBi approximately.

In keeping with Kustom Signals' policy of continued refinement of its products, these specifications are subject to change without notice. SMART is a PATCO product distributed by Kustom Signals. Kustom Signals' warranty includes parts and labor, and warrants all components--without exception--against defects in materials and workmanship. SMART is warranted for one year, the radar is warranted for two years. Service can be performed by the Kustom Signals manufacturing facility. Lease/Purchase available. For more information, a quote, or to place an order, call toll-free: 1-800-4KUSTOM (458-7866). Patent Pending.

KUSTOM SIGNALS, INC.
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Printed in U.S.A. 7/92

RADAR SIGN SET

SPEEDMINDER 200

TRAFFIC MANAGEMENT

REDUCE SPEED USING RADAR ? YOU KNOW IT WORKS !

How ? Hitting the traffic twice - once at long range (up to a mile) and once at short range - flashing on a SLOW DOWN NOW sign.

FEATURES:

* SPEEDMINDER activates radar detectors and traffic slows down.
* SPEEDMINDER switches on 4 foot fiberoptic fixed message sign. Any message or dual alternating message available on special order.
* Day or Night operation. * Construction crew and motorist safety.
* Fast setup or take down. (portable mode)
* Variable speed settings to trigger sign at posted speeds
* Powered from vehicle battery, or 110 volt (optional)
* Reduce speeds in construction sites
* Set up in minutes at emergency site - Police or DOT use
* Portable and fixed models available. Portable model shown.
* FCC approved: Position Detection Sensor, Art. 15
* Licensed for traffic signal control. Not licensed for drone radar usage.

::::::::::::::::::::::::::

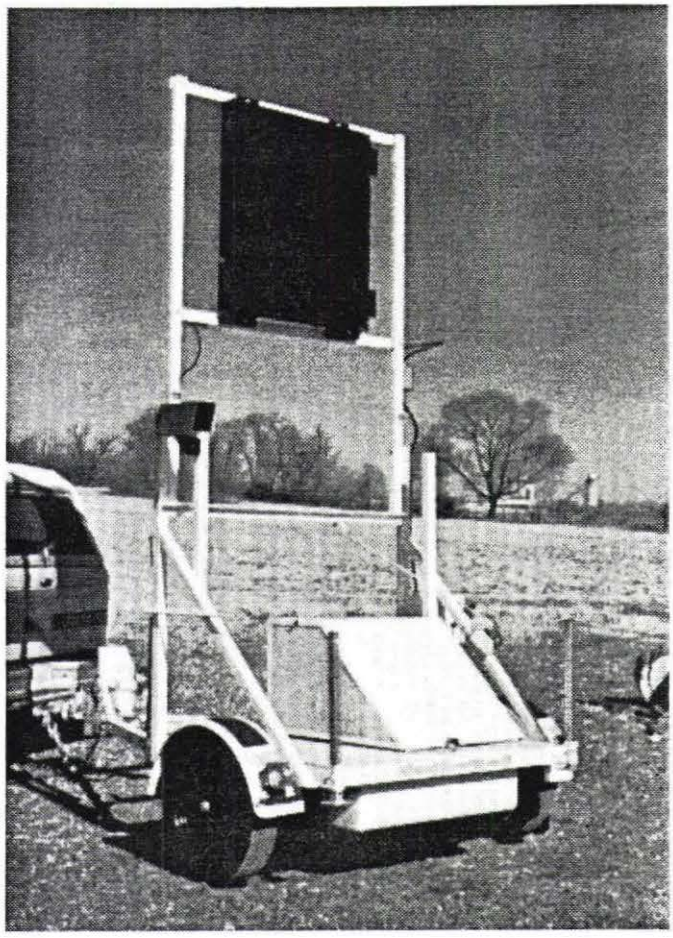
APPLICATIONS:

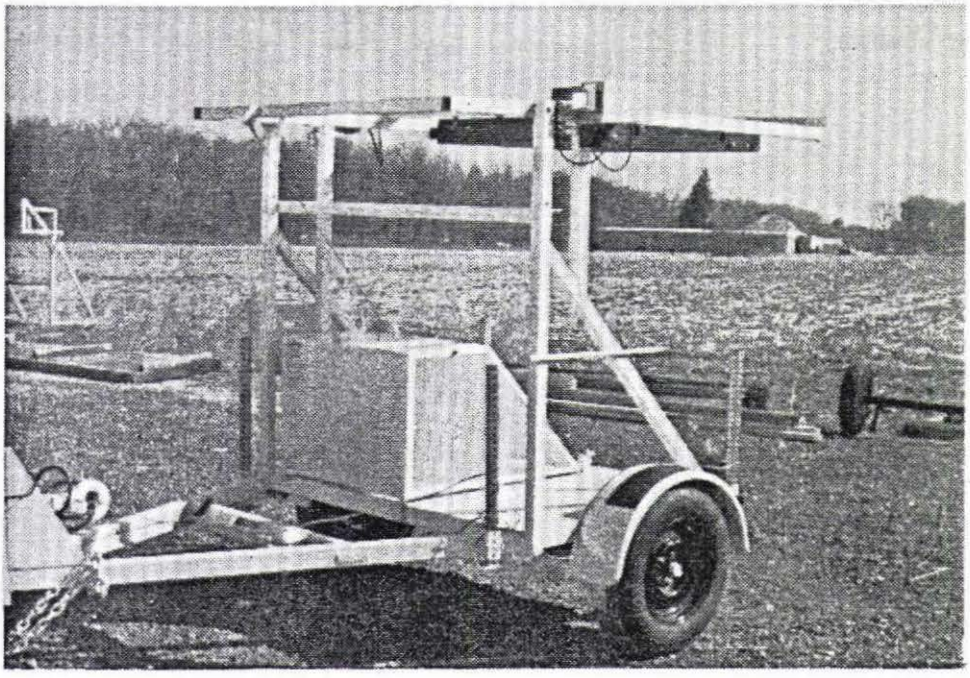
Paving, crossovers, Interstates, high ADT roads, lane change, Turnpikes, patching, painting, sweeping operations, general speed reduction, traffic emergencies, stadium traffic control, on back of crash trucks or follow on vehicles, alert sleepy truck drivers, overhead sign structures, slow moving or fixed maintenance operations, police inspection stations, lane restriction, base & guard rail repair, reduce rear end crashes, bridge maintenance. Combine it with Safe-Lite's portable radio broadcast station Model TT-200 for 2-6 mile radio broadcast extended coverage. Incident Response Team aplications - avoid secondary accidents. Truck, trailer, tripod mounted.

Literature and video/audio tapes on actual one-site driver reaction to the system used on Interstates - available on request.

SAFE-LITE SYSTEMS LTD., POB 688, Newtown, Pa. 18940
Tel: 215-968-9296 Fax: 215-579-1494

SM04250/RAA 13.2.3

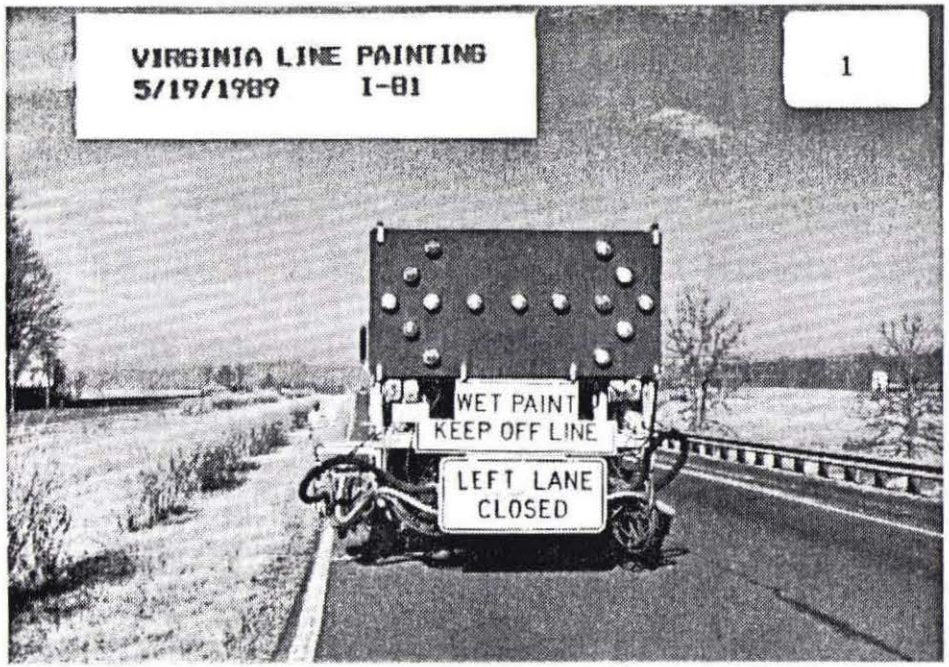




SPEEDMINDER 200 - RADAR/SIGN SET

TRAILER MOUNTED

SAFE-LITE SYSTEMS
P. O. Box 688
Newtown, PA 18940
215-968-9296


VIRGINIA LINE PAINTING
5/19/1989 I-81
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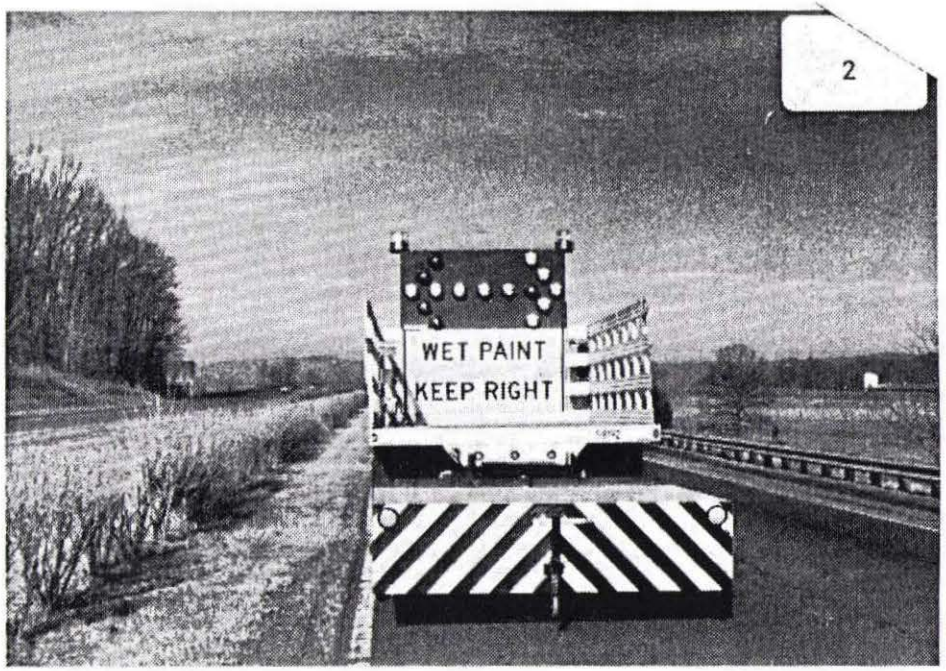
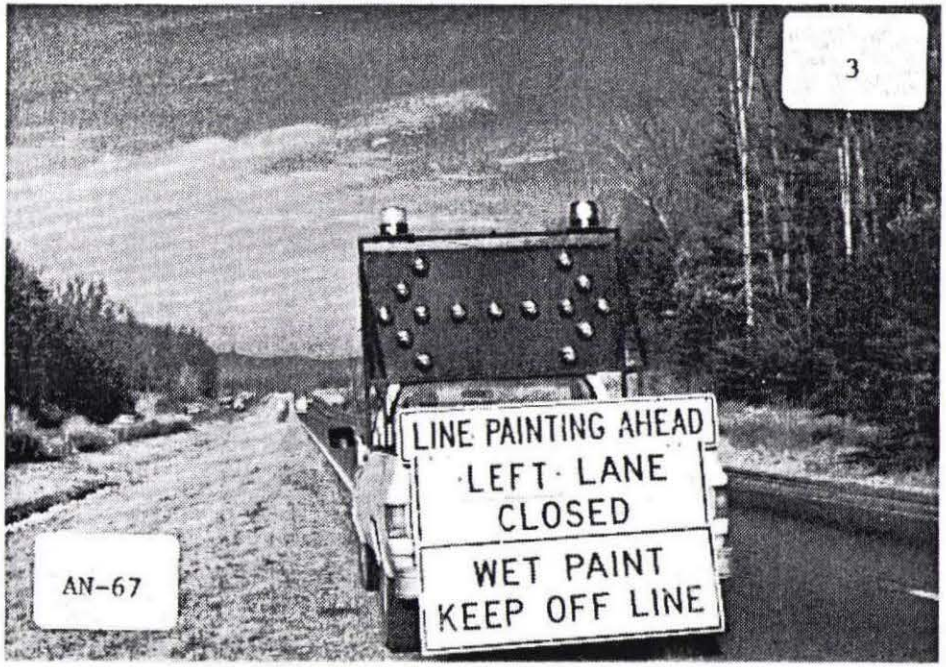
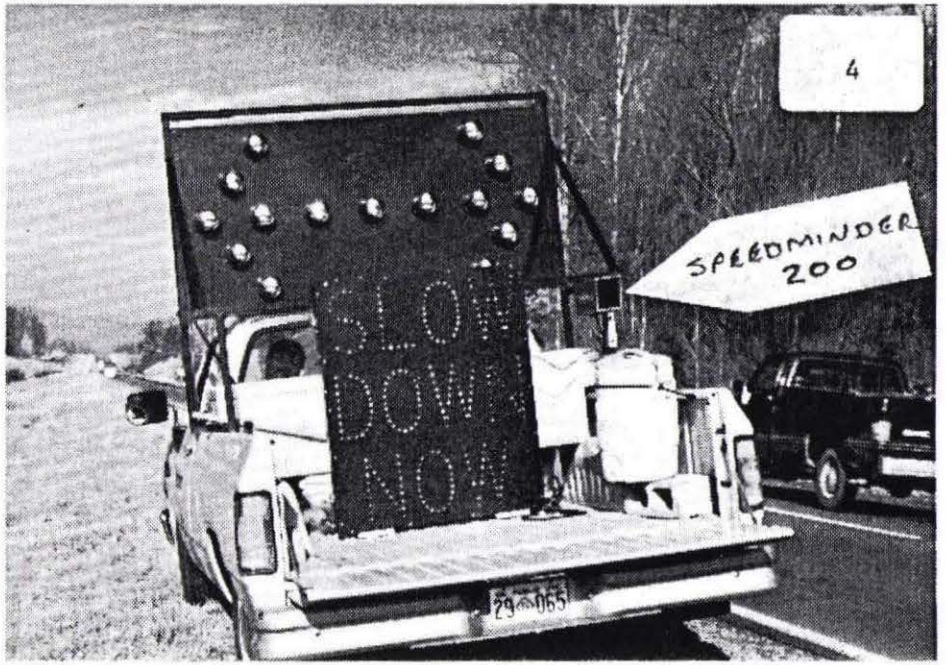
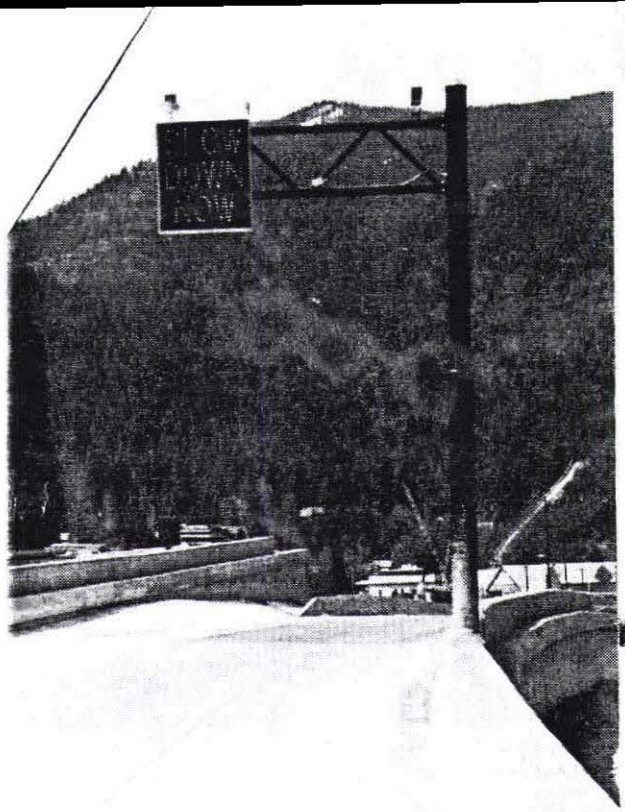
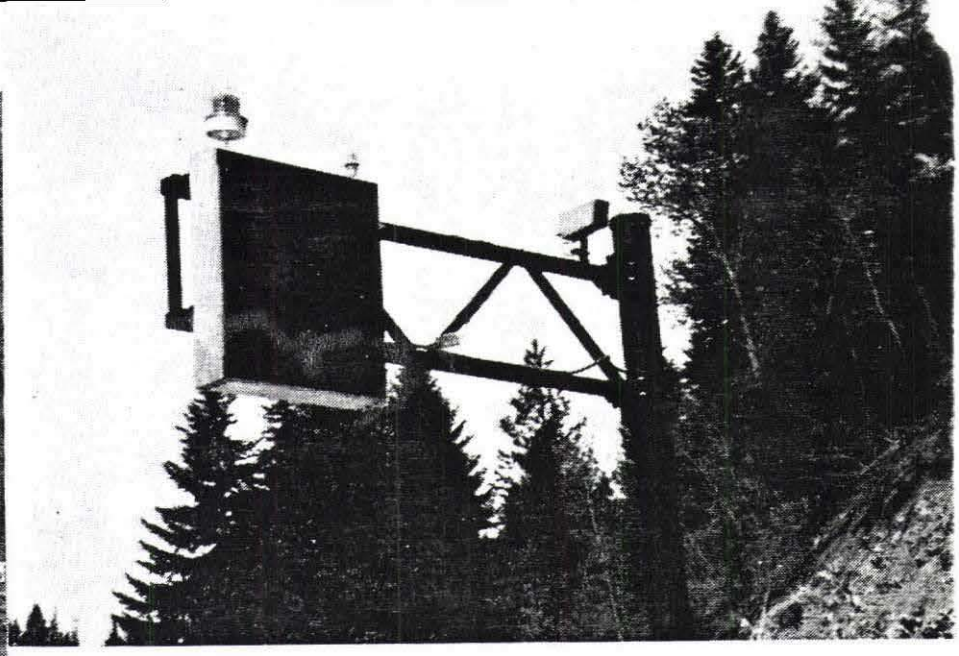
KEEP OFF LINE
LEFT LANE
CLOSED


2
WET PAINT
KEEP RIGHT


3
LINE PAINTING AHEAD
LEFT LANE
CLOSED
WET PAINT
KEEP OFF LINE
AN-67


4
SLOW
DOWN
NOW
SPEEDMINDER
200





SPEEDMINDER 200

RADAR SIGN SET

THE "SMART ROAD"
SAFE TRAFFIC MANAGEMENT
INTERACTIVE SPEED CONTROL

How ? Alert truck traffic twice - at long range (up to a mile) and at short readable range - flashing a message sign - SLOW DOWN NOW.

Two year I-90 construction project. Traffic slows from 65-75 mph to 15 mph. The Speedminder traffic alert system interacts with the drivers. The Zone of Control starts at 5 miles and ends at the flashing message sign.

* FHA Approved Funding
* Speedminder activates truckers radar detectors
* Truckers wake up - slow down and pace all traffic
* Day & Night long term weather proof operation
* Strobe feature (optional) to attract attention
* Variable speed settings to trigger message sign at any speed
* Photo cell (optional) for night dimming
* Other special messages & configurations available
* Adaptable to your existing variable message signs
* Fixed model shown. Portable mobile model available
* FCC approved position detection sensor
* Other Smart Road equipment available. Talk directly to the driver via car radio using Traffic Talker 100. Inquiries welcome

::::::::::::::::::::::::::

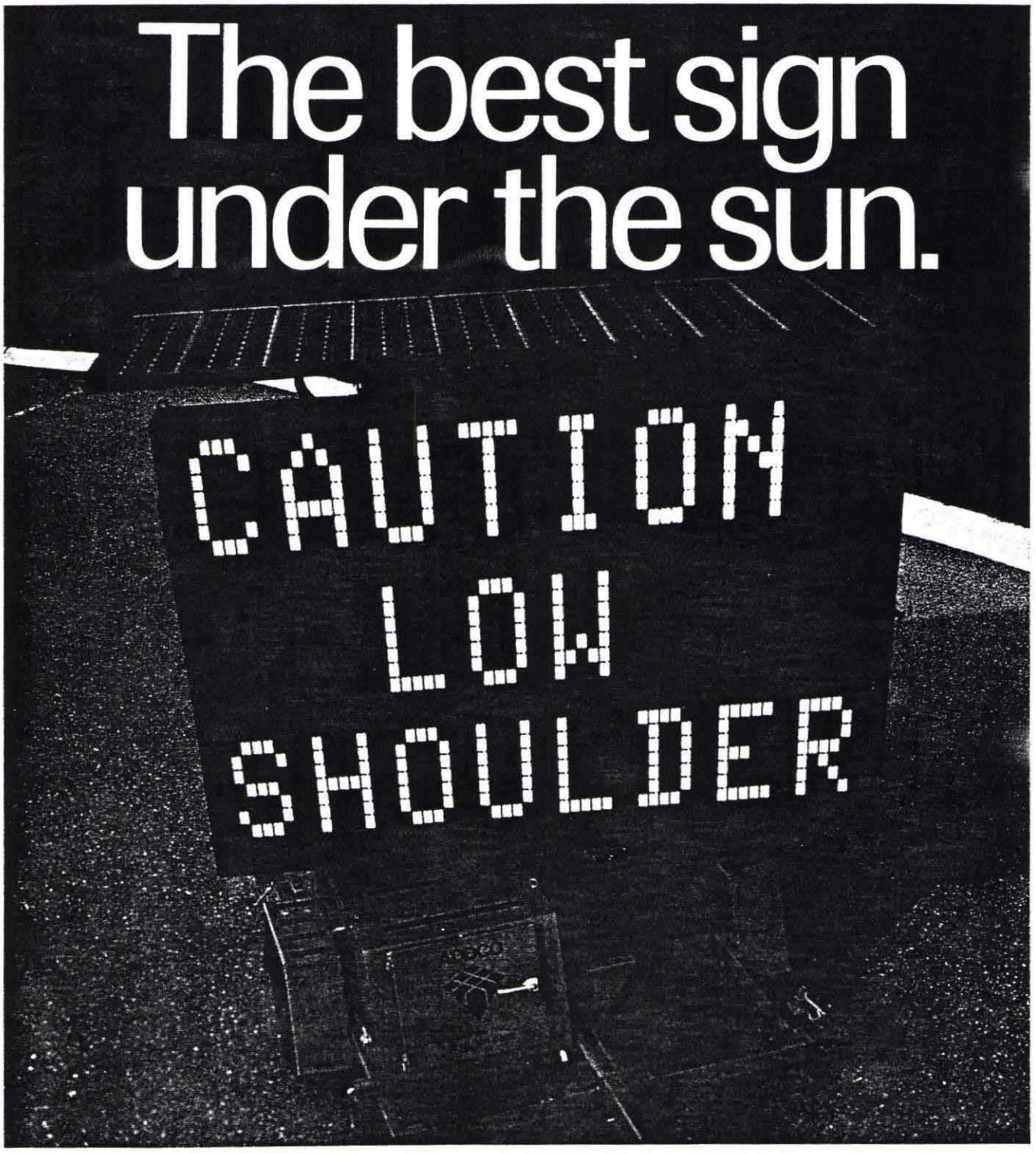
GENERAL SPEEDMINDER APPLICATIONS:

Paving, crossovers, Interstates, high ADT roads, lane change, turnpikes, patching, painting, general speed reduction, traffic emergencies, on back of crash trucks, trailer mounting, sleepy truck drivers, signal control, traffic counter, railroads, overhead sign or temporary structures, slow moving or fixed maintenance operations, lane restriction, base repair, reduce rear end crashes, bridge maintenance. Video tapes on construction and maintenance projects available on loan.

SAFE-LITE SYSTEMS LTD., 1050 Eagle Rd., Newtown, Pa. 18940
215-968-9296

SM06149/RAB 13.2.3

The best sign under the sun.



We took our best sign and topped it—with a solar panel. The result is the solar-powered DH1000 DOT-SIGN® from ADDCO, featuring LED-DOT™ technology.

LED-DOT combines both light emitters and fluorescent flip disks. During the day, the sign uses the fluorescent flip disks, offering the best daylight legibility and more efficiency since they require less power. During low light periods, inclement weather, or at night, the sign uses light emitting diodes, mounted to each flip disk, giving the sign superior punch. Best of all, this sign offers motorists the best legibility from any driving angle—an important safety factor built into the DH1000.

On top of all that is the solar panel, collecting the sun's free energy and storing it in batteries for efficient and environmentally sound use when needed.

With so many advantages to consider, why not call us today for complete specifications on the best sign under the sun, all backed by ADDCO's unwavering standards of quality, service and dependability.

ADDCO

ADDCO Manufacturing Co., Inc.
69 Empire Drive
St. Paul, MN 55103-1856
(612) 224-8800, Fax: (612) 224-1411

Dimensions

Overall:

Height	Sign fully raised--13' 10" Transport--9' 3"
Length	12' 7"
Width	Display 130" Transport 8'
Gross weight	3,400 lbs.

Message panel

Height	76"
Width	113"

Controller

Type	Custom microprocessor controller
Memory	64K of ROM memory and 32K of CMOS RAM.
Display	High contrast LCD 8 lines by 41 characters
Keyboard	100 key IBM/XT type keyboard designed for severe environment applications.

Messages

Standard messages	200 messages
User programmed messages	51
User-created sequences	25, 6-frame seq.
Update rate	.50 seconds
Frames/sequence	1 to 6 selectable
Sequence storage	25
Message display times	.5 to 9.9 seconds

Default message

System displays default message the user creates if the battery is low. The controller turns off the sign after loading default message to conserve battery.

Message editing options:

Includes instant time modification, giant arrow presentations, auto scroll during sign creation, instant message sequence run, selective line blink, on-screen display of line blink.

Solar panels

High efficiency single crystal silicon cells. The cells are "antireflected" coated for improved efficiency.

Solar panels are sized for continuous operation.

Weight -- 12.6 lbs each; Ten 3.05 AMP at 17.4 volts for a total of 30.5 AMPS at 17.4 volts.

Characters/visibility

Each character consists of 35 individual disks; the 35 disks are in a 7 disk high by 5 disk wide matrix.

Each disk has four high output yellow/green LEDs.

Each character is 18 inches high and is legible from 900 feet. At night, there is an increase in the 900-foot legibility.

A photocell controls the brightness of the LED display panel. The photocell provides for automatic dimming (10 to 100 percent).

Power consumption

The Dot-Sign uses 98 percent less electrical power than a conventional lamp matrix board.

During daylight operation, the sign only uses power when flipping disks. During night and low light conditions, the LEDs operate in conjunction with the flip disks to maximize visibility while minimizing battery power.

Less power usage means fewer batteries and more efficient use of solar panels.

Batteries

Standard configuration: 16 each, 6 volt DC, 217 Amp-hour batteries wired to provide 12 volts.

Batteries mounted in easily removable boxes with lifting eyes for ease of maintenance.

Optional configurations available to allow for 100 percent solar operation, regardless of geographic location.

Mounting and Transporting Equipment

Material: ASTM A500 (B) UNS KO 2" x 4" x 3/16" rectangular structural tubing.

Hitch: 6,000 lb. GVWR capacity with 1-7/8" and 2" multi-fit ball coupler.

Jacks: Four, 2000 lb. capacity outrigger type leveling jacks with crank type swivel.

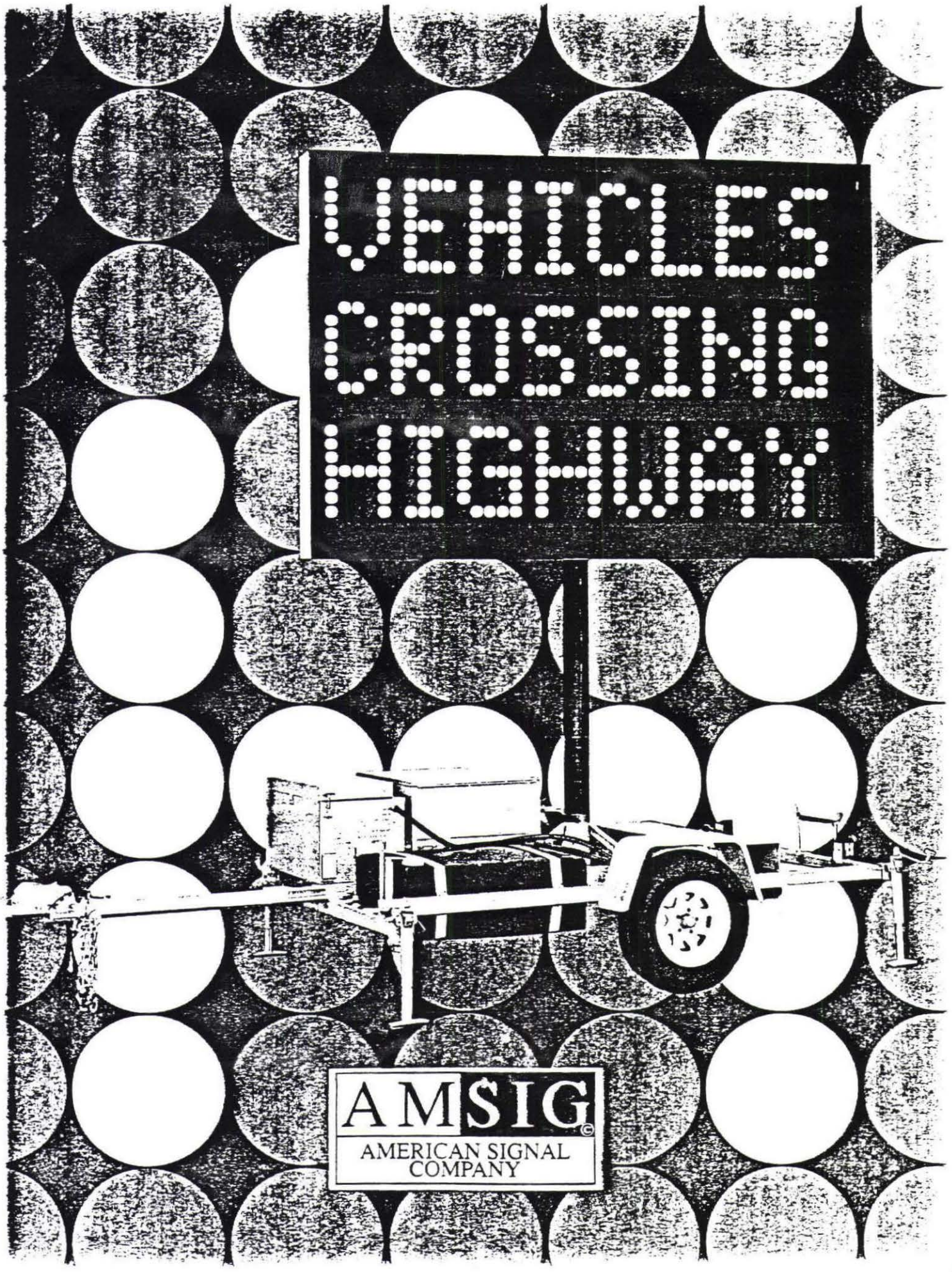
Lighting: Complete lighting to standard highway specifications.

Axle/Brakes: Single 3,500 lb. capacity drop axle.

ADDCO

Please call or write for complete specification and quote

Phone (612) 224-8800
Fax (612) 224-1411


VEHICLES
CROSSING
HIGHWAY
AMSIG
AMERICAN SIGNAL
COMPANY

THE AMERICAN SIGNAL COMPANY CMS-T

The **CMS-T300** is the finest low-cost and effective portable changeable message sign available today.

It offers excellent target value both day and night, under any weather conditions. Its BBPOD© patented power plant system is quiet, clean and efficient—minimizing both environmental air and noise pollution. The CMS-T300 is engineered for minimum refueling, programming and maintenance.

Programming is amazingly simple because the CMS-T300 employs a logical, menu-driven user prompt system that quickly and easily guides even the most inexperienced operator through sign programming—so there's no learning curve required before the sign can be put into service.

The CMS-T300 is designed and constructed of the highest quality components—in fact, a significant number of its parts are off-the-shelf and can be obtained locally when needed. The sign's specially-engineered fuel efficiency means lower consumption of both fuel and oil, resulting in a system that seldom ever needs mechanical attention.

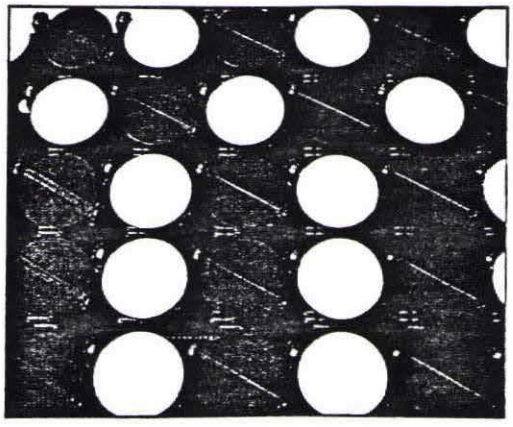
Most importantly, American Signal Company provides all the practical options you need, including radar, remote cellular and land line operation. Our signs are expandable into a complete network of units throughout a city or across the entire state.

American Signal Company designs and manufactures all-season, depen

COST-EFFECTIVE CAPABILITY

- Flip-disk technology consumes minimal power, obsoletes costly lamp systems
- One tankful (50 gal.) of diesel allows a 24-hour display of message for 90 days
- Schedule menu allows user to program sign daily, up to the year 2099.
- Sign includes 199 spaces for factory-programmed messages and 199 spaces for programmable (user-defined) messages
- Power plant is Direct Drive— requires no belts
- Multiple-piece polycarbonate sign face allows easy handling and quick, low-cost replacement
- High quality electronics perform dependably from -30°F to +160°F

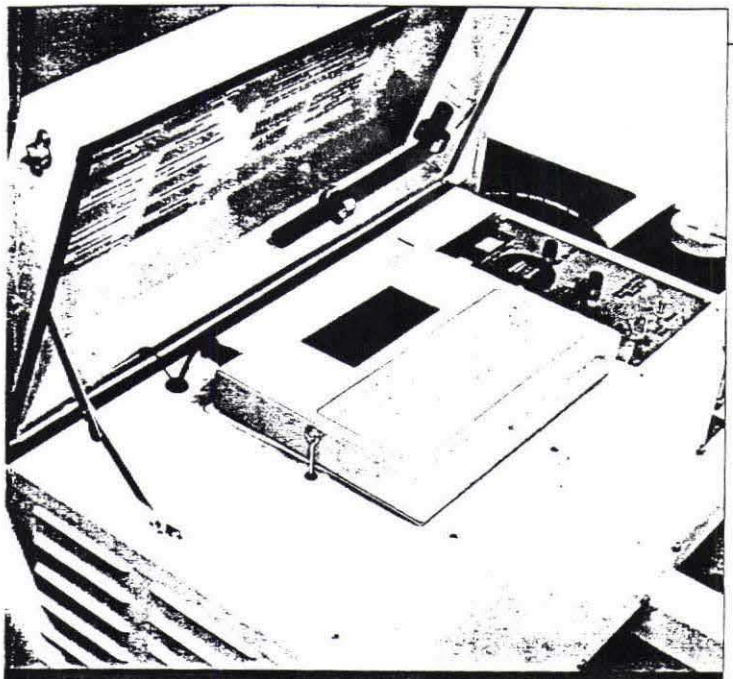
Remote operation of the CMS-T300 through a PC allows instantaneous programming as conditions change.



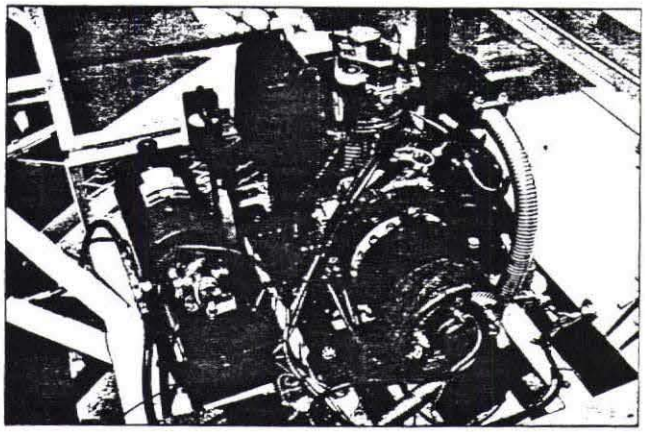
Our circular electromagnetic dots utilize 3M Scotchcal® for added road visibility and durability.

"AMSIG's ease and e —coupled with good distributor—are key to buy their signs."

300 PORTABLE CHANGEABLE MESSAGE SIGN



le fuel-saving signs that significantly reduce negative environmental impact.



The Lombardini 6LD260 is the workhorse which powers the American Signal Company CMS-T300. It's quiet, fuel-efficient, and replacement parts are readily available whenever needed.

HIGH-IMPACT GRAPHICS

- 18" characters offer highest possible legibility
- Sign dots feature brilliant color 3M Scotchcal® for high-impact visibility
- Font choices of 3x7, 4x7, 5x7 and bold 7x7 in both upper and lower case offers maximum flexibility
- Characters are automatically centered across sign face
- Automatic text centering on ALL THREE lines can be done easily
- Our software graphics program allows the largest chevron in the industry—spans ALL THREE lines if desired

SAFE OPERATION

- Engineered to withstand 80 MPH wind gusts with outriggers in place—needs no extraneous weights to keep sign stable
- Easy to trailer, with high over-the-shoulder visibility.
- Because of its rugged construction, the CMS-T300 can be installed on slopes of 6:1 and rides over curbs or other obstacles with ease ...a real plus on rehab jobs

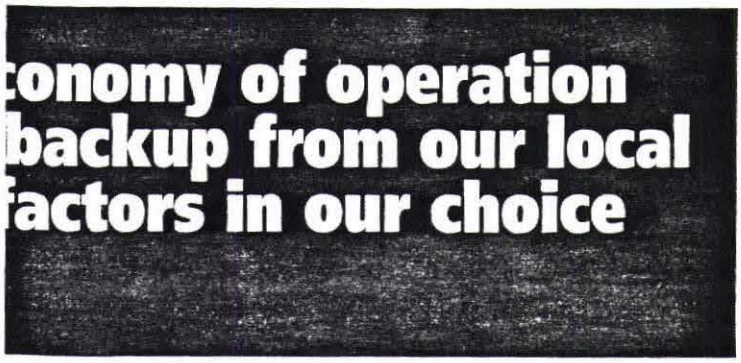
FOR THE ENVIRONMENT

These units are specifically designed to control environmental impact by minimizing the consumption of non-renewable sources of energy:

- Intermittent engine run limits engine operation to 4-5 hours per day to maintain power, resulting in less fumes
- American Signal Company signs produce less waste oil...our greater fuel efficiency reduces the engine's hours of operation, requiring fewer oil changes
- Batteries are off-the-shelf heavy duty truck-type, easily replaced when needed

MEETING YOUR SPECIAL NEEDS

- Expandable
- Radar
- Removeable sign case
- Remote operation

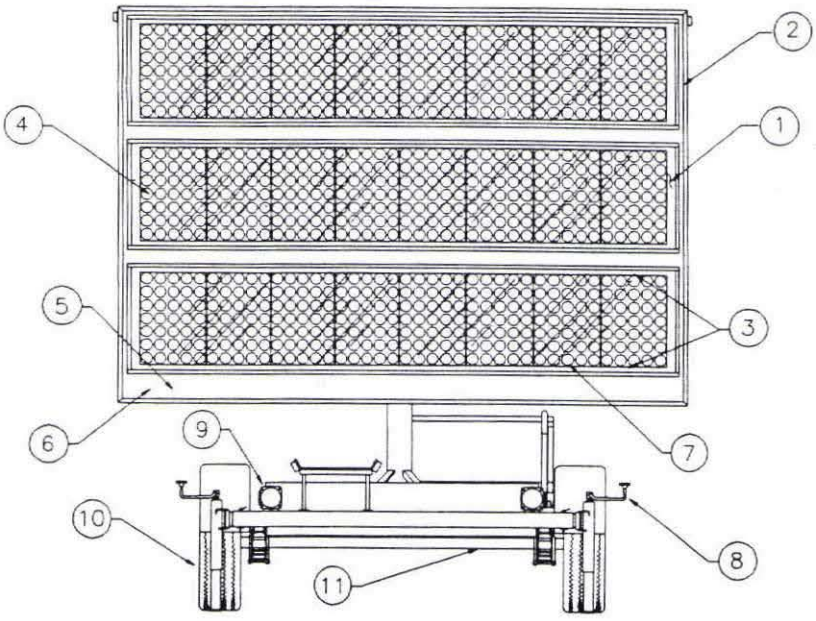


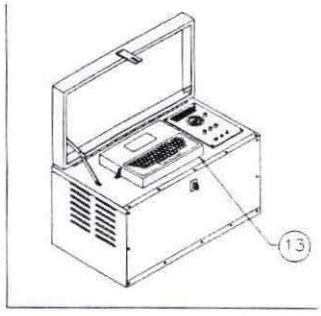
AMSIG©
AMERICAN SIGNAL COMPANY

3649 CLEARVIEW PARKWAY
ATLANTA, GA 30340
(404) 458-7278 • FAX (404) 458-1613

TECHNICAL INFORMATION

1. Polycarbonate Lens; UV Resistent, clear.
2. Vertical Lens Retainer Bar
3. 40-Watt Fluorescent Tube (White or Black)
4. AMSIG 5 x 7 Flip-Dot Panel
5. CPU Circuit Board
6. Fluorescent Lamp Ballast
7. Display Unit Dot
8. 2000 lb. Levelling Jack
9. Running, Tail, Brake, and Turn Signal Lights on 3-Wire System V 440, + V108WA or V108WR
10. P205-75 B15 4-Ply Rated Tire Mounted on 15 x 6 5-Lug on 4-1/2 Wheel & Balanced
11. 3500 LB-Rated Axle w/Surge Brake, Free Backing Hubs
12. 2" Ball Surge Brake Hitch for 3" Square Tongue
13. Removable Keyboard Controller
14. Diesel Engine
15. Alternator
16. Fuel Tank
17. Batteries
18. Power Supply





Height (raised):	162"
Height (storage):	106"
Length (Std. hitch):	196"
Width in use:	115"
Width in storage:	83"
Temp. Range:	-30 to +160 degrees F
Fuel Capacity:	50 gal.
Fuel Economy:	0.53 gal./day
Oil Sump Capacity:	3 qts.
Sign Case Height:	78"
Sign Case Width:	115"
Update Speed:	300 milliseconds
Legibility (5x7):	1000 ft.
(Bold 7x7):	1150 ft.
Flip-disk Size:	2 1/4" dia.
Flip-disk Color:	Saturn Yellow/Black
Control Console Display:	Backlit LCD
Pre-programmed Messages:	199
User-Defined Messages:	199

*Above Dimensions/Values are nominal

Patent Number 5,159,259

AMERICAN SIGNAL COMPANY • 3649 CLEARVIEW PARKWAY • ATLANTA, GA 30340
(404) 458-7278 • FAX (404) 458-1613

AMSIG®

AMERICAN SIGNAL COMPANY

3649 Clearview Parkway
Atlanta, GA 30340
(404) 458-7278 (voice)
(404) 458-1613 (fax)

9503

Radar Activated Message Control

General

The radar speed detection feature optionally installed on a CMS-T330 series sign allows for the display of the speed of a vehicle falling within a range of 300 to 600 feet travelling in excess of a preset trigger speed. The trigger speed is operator programmable from the control console in increments of one mile per hour.

Aiming

The radar detector is attached to the CMS-T330 series sign at the bottom left of the sign case. It may be field swiveled in order to optimize the detection range.

Operation

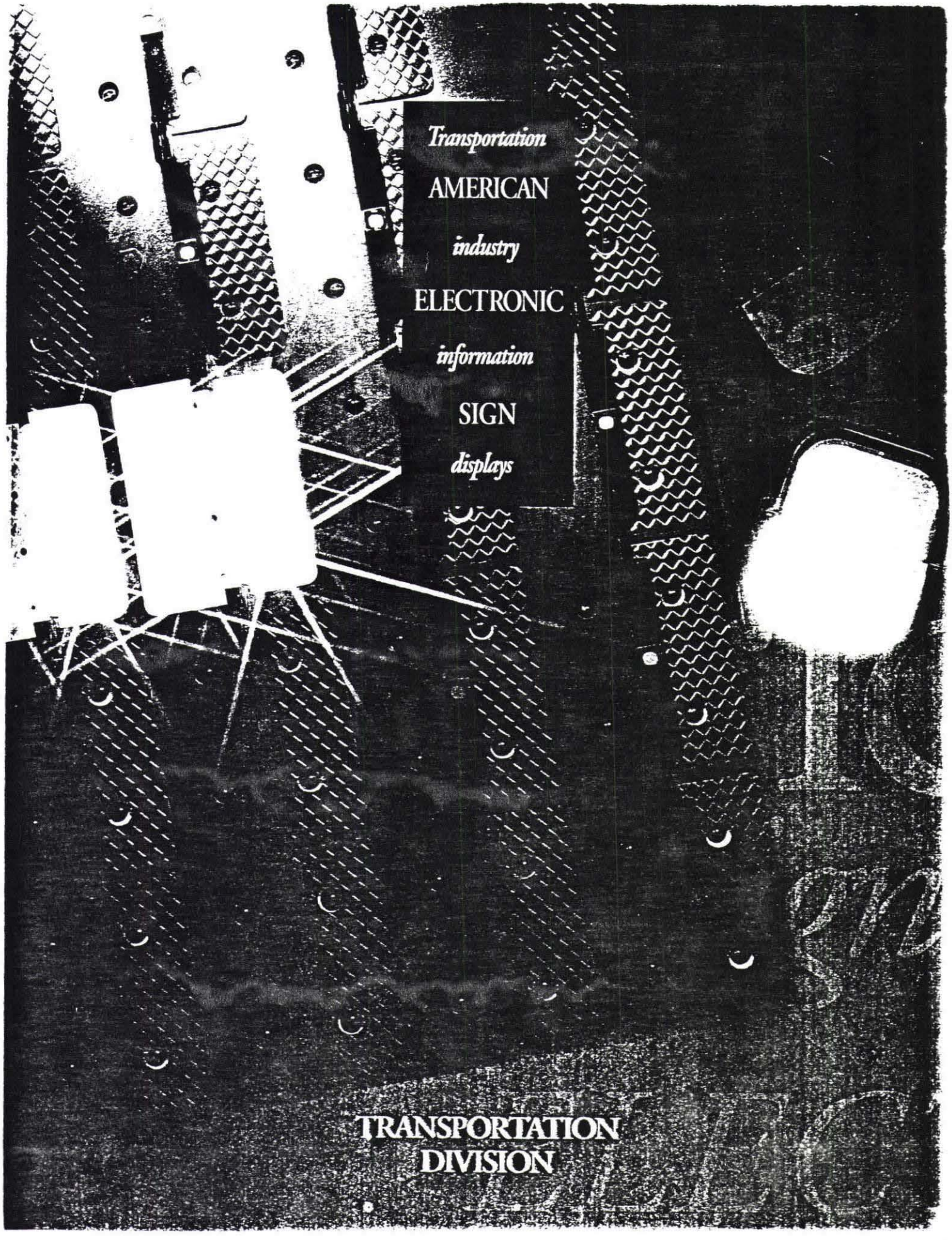
The radar activated message control is operator programmable thru the sign keyboard controller. The radar messages to be displayed must be inserted in the 6 slot "radar message sequence". Any message can be chosen from the list of preprogrammed factory messages or from any keyboard messages that can be created by the operator. Any keyboard message(s) can include the feature of the display of the speed of the oncoming vehicle upon the sign face.

Programming

After entering the user level (or above) password, enter in #3 for the message menu. At the message menu, enter in #1 for the sequence menu. At the sequence menu, enter in #4 for the special message menu. At the special message menu, enter in #2 for the radar message sequence. At the radar message sequence menu, choose the appropriate trigger speed. When the trigger speed has been chosen, the 6 slot radar message sequence appears and you may choose any 6 messages from the up to 199 factory pre-stored messages or up to 199 operator keyboard messages for display during the radar detection period.

To display the speed of the on-coming vehicle on the sign face, you must edit (create) an operator keyboard message with the speed display command (Graphics-Shift, B) contained in it. This command takes up one full line of the three line message display space of an operator keyboard message. The other two lines of the operator keyboard message are available for operator text. Adding this feature requires you to follow the normal procedure for editing (creating) an operator keyboard message. When it comes time to enter the message text, choose and enter the line number on which you want to the oncoming vehicle speed displayed, then press Graphic-Shift, B (at the same time). You will see the statement "Radar Speed" appear on the appropriate line. You may put any other text on the other two lines (or even put the "Radar Speed" message on one or both of the other two lines of the message).

Please note, the sign automatically inserts the characters "MPH" after the speed numerals on the appropriate line(s) chosen.


Transportation
AMERICAN
industry
ELECTRONIC
information
SIGN
displays
TRANSPORTATION
DIVISION

The most dependable technology in the world.

AES traffic management information displays are the only products available that take advantage of three sources of illumination - reflected ambient light during the day, reflectorized light from passing headlights after dark and energy-smart internal illumination (activated by either photo cell or programmed command).

And we're the only company that offers three choices of light emitting sources in our display systems: rear illumination, fiber optic illumination and InGaAlP LED illumination.

Our patented retroreflective pixels create a display that is highly visible in any weather or lighting condition. Each pixel features 3M™ Scotchlite™ Durable Fluorescent Diamond Grade Sheeting. This retroreflective sheeting allows AES displays to have the only sign on the market that can reduce tort liability by displaying a preprogrammed default message, in the event of complete power failure, that is visible any time, day or night.

Trilux I™

Trilux 4™

Trilux™ Fiber Optic

All AES signs are built to last in the demanding work zone and highway environments.

Safer, More Efficient Highways

By efficiently conveying real-time reports on traffic conditions, our display systems allow traffic managers to alter traffic routes and speeds as necessary. A properly managed AES variable information display system can increase traffic safety and the capacity of a roadway, without any physical changes to that roadway.

A Wide Variety Of Traffic Management Solutions

AES Variable Message Signs also provide Smart Solution applications for:

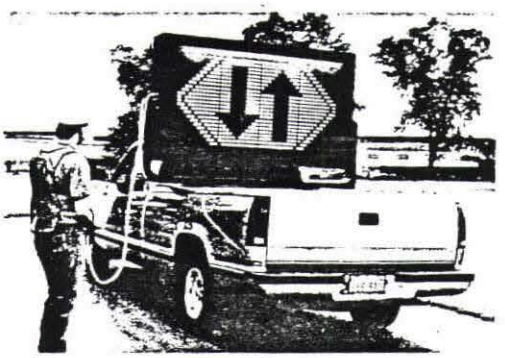
- Work Zones
- Parking Lots
- Port Authorities
- Weather Alerts
- Incident Response
- Event Management
- Bridges, Tunnels & Turnpikes
- Airports & Seaports
- Police Departments

We Back Our Systems With The Strongest Service Warranty In The Industry

All AES signs are built to last in the demanding work zone and highway environments. Our pixels have been tested to over 300 million cycles without failure and have a rated life of over 100,000 hours. Both the portable and permanent-mount displays are housed in specially designed extruded aluminum cabinets. When closed, the entire display is thermostatically controlled and ventilated to maintain an efficient operating environment in any weather or climate.

And all major components - the pixels, modules and driver cards - "snap in" and are replaceable without any special tools!

We unconditionally guarantee the components, cabinets and performance of all our variable message sign systems with the best warranty in the business. We back up that guarantee with expert technical support and a toll-free hotline. And if a problem ever arises, we take care of it...period. No questions asked! It's a quality statement that's unique to our industry.



TRANSPORTATION DIVISION

Smart solutions.

The world's transportation network depends on information to keep it running smoothly. The more efficiently that information is conveyed, the more time, money and lives are saved.

That's why American Electronic Sign (AES) has taken a "Smart Solutions" approach to the design and production of the most reliable variable message display systems currently on the market.

Our Transtar™ stationary and Guardian™ portable information displays have revolutionized virtually all areas of Traffic Management and Work Zone Safety. Designed with sophisticated solid state components and an open, flexible protocol for easy integration into all traffic management systems, AES displays provide years of efficient trouble-free service.

For more information call
1-800-727-9111

AMERICAN ELECTRONIC SIGN

Spokane Industrial Park, Bldg. 10
N. 3808 Sullivan Rd. • Spokane, WA 99216

Laser Technology Marksman™

Optional 2X magnification SpeedScope™ features in-scope display of target range and speed information, and aids target identification and visual confirmation of seatbelt compliance.

Standard variable-intensity Red Dot scope target beam provides easy aiming with audible confirmation of target acquisition.

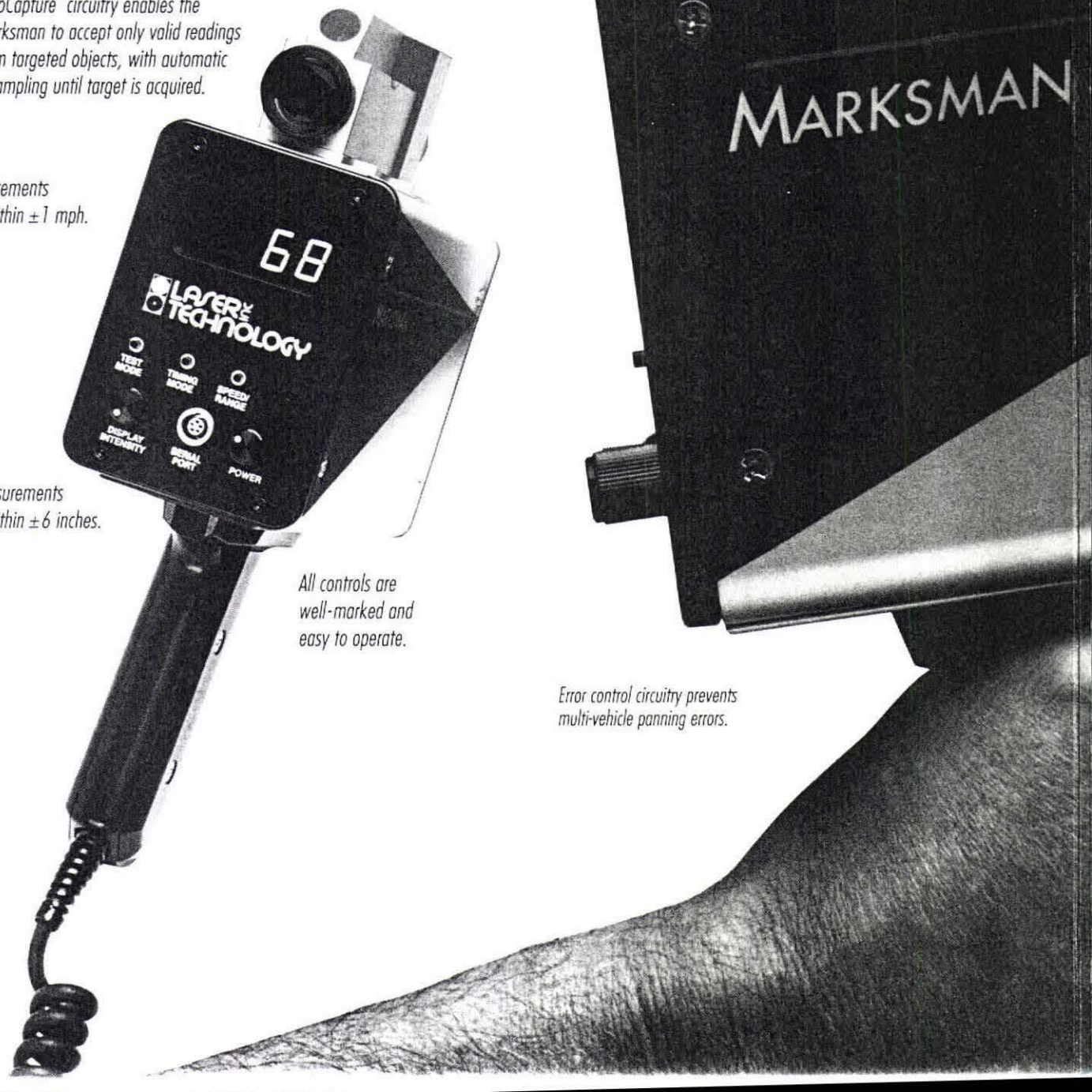
AutoCapture™ circuitry enables the Marksman to accept only valid readings from targeted objects, with automatic resampling until target is acquired.

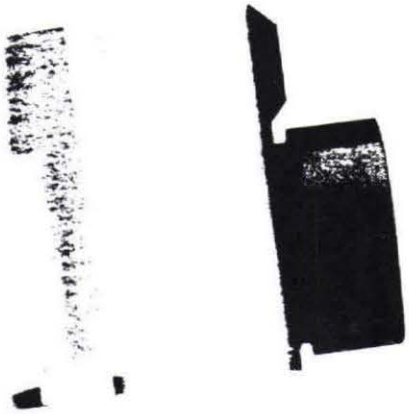
Speed measurements accurate to within ±1 mph.

Distance measurements accurate to within ±6 inches.

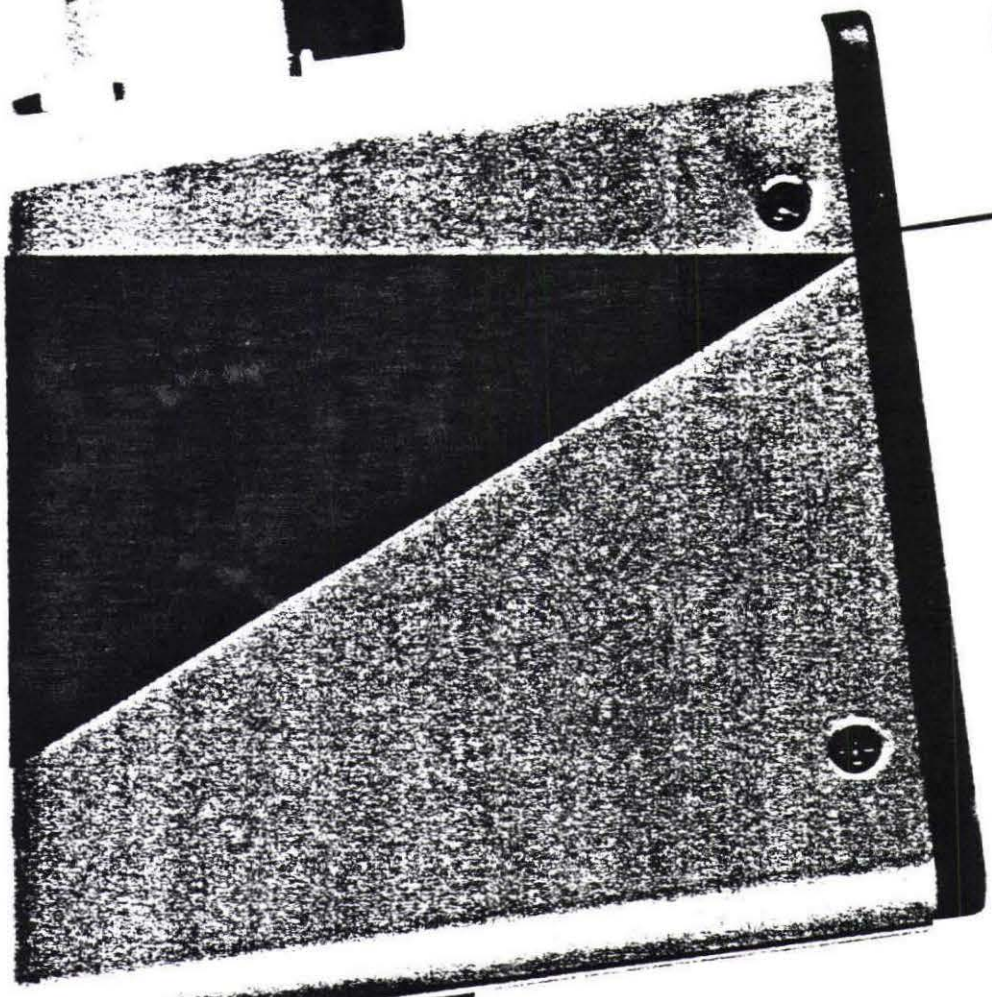
All controls are well-marked and easy to operate.

Error control circuitry prevents multi-vehicle panning errors.





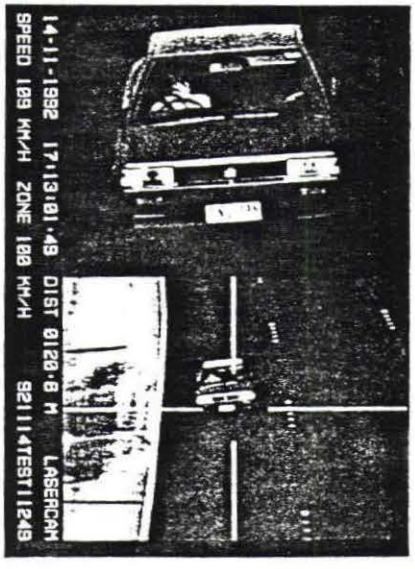
Optional SpeedStat™ software automatically downloads highway traffic speed and volume into pre-formatted surveys.



Power output is less than typical television remote, and the beam is Class I Eye Safe.

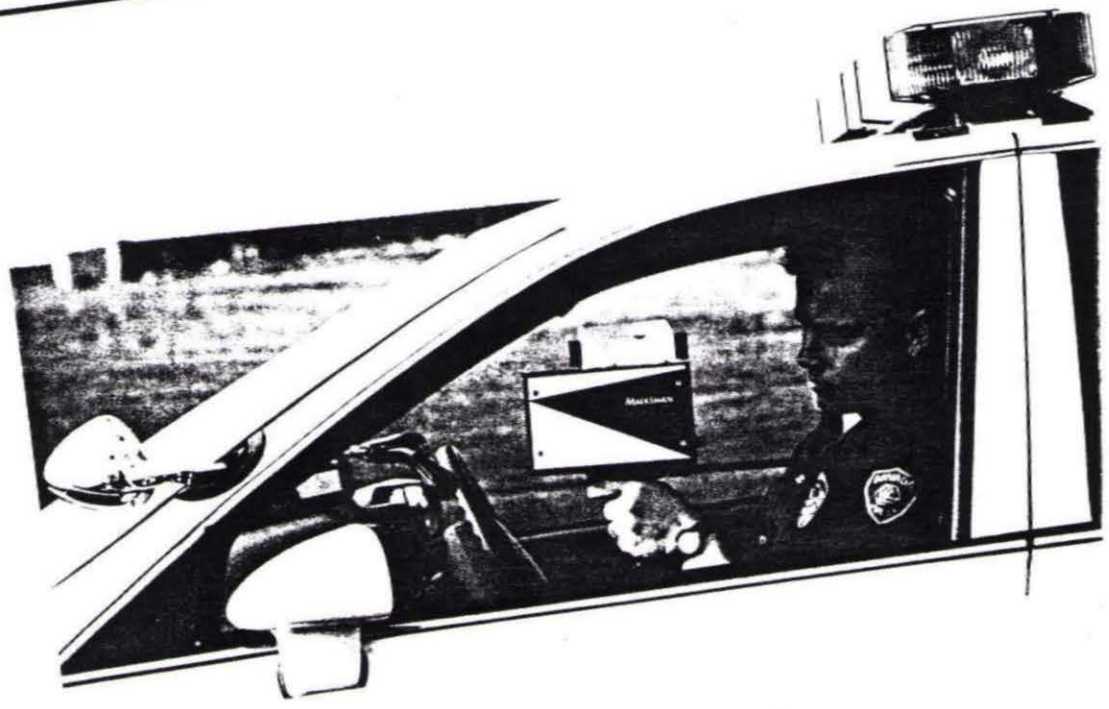
Superior manufacturing, outstanding optics and advanced laser technology enable split second target acquisition.

Marksman interfaces with video image capture equipment to provide the first photo-laser speed control system.



Technology developed for and used on NASA's Space Shuttle is durable, accurate and easy-to-use.

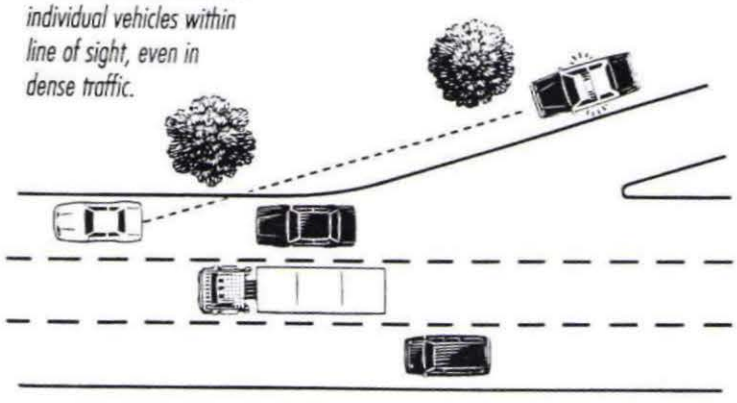
The tools we developed for reading through NASA's Space Shuttle windshield give the Marksman double the typical laser range through automobile windshield glass. ***No other laser speed control device performs this well through glass.***



Marksman laser speed control excels in tight, cluttered and crowded conditions where radar is ineffective. Its narrower beam provides outstanding individual vehicle isolation, and its longer range enables speed measurement from significantly greater distances. Its range through glass is unequalled, and Auto-Capture makes inaccurate readings impossible. The Marksman renders commercial surveillance detectors ineffective due to the brevity of the measurement and tiny footprint of the beam. The ability to positively identify the target vehicle eliminates the requirement for traditional tracking history, and the quickness of target acquisition eliminates panning and the disruptive effect of roadside obstacles.

The Marksman is easier to use and more accurate than any other speed control device. Plus, laser collars generate fewer challenges, reducing municipal court costs and the overtime burdens on personnel. And with its multiple functions, it provides a level of versatility that simply isn't available with any other device.

Narrow 3-milliradian (17/100 of 1°) beam enables 100% isolation of individual vehicles within line of sight, even in dense traffic.



Laser Technology Marksman™

Faster, more accurate and reliable speed control is only the beginning.

Marksman casts a beam that's barely three feet wide even at a thousand feet.

Marksman also expedites accident reconstruction and performs highway speed and volume surveys.

The demands of today's speed control tax the abilities of even the most highly-trained enforcement personnel and equipment. Overcrowded highways and radar detectors combine to make speed enforcement increasingly difficult. For a growing number of municipalities and state law enforcement organizations, radar simply isn't getting the job done.

Worst of all, the toughest areas to enforce speed laws are the roadways that need it the most.

The solution comes from the company that pioneered laser speed enforcement. Laser Technology, Inc. now raises the performance standard, with the second generation of laser speed enforcement tools: the Marksman™. The most advanced instrument of its kind, representing a new level in speed control efficiency.

The Marksman laser speed and ranging tool goes beyond the traditional functions of radar guns and first-generation lasers, in a durable, easy-to-use, intelligent package. The Marksman uses the same technology NASA depends on to measure the distance and closing speed of approaching satellites to set the new benchmark in speed control laser performance.

The Marksman fires a harmless, narrow laser beam. Radar projects a broad, cone-shaped beam 200 to 400 feet wide, with an effective range of only a few hundred yards. The Marksman casts an invisible shaft of light that widens to just over a *yard* at a quarter-mile range. Individual vehicles can be isolated at the push of a trigger, even weaving from lane to lane, at ranges up to a half mile away.

The Marksman is fast. Too fast for detection devices. The 0.3-second invisible laser burst that creates the speed measurement is so brief and focused, electronic countermeasures are completely ineffective.

The Marksman is durable. Casing seams are resistant to both moisture and water vapor, inherent surge protection safeguards vital circuitry, and each instrument is designed with no internal moving parts or adjustable radio frequencies to go out of alignment. The Marksman is exceptionally shock resistant. One unit was dropped into interstate traffic and hit by several vehicles traveling at high speed, but once a circuit board was remounted, it performed to original specifications.

Marksman is versatile. The same circuitry that computes a moving object's speed also makes accurate *distance* measurements as far as half a mile away. This becomes extremely valuable when performing fast, simple, and more accurate accident reconstruction, or performing any other distance-determination function. Even checking for false walls in semi trailers, all the officer has to do is point and shoot.

The Marksman is useful, to officers and highway engineers alike. It downloads complete traffic data surveys via standard serial port and Speed Stat™ software, to a separate laptop computer, in reports including all statistical data and time/date groupings.

The Marksman gets results. Nothing is more effective in quickly measuring speed and distance than a laser. Speed measurements are more selective and accurate, and thanks to the laser's reputation for unbeatable accuracy, they hold up better in court if they ever get that far.

The Marksman is proven. Results in the courtroom speak for themselves, with judicial notice already served in hundreds of jurisdictions. Laser Technology has been the pioneer in establishing laser speed enforcement in the courtroom and the laboratory. No other gun has received the level of unrestricted independent testing approval we have, both here and abroad.

The Marksman simply makes a tough job easier. Nothing makes line-of-sight speed measurement readings more quickly, quietly or accurately. Technological advances like outstanding range and accuracy through glass, auto-capture, and the versatility of full-function traffic survey make the Marksman the standard by which all laser speed control devices are judged. It is the *intelligent* answer to today's most complex demands of highway safety.

Speed Measurement

Operational Distance: 30' to 3500'
Speed Maximum: +200 mph to -200 mph
(accurate zero reading)
Accuracy: +/- 1 mph
Acquisition Time: .3 seconds

Range Measurement

Operational Distance: 30' to 3500'
(In excess of 9000' to a reflective road sign)
Accuracy: +/- 6 inches
Acquisition Time: .3 seconds

Targeting

Pin-point beam
(3 milliradian divergence, 3' wide at 1000')
Adjustable illuminated red dot sight
AutoCapture triggering
Optional SpeedScope with in-scope data display

Dimensions

Size: 3.5" x 5" x 8"
Weight: 4.5 lbs.

Power Requirements

10.6v - 16v (12v nominal) 750 ma

Eye Safety

Certified Class 1 eyesafe by the U.S. Department of Health and Human Services Center for Devices and Radiological Health by way of the Food and Drug Administrations CFR 1040.10 and 1040.11 regulations.

Communication

1/2" adjustable illuminated display
RS232 Serial

Environment

-22 to +144 Fahrenheit

Laser Technology Inc.
7070 South Tucson Way
Englewood, CO 80112
Voice: (303) 649-1000
Fax: (303) 649-9710

LASER TECHNOLOGY INC

APPENDIX D
SPEED DATA

SITE LOCATION #1
(4000' IN ADVANCE OF WORK ZONE TAPER)

Hour Ending	BEFORE STUDY July 16, 1996 Sample Size	85%tile Speed	Average Speed	AFTER STUDY July 30, 1996 Sample Size	85%tile Speed	Average Speed
01:00 AM	60	74.3	66.8	43	73.7	67.3
02:00 AM	49	76.1	67.6	40	69.4	63.8
03:00 AM	31	71.5	64.5	39	70.3	64.3
04:00 AM	27	74.0	66.4	30	69.8	63.3
05:00 AM	29	74.7	65.2	39	70.9	64.2
06:00 AM	48	74.3	67.8	50	70.8	63.3
07:00 AM	84	77.5	70.4	86	70.9	63.0
08:00 AM	139	76.3	69.3	130	73.2	64.9
09:00 AM	169	76.3	69.8	186	74.1	66.7
10:00 AM	204	76.3	68.8	234	74.5	67.2
11:00 AM	222	76.1	68.8	261	73.2	66.2
12 Noon	224	75.8	68.3	253	75.3	67.3
01:00 PM	223	76.4	68.7	235	73.5	66.5
02:00 PM	247	75.5	69.1	231	75.1	66.5
03:00 PM	242	76.3	69.3	264	75.9	67.4
04:00 PM	248	74.1	66.1	241	74.8	66.6
05:00 PM	240	74.5	66.7	248	73.5	66.4
06:00 PM	227	75.6	68.0	243	76.1	67.5
07:00 PM	205	76.6	68.5	206	73.7	67.2
08:00 PM	199	76.8	68.8	163	73.5	67.2
09:00 PM	155	76.5	68.2	154	72.3	66.3
10:00 PM	123	75.5	66.8	142	73.4	67.1
11:00 PM	91	75.1	66.7	132	71.6	65.6
12 Midnight	70	76.3	68.3	90	71.3	65.3

Daily 15%tile Speed	60.4	Daily 15%tile Speed	59.7
Daily 50%tile Speed	69.0	Daily 50%tile Speed	66.6
Daily 85%tile Speed	75.9	Daily 85%tile Speed	73.8
Daily Avg. Speed =	68.2	Daily Avg. Speed =	66.5
Std. Dev. of Speed =	7.5	Std. Dev. of Speed =	7.0
Sample Size =	3556	Sample Size =	3740
10 mph Pace =	66 - 76	10 mph Pace =	60 - 70

APPENDIX D
SPEED DATA

SITE LOCATION #2
(BEGINNING OF THE WORK ZONE TAPER)

Hour Ending	BEFORE STUDY July 16, 1996 Sample Size	85%tile Speed	Average Speed	AFTER STUDY July 30, 1996 Sample Size	85%tile Speed	Average Speed
01:00 AM	60	69.8	60.9	43	73.6	65.6
02:00 AM	44	72.3	62.5	39	69.9	61.6
03:00 AM	29	66.7	59.1	42	67.9	61.1
04:00 AM	22	71.7	63.0	25	72.4	61.3
05:00 AM	23	73.9	63.2	37	69.3	63.8
06:00 AM	42	76.2	67.7	40	69.8	63.1
07:00 AM	76	76.7	69.8	79	68.3	60.5
08:00 AM	116	75.7	66.3	118	70.6	62.8
09:00 AM	146	74.0	64.8	154	70.0	62.6
10:00 AM	172	71.8	63.1	187	68.7	62.6
11:00 AM	160	72.3	62.3	205	67.8	61.6
12 Noon	175	72.0	62.8	197	69.2	61.9
01:00 PM	167	72.4	62.2	196	67.9	60.6
02:00 PM	199	73.3	64.2	193	68.4	61.3
03:00 PM	184	70.1	62.0	201	68.6	61.3
04:00 PM	165	68.9	61.3	186	67.8	60.7
05:00 PM	195	71.3	61.0	201	67.9	61.0
06:00 PM	175	72.5	63.8	195	69.3	61.7
07:00 PM	170	74.6	65.1	186	70.1	62.7
08:00 PM	162	73.9	66.1	146	70.5	63.3
09:00 PM	134	73.6	65.8	130	71.5	64.4
10:00 PM	109	70.6	62.7	127	70.2	61.8
11:00 PM	88	70.9	62.0	116	68.9	61.2
12 Midnight	69	70.2	61.3	85	68.1	62.5

Daily 15%tile Speed	54.5	Daily 15%tile Speed	53.9
Daily 50%tile Speed	62.9	Daily 50%tile Speed	62.2
Daily 85%tile Speed	72.8	Daily 85%tile Speed	68.9
Daily Avg. Speed =	63.5	Daily Avg. Speed =	61.9
Std. Dev. of Speed =	7.9	Std. Dev. of Speed =	7.0
Sample Size =	2882	Sample Size =	3128
10 mph Pace =	59 - 69	10 mph Pace =	59 - 69

APPENDIX D
SPEED DATA

SITE LOCATION #3
(END OF THE WORK ZONE TAPER)

Hour Ending	BEFORE STUDY July 16, 1996 Sample Size	85%tile Speed	Average Speed	AFTER STUDY July 30, 1996 Sample Size	85%tile Speed	Average Speed
01:00 AM	59	64.6	57.4	44	72.6	65.4
02:00 AM	43	68.3	59.2	40	69.8	62.9
03:00 AM	30	62.5	56.3	42	68.2	62.1
04:00 AM	22	70.1	60.4	26	73.1	62.3
05:00 AM	23	69.4	59.5	39	68.5	62.7
06:00 AM	42	70.3	63.0	42	68.9	62.9
07:00 AM	75	71.7	64.2	64	66.6	58.4
08:00 AM	115	70.1	61.1	121	65.0	57.0
09:00 AM	140	69.6	60.6	157	67.2	58.8
10:00 AM	173	68.1	59.3	183	66.9	58.6
11:00 AM	164	65.7	57.1	200	65.7	58.8
12 Noon	176	66.9	57.2	194	67.0	59.1
01:00 PM	171	63.8	56.0	197	65.1	58.7
02:00 PM	201	68.6	59.6	184	65.6	58.9
03:00 PM	177	65.0	57.2	196	65.5	58.3
04:00 PM	171	63.1	56.8	194	64.7	57.6
05:00 PM	186	66.8	57.9	197	65.9	58.4
06:00 PM	176	68.4	59.8	196	67.2	59.0
07:00 PM	166	70.4	61.7	180	67.3	59.8
08:00 PM	160	70.3	62.3	146	68.6	61.3
09:00 PM	128	70.1	62.5	128	69.2	61.5
10:00 PM	109	66.6	59.7	132	68.1	59.9
11:00 PM	86	68.6	59.9	116	67.5	60.9
12 Midnight	69	68.8	59.4	87	67.5	61.2

Daily 15%tile Speed	50.4	Daily 15%tile Speed	51.0
Daily 50%tile Speed	58.7	Daily 50%tile Speed	59.4
Daily 85%tile Speed	68.2	Daily 85%tile Speed	67.0
Daily Avg. Speed =	59.3	Daily Avg. Speed =	59.4
Std. Dev. of Speed =	7.7	Std. Dev. of Speed =	7.0
Sample Size =	2862	Sample Size =	3105
10 mph Pace =	53 - 63	10 mph Pace =	54 - 64