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OPERATIONAL SYSTEM GUIDELINES FOR VORTEX ADVISORY SYSTEM

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RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION
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FINAL REPORT

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16. Abstract

The phenomenon of wake vortices has introduced a major operational constraint on airport operations, resulting in a reduction of runway capacities. Increased knowledge about the behavior of wake vortices has resulted in the development of a model of vortex behavior as a function of meteorological conditions. Based on this vortex behavior model, a Vortex Advisory System (VAS) has been designed and built. The VAS measures the primary meteorological parameter (wind) which affects vortex behavior and indicates to controllers via displays when conditions are such that more efficient runway use is possible. A detailed description of the VAS and guidelines for an operational system are given.

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PREFACE

A major problem facing the U.S. air transportation system is the restricted capacity at the major airports and the resulting costly delays. A major contributing factor to the delay problem is the need to maintain large separations between aircraft in the approach corridor to a runway due to the vortex hazard.

Under sponsorship of the FAA, the Transportation Systems Center has conducted an intensive investigation of the vortex phenomenon, factors affecting vortex generation, motion and delay and the impact of the vortex hazard on air traffic operations. The result has been the development and field test of the Vortex Advisory System (VAS) whose deployment at major airports promises to significantly reduce aircraft delays.

The VAS represents the results of the efforts of a large number of individuals at DOT/TSC, FAA Headquarters and O'Hare ATCT personnel, all of whom made major contributions to the development of the operational VAS.

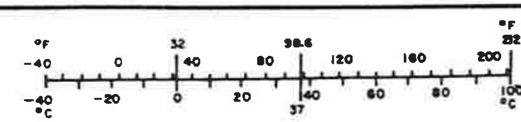
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

The purpose of the following introductory notes is to provide an overall rationale for the Vortex Advisory System (VAS) and a general description of its mechanization.

A major problem facing the U.S. air transportation system is the restricted capacity at its major air terminals and the resulting airline and passenger delay costs. The need to increase airport landing and takeoff capacity under all weather conditions without degrading current high levels of aviation safety is therefore of prime importance to the air transportation system. When the major commercial air terminals operate at or near saturation in the current capacity-demand environment, aircraft delays are commonplace and poor weather only compounds the delay problem. Existing airport and airway system utilizations are projected to increase significantly in the U.S. by 1980 and to quintuple by 1995. Potential capacity relief through construction of more air terminals is not likely in the current or near future economic or environmental climate; expansion of runway quantities at existing terminals is just as unlikely. A solution which must be pursued is to allow increased aircraft operations into and out of the major terminals by decreasing the longitudinal spacings or intervals between successive aircraft operations.

Although the phenomenon of aircraft wake vortices has been known since the beginnings of powered flight, it is only recently that operational problems associated with the phenomenon have been experienced. Aircraft wake vortices now constitute one of the major problems confronting the air traffic control system. Before 1970, landing aircraft maintained 3-nautical-mile separations under Instrument Flight Rule (IFR) conditions. This separation standard was based primarily on radar operating limits and to a lesser extent on runway occupancy limitations.

There were no separation standards imposed because of vortex considerations.

With the introduction of the wide-bodied jets and the increasing number of aircraft operations at the major airports, the wake vortex problem has taken on increasing significance. The probability of a vortex encounter is greatest in the terminal area where light and heavy aircraft operate on the same flight path in close proximity and where recovery from an upset may not be possible because of the low aircraft altitude.

Accordingly, the solution implemented by the Federal Aviation Administration (FAA) in March 1970 was to increase the separation standards behind the heavy jets to 4 nautical miles for following heavy aircraft and to 5 nautical miles for a following non-heavy aircraft. In November 1975 the standards were revised to require the addition of an extra nautical-mile separation for following aircraft with a maximum certificated takeoff weight less than 12,500 lbs.

The FAA is developing ground systems which will provide information on the presence or absence of potentially hazardous vortices in the approach corridor such that a following aircraft may completely avoid contact with these vortices. The concept of wake vortex avoidance is based on two considerations which the available wake turbulence data supports:

1) Meteorological conditions exist a large percentage of the time which cause vortices to move quickly off the flight path or decay rapidly in the approach corridor such as to not present a hazard to aircraft following on the same flight path.
2) The duration, intensity, and movement of vortices can be reliably predicted if adequate knowledge of the existing meteorological conditions and the generating aircraft's characteristics are known.

The feasibility of developing an applicable vortex system which would use the above considerations is predicated on the observation that separation criteria are overly conservative most of the time.

RATIONALE FOR VAS

Until recently the lack of knowledge about the life cycle of wake vortices generated by today's large aircraft mandated large separation distances for following aircraft and thus limited approach and landing capacities. Analysis of the extensive data on vortex behavior as a function of meteorological conditions recorded at Denver's Stapleton, New York's John F. Kennedy and London's Heathrow International Airports has indicated that there are wind conditions which predictably remove vortices from the approach corridor. The analysis indicated that a wind rose criterion can be used to determine when the separations could be uniformly reduced to 3 nautical miles for all aircraft types rather than using the 3-, 4-, 5-, and 6-mile separations currently required.

A Vortex Advisory System (VAS) was designed to take advantage of the wind rose criterion. The system is based on comparing the measured wind magnitude and direction (with respect to each runway heading) with the wind criterion. The comparison indicates via a simple display when separations could be reduced safely to three nautical miles for all approach and landing aircraft.

A decision was made to test the VAS concept at an airport under actual operating conditions. Since the main objective of the VAS is to allow increases in capacity, the major high density terminals with a significant percentage of jumbo jet operations and with capacity at or near saturation were considered for the feasibility tests. Chicago O'Hare was selected.

A breadboard VAS was successfully demonstrated at O'Hare. Following the test phase, the breadboard system's components were replaced with operational hardware.

O'HARE VAS SYSTEM DESIGN

The VAS consists of four major subsystems: a Meteorological Subsystem for the measurement of the meteorological conditions existing in the operating corridors of the airport; a Data Processing Subsystem which processes all meteorological data and, based on the VAS algorithm, determines when spacings between aircraft can be reduced; a Data Display Subsystem for the display of separation requirements and meteorological conditions to the air traffic controllers; and a VAS Performance Monitoring and Data Recording Subsystem which monitors system performance, indicates failures and displays these to maintenance personnel, and records all VAS input and output data.

Meteorological Subsystem. The meteorological subsystem consists of a network of instrumented meteorological towers placed about the airport perimeter. Ideally, each runway end would be instrumented with a single tower placed approximately halfway between the runway threshold and the Middle Marker and about 800 to 1000 ft. to one side in order to prevent vortex impingement on the tower disturbing the meteorological measurements. However, the proximity of runway thresholds generally allows the placement of a single tower to serve two (or more) approaches. Seven towers are used in the O'Hare system.

Each 50 ft. meteorological tower is instrumented with three sets of wind magnitude and direction sensors, one sensor set located at 50 ft., the remaining two at 47 ft. The redundancy provided by a triple-sensor installation greatly increases system reliability insuring the acquisition of valid data and sensor-failure detection.

The instrumentation transmitting the meteorological data from each tower to a central facility consists of a multiplexer and A/D converter which sequentially samples the sensor outputs and a line modem which serializes the data and transmits it over a wire pair to receivers located in the control tower. A 16 channel, 12-bit Data Acquisition System (DAS) is used. The DAS operates under the control of the modem which commands the scan rate. The modem operates in a line-switching mode at a crystal-controlled 5440-Hz bit rate. In addition to the six multiplexer channels used to read the meteorological sensor outputs, four channels are used to monitor the status of the tower electronics by monitoring a precision voltage reference and power supply outputs, enabling the detection of electronics failures which could affect the accuracy of the meteorological measurements.

All tower electronics are housed in an environmental enclosure mounted near the base of each 50 ft. tower. Since lightning strikes are a major problem in this type of installation, great care was taken to insure against this type of system damage. All input and output signal lines are protected with transient arrestors. The input 60-Hz power line is regulated and contains a separate transient arrestor. Standard FAA control lines normally available at various airport NAV-AID sites are used to transmit the data from each meteorological tower to the equipment room in the Air Traffic Control Tower where the VAS microprocessors are located.

Data Processing Subsystem. The serial data stream from each meteorological tower is received by a modem which converts the serial input into parallel 16-bit words (4 channel address bits and 12 channel data bits). The output from each receiving modem is input to individual microprocessors (Intel SBC80/20) packaged on single plug-in boards. The microprocessors sample the meteorological data at a 2-sample/second rate. The sampled wind magnitude (R) and wind direction (Θ) are used to compute a one-minute running average ($\bar{R}$ and $\bar{\Theta}$) by the following scheme: for each sample $U=R\cos\Theta$ and $V=R\sin\Theta$ are computed; next $\bar{U}$ and $\bar{V}$ are computed using a running 128-sample average and finally $\bar{R}=(\bar{U}^2+\bar{V}^2)^{1/2}$ and $\bar{\Theta}=\tan^{-1}(\bar{V}/\bar{U})$ are computed. The microprocessor also calculates wind gusts. The criterion used is that a measured peak wind must exceed $\overline{R}$ by 9 KTS in order to qualify as a gust. Gust values are retained for 30 seconds.

The microprocessors perform the important function of failure detection. The sampled R and Θ from each sensor on a tower are compared to each other at the end of each sampling interval and must agree within 5 knots and 20 degrees. Normally, the 50 ft. sensor data are selected. If the 50 ft. sensor fails, the microprocessor switches to the 47 ft. sensor which is not in the wind shadow of the tower. Failure of at least two R's or Θ's to agree for eight successive samples causes a tower-failure signal to be generated. The microprocessor also checks the voltage reference and the power supply outputs as well as the address sum and timing of the incoming data. A deviation beyond preset limits results in a tower-failure signal.

In addition to outputs of $\overline{R}$, $\overline{\Theta}$ and gust, the microprocessor outputs system status words to indicate which specific failure is detected. This information is displayed on a system-maintenance console thereby providing maintenance personnel with the means to effect rapid repairs.

The microprocessor, using the VAS algorithm, then determines which aircraft landing separations may be utilized; i.e., the standard 3/4/5/6 nm or a reduced 3 nm separation for all aircraft. The VAS algorithm consists of an elliptical pattern with major and minor axes of 12.5 knots and 5.5 knots, respectively. The major axis is aligned in the direction of the runway. A wind condition resulting in a wind vector $\overline{R}(\overline{\Theta})$ inside the ellipse requires the use of the 3/4/5/6 separation criteria, while a wind vector outside the ellipse allows a uniform separation of 3 nm.

Logic in the VAS processor program combined with the use of a 2-knot guard band around the elliptical region separating the two operating conditions combine to insure a gradual transition from one state to the other.

Data Display Subsystem. Two types of displays are used in the VAS, a System Monitor Display and a Runway Monitor Display.

The System Monitor Display (Fig. 21) is intended for use by the tower cab and IFR-room supervisors. The display indicates in summary form all surface wind conditions and the aircraft separation advisories for the approach/departure corridors for which the wind measurements apply. Its primary function is to provide an overview of the wind conditions across the entire airport enabling the supervisor to select an operating configuration which will maximize traffic flow for the existing meteorological conditions.

The Runway Monitor Display (Fig. 20) is designed for use by a local controller and displays data for a single runway. The controller selects a specific runway via a set of thumbwheel switches. The controller must also indicate whether the runway is being used for arrivals or departures; e.g., he enters A32L for arrivals to runway 32-Left and D32L for departures from runway 32-Left. The display thereafter accepts data with the corresponding label from the data bus. Thus, if A32L is entered, wind parameters measured by the tower near the approach end of runway 32L are displayed, while a D32L entry causes wind parameters measured by the tower nearest the departure end of runway 32L to be displayed.

In the present system separation requirements are indicated by a RED or GREEN light and are indicated only when an arrival runway is selected. A RED light indicates the need to maintain 3/4/5/6-nm landing spacing, while a GREEN light indicates that an all 3-nm separation may be applied.

Performance Monitoring and Data Recording Subsystem. In order to facilitate the maintenance of the VAS, the VAS equipment console containing the microprocessors, modem receivers, power supplies etc., also contains system maintenance equipment which indicates to the maintenance personnel the system status and repair requirements.

All data acquired, processed, and output by the VAS are recorded on 9-track digital tape. Each tape contains a complete record of all VAS operations for use in system diagnostics and to meet the FAA's operational requirements for a record of all ATC operations.

1.1 Scope. This specification defines the hardware and software requirements for a Vortex Advisory System (VAS). The VAS measures wind conditions at a number of locations at an airport, processes this meteorological data and outputs it to controllers via displays. The system also utilizes a wind rose criterion to determine whether a 3-4-5-6-nm separation must be used between landing aircraft depending on aircraft type or if the separation can be reduced to 3 nm between all aircraft. In addition, the VAS equipment contains the means to monitor system status, diagnose failures, record system outputs and print out a detailed report of the system status.

1.2 System. The VAS consists of the following major subsystems as shown in Fig. 1.:

A. Meteorological Subsystem - A set of VAS towers, sensors and the associated field electronics, as well as electronics required to record the output of the presently used airport center-field wind sensor (National Weather Service F-420).

B. Data Processing Subsystem - a micro-computer for each meteorological tower and the center-field sensor which processes all incoming data, determines allowable aircraft separations and outputs all data on a data bus.

C. Display Subsystem - a set of displays for the controller in the TRACON and CAB to display the prevailing wind information and allowable aircraft separations.

D. Maintenance Subsystem - a subsystem to monitor the VAS status, collect failure statistics and display this information to maintenance personnel, and record all system outputs.

2. APPLICABLE DOCUMENTS

2.1 FAA Documents. The following FAA specifications, handbook and standards of the issues specified in the invitation for bids or request for proposals, form a part of this specification

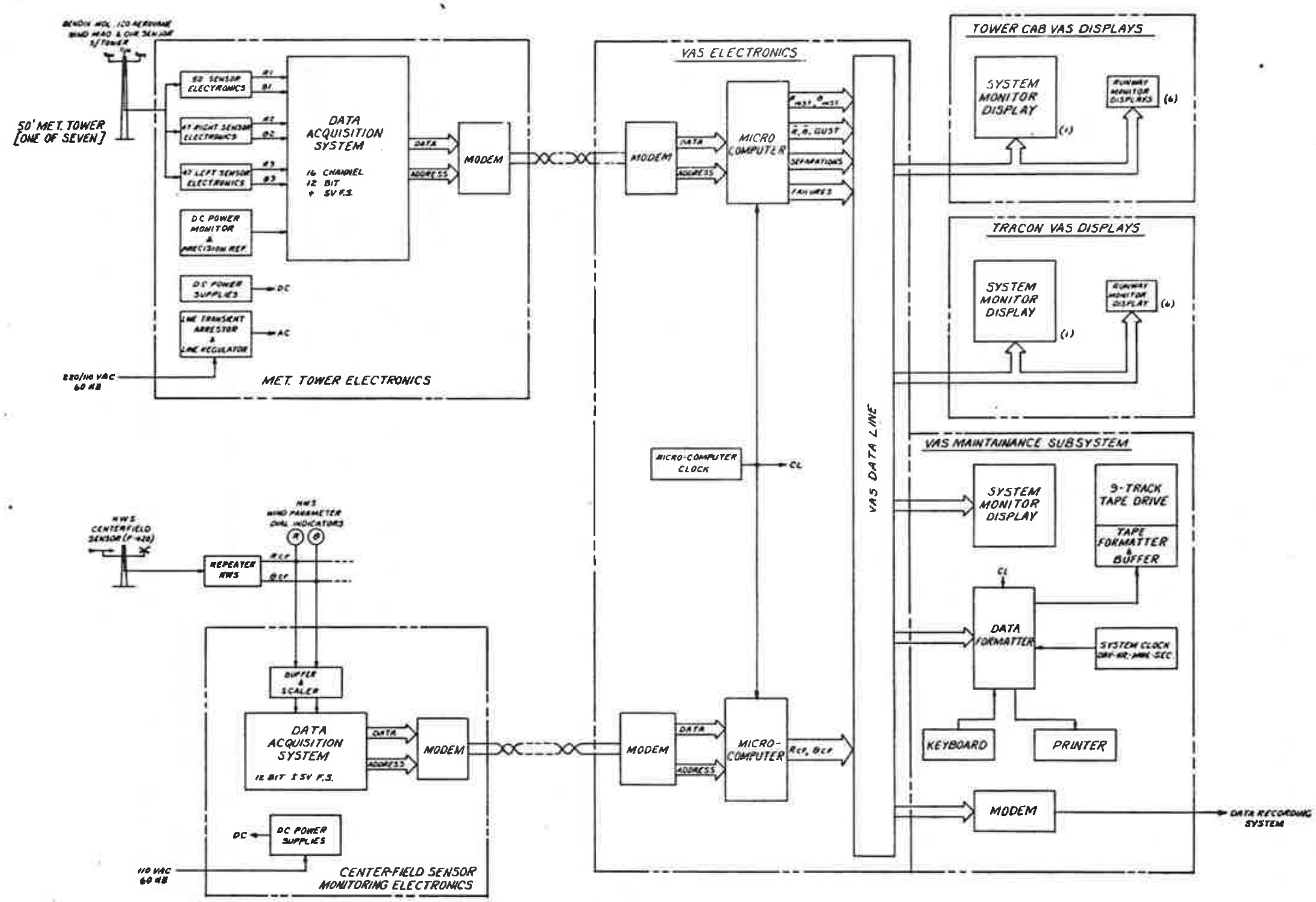


FIGURE 1. VAS BLOCK DIAGRAM

and are applicable only to the extent specified herein.

2.1.1 FAA Specifications.

FAA-E-163	Rack, cabinet and open frame types
FAA-G-2100/1	Part I, Electronic Equipment, General Requirements; Basic Requirements for all Equipments
FAA-G-2100/3	Part 3, Requirements for Equipment Employing Semiconductor Devices
FAA-G-2100/4	Part 4, Requirements for Equipments Employing Printed Wiring Techniques.
FAA-G-2100/5	Part 5, Requirements for Equipments Employing Microelectronic Devices
FAA-G-2300	Panel and Vertical Chassis Rack
FAA-D-2494/1	Technical Instruction Book Manuscripts: Electronic Equipment, Requirements for
FAA-D-2494/2	Preparation of Reproducible (Camera Ready) Copy

2.1.2 FAA Standards.

FAA-STD-013	Quality Control Program Requirements

2.2 Military and Federal Publications.

2.2.1 Military Specifications and Standards.

MIL-E-17555	Electronic and Electrical Equipment and Associated Repair Parts; Preparation and Delivery of
MIL-STD-470	Maintainability Program Requirements for systems and Equipment
MIL-STD-471	Maintainability Demonstration
MIL-STD-785A	Reliability Program for Systems and Equipment
MIL-STD-810	Environmental Test Methods

2.2.2 Military Handbook.

MIL-HDBK-217	Reliability Stress and Failure Rate Data for Electronic Equipment

2.2.3 Federal Standard.

FED-STD-102 Preservation, Packaging and Packing Levels

2.3 Other Publications.

National Fire Protection Association NFPA-70 National Electrical Code

3. REQUIREMENTS

3.1 General. The VAS equipment to be furnished by the successful offeror shall be in accordance with all specification requirements stated herein.

3.2 System Characteristics. The VAS shall be a meteorological system which measures wind parameters at a selected number of locations at an airport, processes the data, determines allowable separation requirements between landing aircraft and outputs the separation and wind parameter information to controllers via displays. The VAS equipment shall also contain the means to determine system and component failures, alert maintenance personnel to their occurrence, print out system or component failure statistics and record on magnetic tape the VAS data outputs containing the separation requirements, wind parameters and failure indications.

3.3 Equipment to be Furnished. Each VAS furnished by the contractor shall consist of the following items:

a. Four (4) to seven (7) instrumented meteorological towers.

b. Center field sensor monitoring electronics.

c. A VAS electronics console containing the Data Processing and Maintenance Subsystems.

d. VAS displays consisting of a minimum of two (2) System Monitors and six (6) Runway Monitors to a maximum of three (3) System Monitors and twelve (12) Runway Monitors.

3.3.1 VAS Deployment. The VAS will be deployed at a number of major U.S. airports. The airport selection and the determination of the VAS equipment complement at each of these airports will be made by the FAA operating services at a later date.

3.3.2 VAS Meteorological Subsystem. The VAS Meteorological Subsystem shall consist of a set of meteorological towers each instrumented with three (3) wind speed and direction sensors, associated electronics for signal conditioning, data multiplexing, data conversion and transmission electronics, power supplies, a power conditioning unit, transient protection devices, and an environmental enclosure.

In addition, the meteorological subsystem shall contain one (1) electronics unit required to acquire signals from the National Weather Service F-420 wind speed and direction sensor which is generally located at the center of the airport. The unit shall contain signal conditioning, data multiplexing, conversion and data transmission electronics, power supplies, a power conditioning unit, and transient protection devices. This unit shall be housed in a suitable enclosure which shall be located in the equipment room of the Air Traffic Control Tower where the F-420 output signal lines are available. Although the VAS console may be located in the same vicinity, no assumption shall be made that this will be the case at every airport and the design shall provide for the case where a considerable distance exists between the VAS console and the F-420 monitoring electronics.

3.3.2.1 VAS Meteorological Towers. The VAS Meteorological Towers shall be configured as shown in Figure 2. All equipment and installations shall conform to the appropriate sections of the following codes and regulations:

ANSI	-	American National Standards Institute (Formerly ASA)
ASME	-	American Society of Mechanical Engineers
ASTM	-	American Society for Testing Materials
ETL	-	Electrical Testing Laboratories, Incorporated
FAA	-	Federal Aviation Administration
IEEE	-	Institute of Electrical and Electronic Engineers
IPCEA	-	Insulated Power Cable Engineers Association
NAVFAC	-	Naval Facilities
NBFU	-	National Board of Fire Underwriters
NBS	-	National Bureau of Standards
NEC	-	National Electrical Code
NEMA	-	National Electrical Manufacturers' Association
NESC	-	National Electrical Safety Code
OSHA	-	Occupational Safety and Health Administration U. S. Department of Labor
UL	-	Underwriters' Laboratories, Incorporated
AASHO	-	American Association of State Highway Officials
	-	Local Building Codes

3.3.2.1.1 Tower Location. The most desirable location for the placement of a tower is approximately 1000' - 2000' from the runway threshold and 800' - 1000' to either side of the extended runway center line. This is shown diagramatically in Figure 3.

These areas are chosen for two main reasons:

1) Data collected at various test sites have shown that vortices in the region between threshold and the middle marker are most likely to stall in this approach area.

2) The tower must be offset from the approach path so that the vortices themselves will not interfere with the ambient wind measurement instrumentation.

Several factors can preclude the placement of the towers

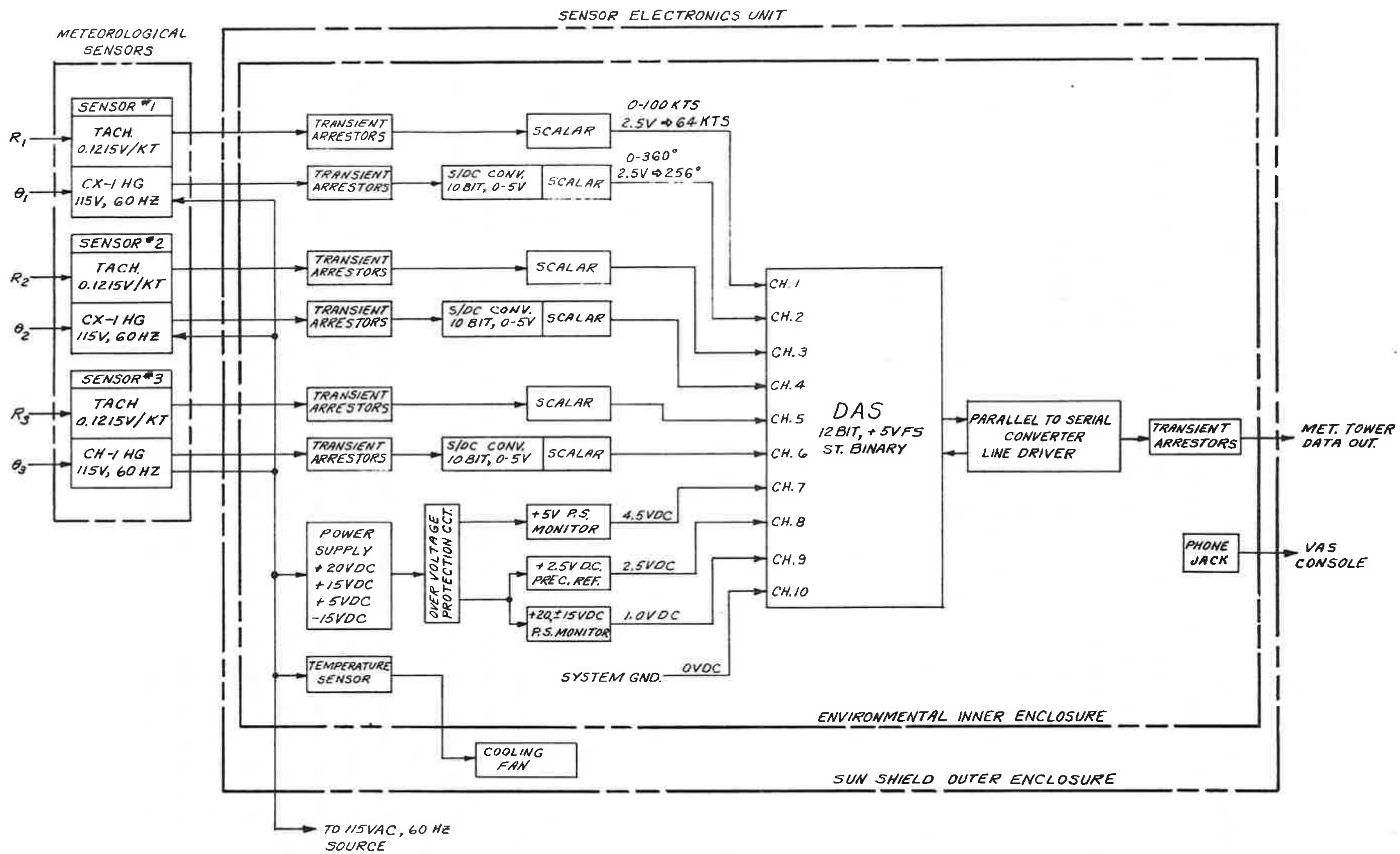


FIGURE 2. BLOCK DIAGRAM METEOROLOGICAL SENSOR/ ELECTRONICS SUBSYSTEM

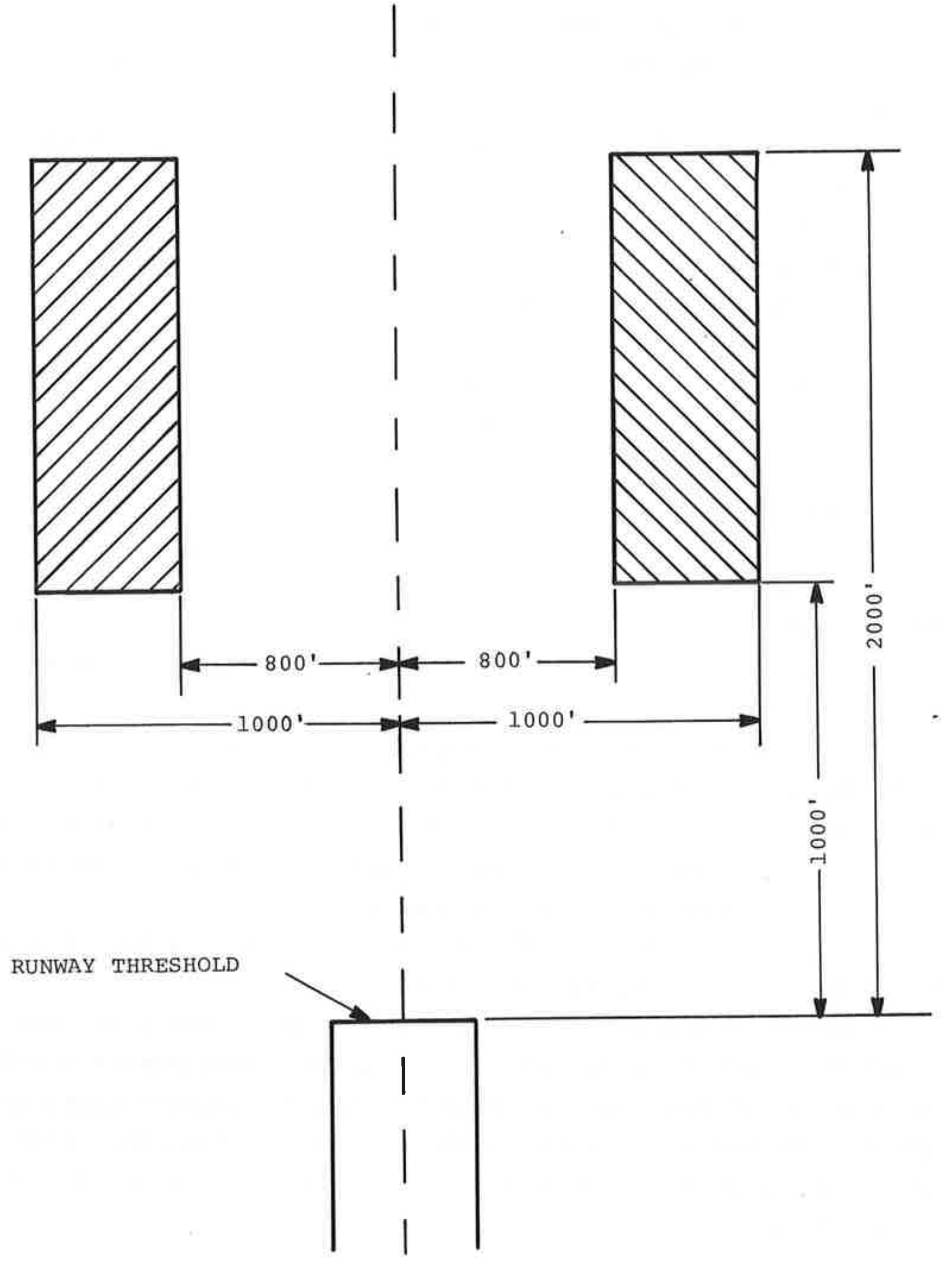


FIGURE 3. PREFERRED AREAS FOR THE LOCATION OF VAS METEOROLOGICAL TOWERS

at these locations including the following:

- These areas not on airport property

- Too many relatively large obstructions, e.g. large buildings, trees, elevated roadways, etc., in the immediate area.

- Areas are located in water, e.g. most areas at Logan Airport.

- Area is located too close to the approach path of another runway.

- Undesirable terrain features, such as small hills or gullies which will affect measurement accuracies.

If any of the above conditions are encountered the tower location shall be modified, such as moving its location closer to the runway threshold, or further to one side, depending on the terrain features in the approach region. Flat terrain obviously provides much greater flexibility in tower location. The services of a trained meteorologist shall be required at difficult sites in order to insure the selection of a tower site which will not result in erroneous tower reading.

At many airports runway thresholds are sufficiently near each other to lend themselves to their being instrumented by one tower. No more than two (2) runway thresholds shall be served by one tower. The maximum number of towers per airport shall be limited to seven (7) towers.

3.3.2.1.2 Towers. The towers shall be similar to Rohn, SSV type, free-standing steel towers.

All towers shall have a height of 50'. Two wind sensors shall be mounted at the 47' level and one wind sensor mounted at the top of the tower so that the sensor extends above the top of the tower. The enclosure for the wind sensor electronics shall be mounted on the side of the tower approximately 4' above the base.

The towers shall have the following mechanical properties:

- designed for 30 pounds/sq. ft. load, minimum
- Welded, not dipped galvanized construction
- must meet EIA spec. RS-222B
- painted international orange and white according to FAA standards

The towers shall have the following additional provisions:

- obstruction lighting kit, consisting of two lamps, red colored cover, 100 watts each, satisfying latest issue of FAA specification L-810, minimum 65' of #14 TW wire, necessary conduit and junction boxes for wire run from top to bottom of tower.
- grounding rods: two 5/8" diameter, 10' long stainless steel ground rods at the opposite ends of a 10' square around the tower as shown diagramatically in Fig. 4.
- Climbing ladder with safety cable
- Work platform at top
- Lightning protection: a lightning rod, extending above the highest point of the top-mounted wind sensor shall be installed with provision for an adequate connection from this point to one of the grounding rods at the base. Lightning masts shall be 1/2" dia. 36" long, solid copper complete with base connector for down lead. Mounting clamp shall be adjustable tinned bronze for attaching to pipes through 2" outside diameter.

3.3.2.1.3 Meteorological Sensors. The Wind Speed and Direction Sensors shall be similar to the Bendix Model 120 Aerovanes operating in conjunction with a Transmagnetic Corp. Model 5239 Signal Conditioning unit or a similar electronics device. The combined sensor-electronics unit shall meet or exceed the following specifications:

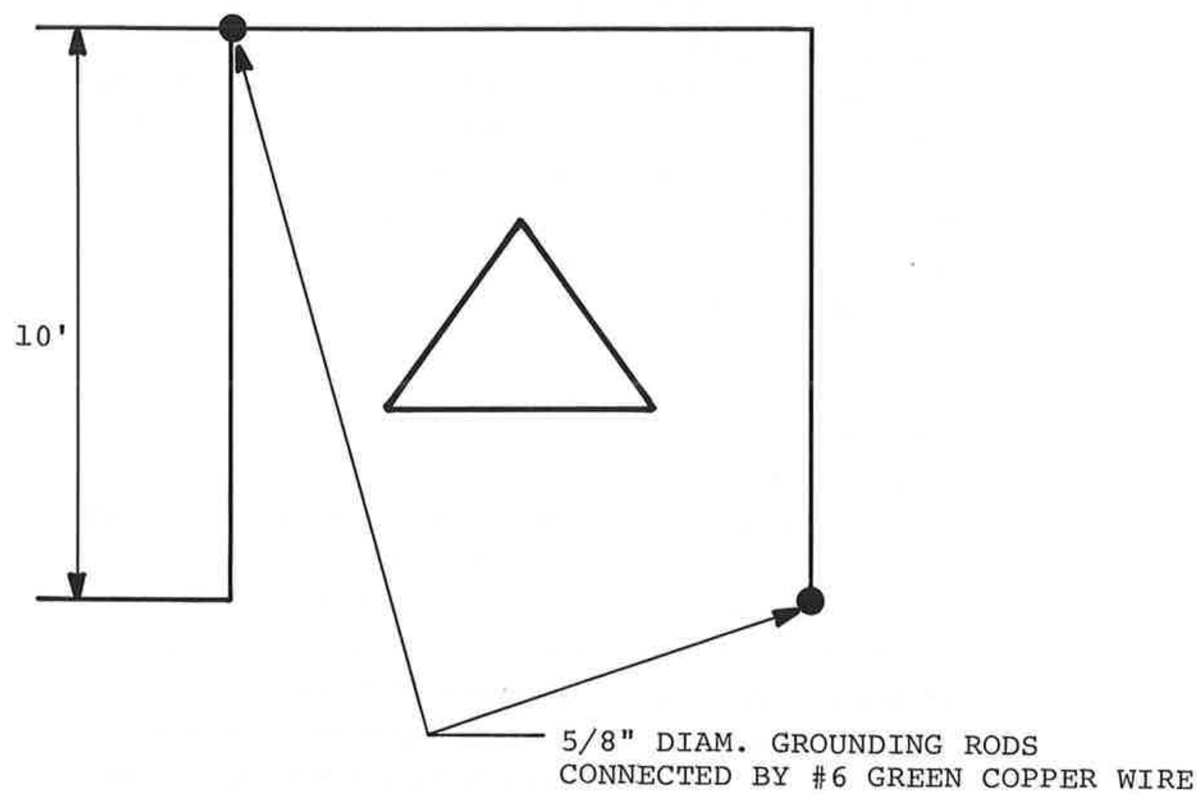


FIGURE 4, METEOROLOGICAL TOWERS GROUNDING ROD INSTALLATION

. Wind Speed Accuracy ±0.5KTS for 3 - 15KTS inputs
±1.0KTS for 15 - 100KTS inputs

. Wind Speed Scale Factor-3.906 V/100KTS
(2.5V = 64KTS)

. Wind Speed Threshold - 2KTS

. Wind Speed Distance Constant - 15 feet max

. Wind Speed Transducer - Tachometer (no lamps or LED's)

. Wind Direction Accuracy - ±2°

. Wind Direction Scale Factor - 3.51 V/360°
(2.5V = 256°)

. Wind Direction Threshold - 3KTS

. Wind Direction Distance Constant - 34 ft. max.

. Wind Direction Transducer - 60 Hz, 90V L-L Synchro

. The sensor shall survive 160KTS winds in operating condition.

. The sensor shall weigh less than 15 lbs.

. The sensor shall mount at the end of a vertical pipe.

. The sensor shall have a reference surface to be utilized in its alignment to within 1° of Magnetic North

. Reliability: Vendor shall furnish evidence of a mean-time-between-failure of at least one year (for the total speed-direction package) based on data from at least 3 customers over a time of 5 years.

. Tower-mounted sensor components shall be designed for simple removal, replacement or maintenance.

3.3.2.1.4 Data Acquisition Module. The Data Acquisition Module shall be similar to a Datel, Inc. Model DAS-16-L12B2A1B exhibiting the following general characteristics:

. Number of analog inputs - 16 (single ended)

. Input voltage range - 0 to +5V

. Channel input impedance - 100MΩ "ON" or "OFF"

. Channel Input Acquisition Time - 5M sec to 0.025%

. System Aperture Time - 50 nsec

- System Accuracy - ±0.05% FS
- Linearity - ±1/2 LSB
- System Throughput Rate - 25 kHz
- Temperature Coefficient - ±40PPM/°C
- System Control Inputs - Random/Sequential device select
  Convert
  Reset
  Strobe
- System output - 12 bits data
  4 bits channel address
  Serial data output
  End of Conversion pulse
  Multiplexer Shortcycle pulse
  Frame Synch pulse
- Operating Temperature Range - -55°C to 95°C
- Power Requirements - +5VDC, ±15 VDC

3.3.2.1.5 Data Transmission/Reception Modem. The Modem used to transmit the meteorological tower data from the towers to the receiving Modem in the VAS electronics console shall be similar to the Larse Corp. Model LCS-111-5440-0-G,K,O.W units operating in conjunction with the Model LCS-211-5440-0-B,I,W Receivers. The data shall be transmitted over standard FAA control lines consisting of twisted unshielded wire pairs. The salient features of these or equivalent Modems are:

- Data Inputs/outputs - sixteen, 0 to +5V
- Transmission - Continuous, line switching mode
- Transmission Rate - 5440 bps
  34 bits/word
  160 words/second

3.3.2.1.6 Power Supplies. Standard commercial power supplies shall be utilized to generate the required DC power sources (+20V, +5V, ±15V). The power supplies shall be hermetically sealed units capable of operating over a temperature range of -25°C to 95°C. If switching type supplies are utilized, additional RFI line filters shall be placed in the 115V, 60Hz input lines to the power supply and to the sensor synchro in order to prevent the power supply generated interference to affect the system electronics.

Each Power Supply output shall have an over-voltage and shortcircuit protection device. The device shall be a selfcycling type, thus eliminating the need for maintenance personnel having to go out to the tower to reset the circuit.

3.3.2.1.7 Failure Monitoring Electronics. The subsystem shall contain monitoring circuits the output of which is transmitted to the microcomputer and utilized to detect component malfunctions. As shown in Fig. 2, a 2.5V precision reference shall be utilized (Motorola MC1503AU or equivalent) to generate a known voltage used to check the A/D converter accuracy and drift. Precision resistor networks shall be utilized to monitor the power supply voltages, the 4.5V and 1.0V monitor outputs also providing an additional check on the A/D operation.

3.3.2.1.8 Power, Regulation and Transient Suppression. Each VAS Meteorological Tower shall be equipped with a SOLA Corp. Model CVS Ferroresonant line voltage regulator or an equivalent unit. In addition, a lightning arrestor, similar to the Joslyn Electronics Systems Model #1201 Surgitron shall be used to arrest any high voltages generated by lightning strikes or other occurrences.

A convenience duplex receptacle shall be available externally for plugin of test equipment.

The power regulator and lightning arrestor shall be mounted in a separate enclosure and the units wired according to the line schematic shown in Fig. 5.

In addition a TII Corp. Model 323T.F.S.-LC or similar surge arrestor shall be placed on the 115V, 60Hz input line

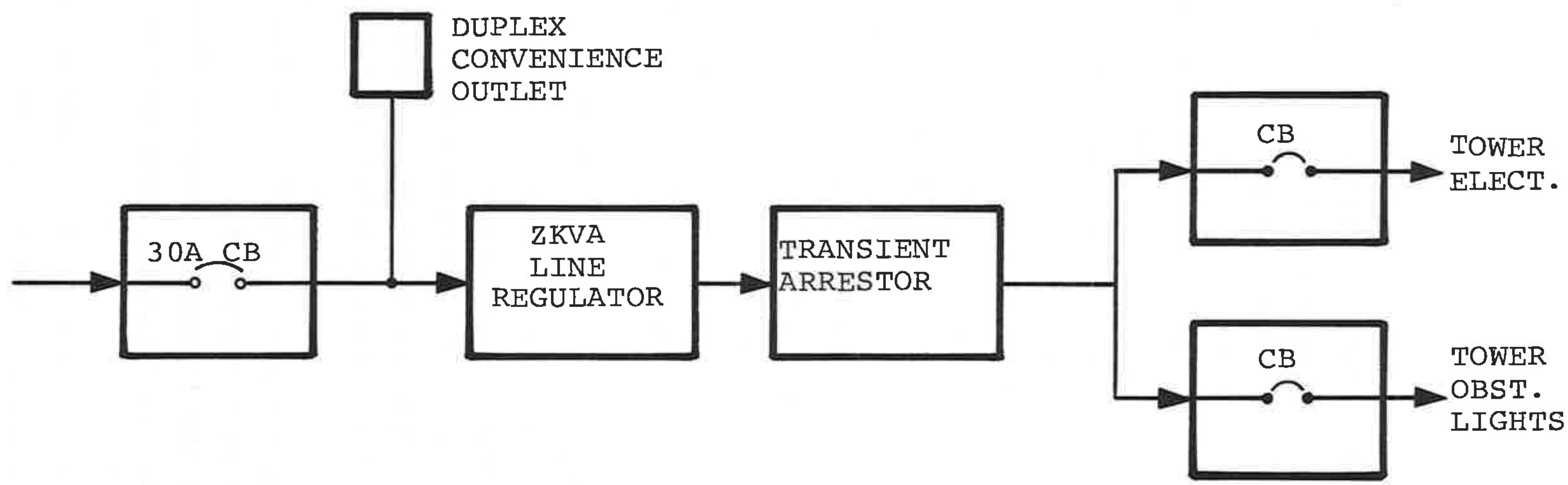


FIGURE 5. VAS TOWER POWER DISTRIBUTION

in the sensor electronics enclosure. GE Varistors or other suitable transient suppression devices shall be used on all the electronics enclosure input and output lines.

3.3.2.1.9 Electronics Enclosure. A dual enclosure shall be used to house the VAS tower electronics. The inner enclosure shall be a Hoffman NEMA EMI/RFI Type 12 unit, or a similar unit providing environmental protection for the tower electronics. An outer enclosure shall be utilized as a sun shield and shall also be a NEMA type unit but open to the atmosphere. The inner enclosure shall be cooled by a fan mounted in the outer unit and controlled by a thermal switch in the inner enclosure. If required, a thermostatically controlled heater shall be provided in the inner enclosure to maintain temperatures within the components operating ranges.

3.3.2.2 National Weather Service (NWS) F-420 Sensor. The NWS F-420 wind speed and direction sensor is at present the standard airport wind monitoring instrument. It is a cup and vane anemometer utilizing a tachometer as the speed sensor transducer and a Patin-type drive to sense vane angle. The output of the angle transducer is shown in Figure 6, the three voltages V_{AB}, V_{BC} and V_{CA} are generated by a continuous potentiometer containing a dual wiper connected to a voltage source and physically tied to the vane. Vane position is established by the unique relation of the three voltages at each angle.

The center-field wind speed and direction signals are brought into the control tower where they are tied to the controller's analog wind magnitude and direction displays. An amplifier (repeater) is used on the lines for isolation and power amplification.

The VAS instrumentation shall monitor the F-420 signals, determine the indicated wind speed and direction and display this information to the controller in digital form. (No use is made of this data for aircraft separation.)

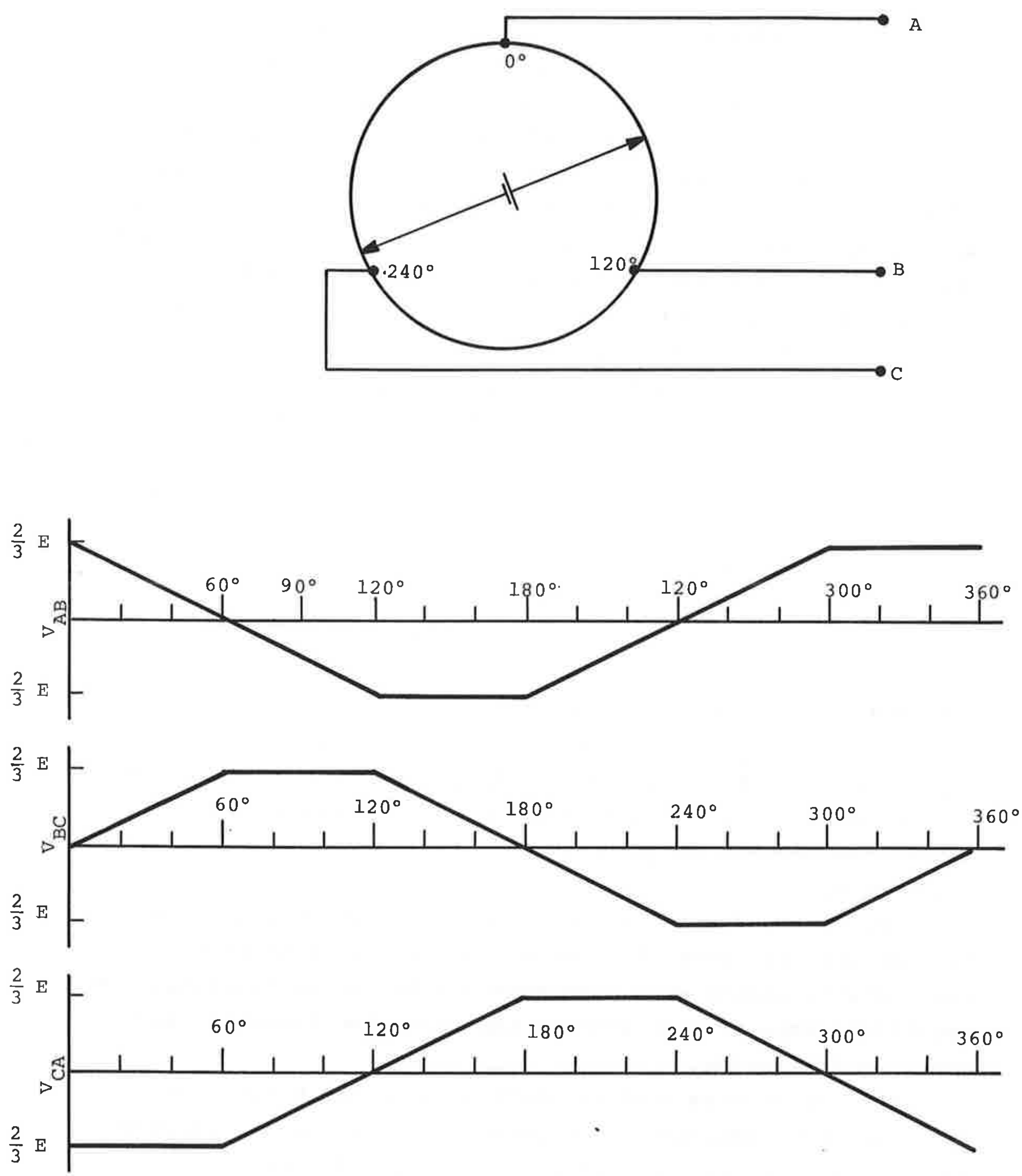


FIGURE 6. NWS CF SENSOR Θ OUTPUT

Since the F-420 is usually located near the airport center it is generally known as the Center-Field (CF) sensor and will be referred to as such.

Center-Field Sensor Monitoring Electronics. The CF sensor monitoring electronics shall be configured as shown in Figure 7.

The instrumentation shall be identical to that of the VAS towers with the following exceptions.

a. Precision instrumentation amplifiers shall be used to scale the CF sensor outputs. Large value input resistors shall be utilized on the amplifier input lines in order to insure minimal or no disturbance to the CF sensor signal lines caused by shorts in the VAS CF sensor instrumentation.

b. The Data Acquisition Module shall have a range of ±5 volts and a corresponding change in the data output format. The module utilized shall be similar to the Datel DAS-16-L12B2C3B with an operating range of -25°C to 95°C.

Although not indicated in the diagram in Fig. 7, the unit shall contain all transient suppression devices contained in the field units. The CF sensor monitoring electronics will be located in the equipment room of the airport control tower but not necessarily in the vicinity of the VAS console.

3.3.3 VAS Data Processing Subsystem. The VAS Data Processing Subsystem shall utilize an array of microcomputers. As shown in Figure 8, each VAS tower as well as the CF sensor shall be served by one microcomputer. All microcomputers shall be identical, the program contained in the Read Only Memory (ROM) of any one of up to eight (8) microcomputers shall be able to process data from any tower or the CF sensor. The function to be performed by any individual meteorological tower (VAS or CF) processor shall be selected via hardwired inputs to the microcomputer input lines.

The microcomputers shall be Intel SBC 80/20 single board computers or similar units with 8K or more of PROM and 2K of

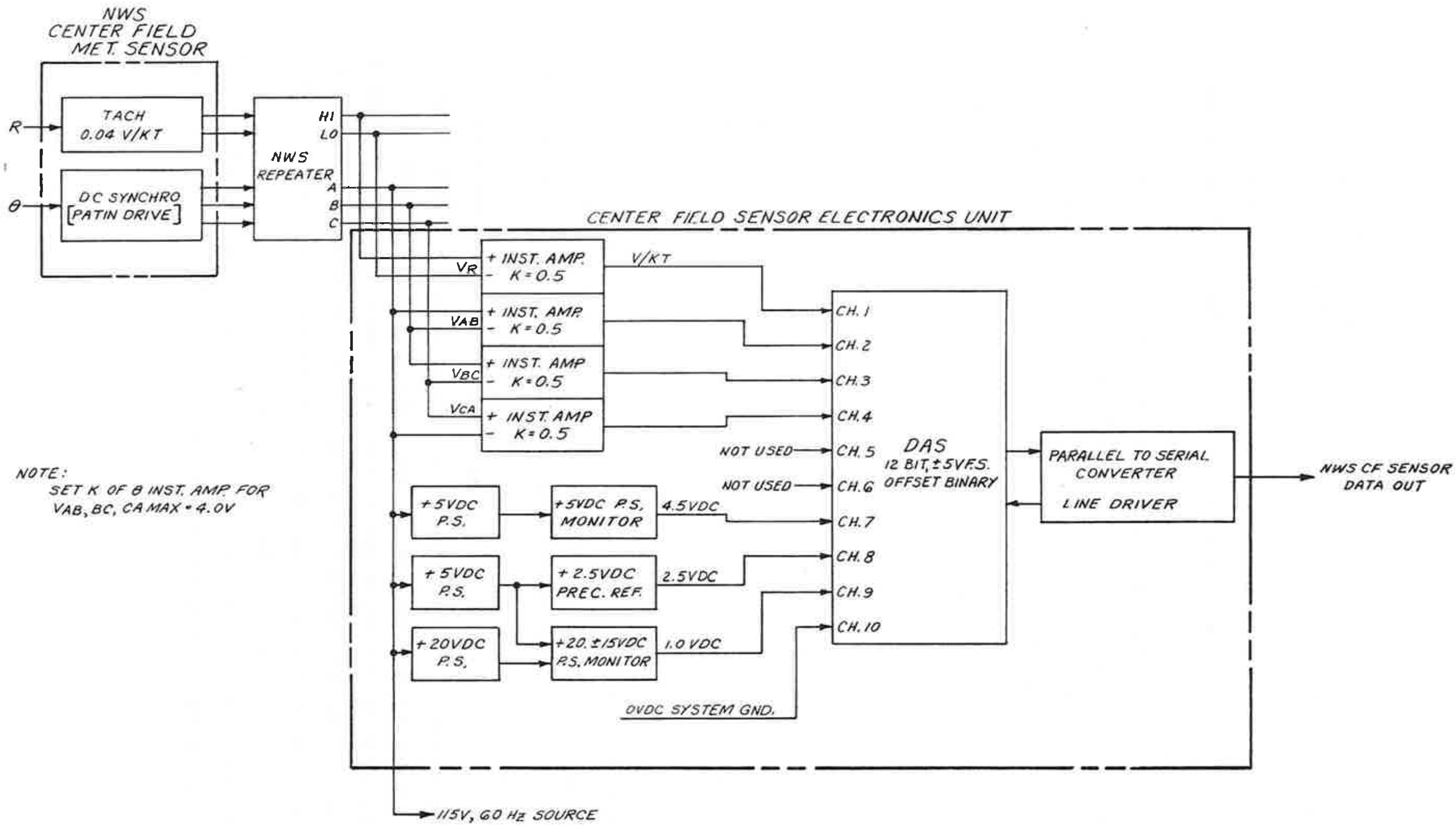


FIGURE 7. CF SENSOR OUTPUT MONITORING ELECTRONICS

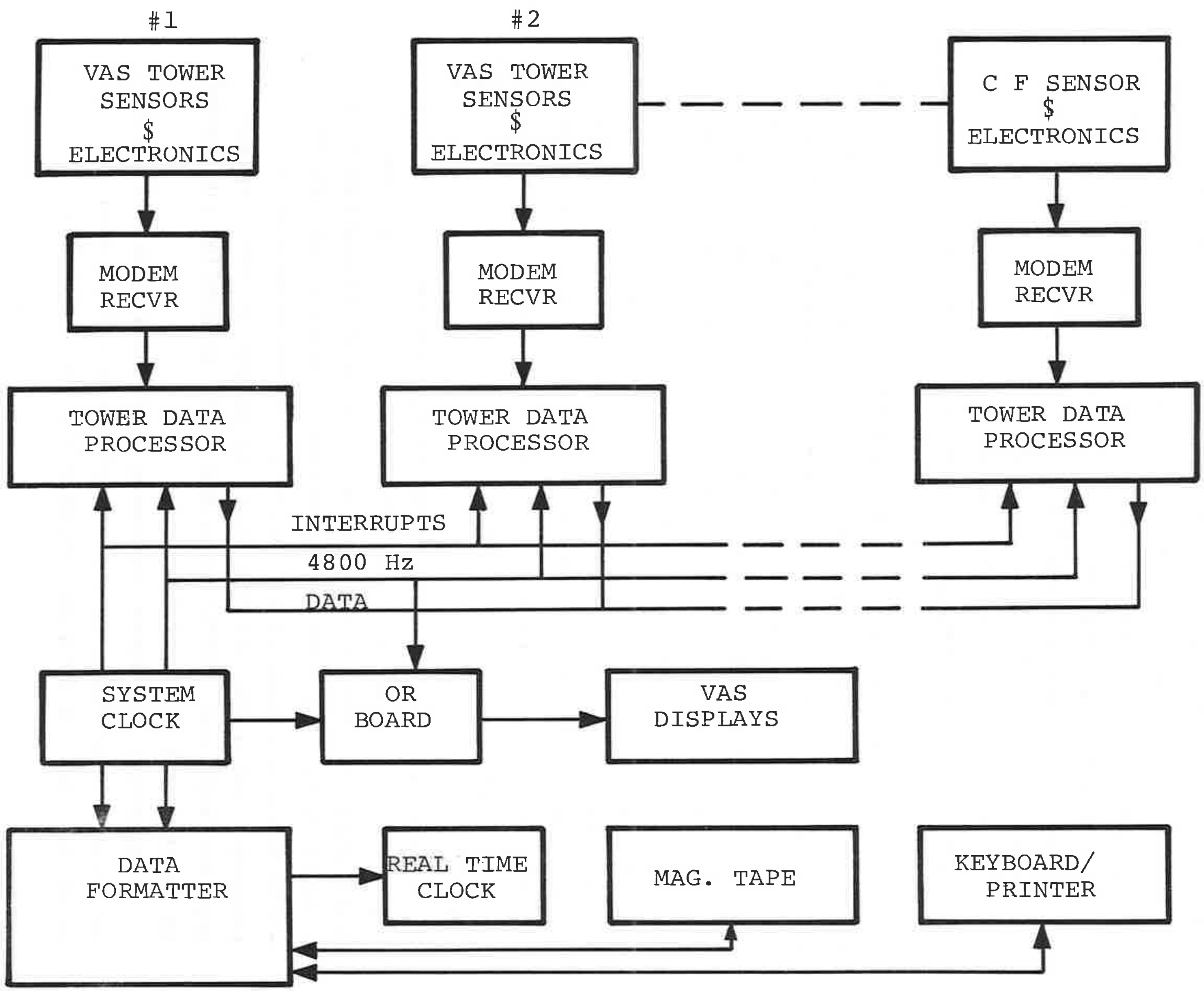


FIGURE 8. VAS DATA PROCESSING SUBSYSTEM

RAM. The computations performed by each meteorological data processing microcomputer shall consist of:

- . Check the validity of the incoming meteorological data.
- . Compute wind parameters.
- . Determine the allowable landing separations for the runways served by the tower.
- . Output VAS data to the displays.
- . Output system status and failures to the maintenance subsystem.

As shown in Figure 8, timing for the tower microcomputers shall be provided by the system clock, another microprocessor unit (SBS 80/20 or similar) programmed to perform the clock function. The serial data output from each microcomputer is input to the "OR" board which outputs the data and a clock to the VAS displays. The serial data output rate shall be 4800 baud and shall be transmitted differentially.

3.3.3.1 VAS Tower Data Processing Program. The VAS Tower Data Processing program shall follow the general outline shown on pages 33 to 64. The program shows the implementation of the O'Hare VAS software and is included only as an example. Specific runways are referenced here only to better demonstrate the use of the software.

Microcomputer cold start initialization takes place after application of power when the CPU automatically receives a reset pulse or when a reset pulse is generated manually using a reset switch for each microprocessor. During cold start, while the microcomputer accumulates the one minute wind parameter averages, all 8's shall be output to the displays and the "RED" and "GREEN" bits are "off" indicating the system is in the cold start state.

Processor operation commences upon the receipt of a clock interrupt. All data are output and a new set of data are read in. The new data are checked for the following:

- The End of Word (EOW) pulses from the receiving modem arrive within the allotted time interval.
- The channel address check-sum equals 55 (10 channels)
- The monitored voltages are within the preset limits.
- There is agreement between at least two wind magnitude (R) and wind direction (Θ) sensors.

If the incoming data are not accepted on the first Read, a second Read is executed immediately. If the data still fail to meet the above criteria, an error count is started. If the tower data fails to pass on eight successive 1/2-second samples, the tower is declared to have failed and the tower failure bit is set. Until the tower is failed, the last good data value is output to the displays.

If the incoming data are valid, they are processed to determine the average value of Wind Speed ($\bar{R}$), average wind direction ($\bar{\Theta}$), gust (G) and the allowable landing separations for the one or two runways served by the tower.

The $\bar{R}$ and $\bar{\Theta}$ are calculated using a running 128-sample (64-second) average. The incoming instantaneous values of R and Θ are resolved into North ($U=R\cos\Theta$) and East ($V=R\sin\Theta$) components. The component 128 sample average ($\bar{U}$ and $\bar{V}$) is updated and a new value of $\bar{R}$ and $\bar{\Theta}$ calculated $[R=(\bar{U}^2+\bar{V}^2)^{1/2},\ \Theta=\tan^{-1}(V/U)]$. The new values of $\bar{R}$ and $\bar{\Theta}$ are checked for reasonableness, the maximum change limited to 2 KTS and 20°. If the new $\bar{R}$,$\bar{\Theta}$ values exceed these limits the data is invalid and a failure count started.

Wind Gust Values (G) are determined using a running four (4) sample (2-second) average of R. The four sample average is compared with the current $\bar{R}$ value. If the difference equals or exceeds 9 KTS it is declared a gust. The value of $\bar{G}$ is output for 64 samples (32 seconds) unless a new and large value of G supercedes it, i.e., a running 32-second window is used, and the largest 4 sample average in the window whose magnitude equals or exceeds the concurrent average $\bar{R}$ by 9 KTS is output as a Gust.

The separation requirements are computed using the VAS elliptical algorithm shown in Fig. 14, and the details of which are shown on pages 53-55 .The major axis of the ellipse is aligned with the runway centerline. The region enclosed by the inner ellipse is the "RED" region. If the wind vector is inside or on the boundary of this region, the condition is "RED" and the standard 3/4/5/6 separations must be maintained. The region outside the inner ellipse is the "GREEN" region. When the wind vector is outside the inner ellipse, the condition is "GREEN" and all aircraft separations may be reduced to 3 NM. An outer ellipse is used to generate a buffer which reduces frequent transitions between the RED and GREEN states.

The rules governing the RED and GREEN states are as follows:

- During cold start, or in case of tower failure both GREEN and RED are "OFF"
- If the wind vector $\bar{R}\underline{|\Theta}$ is inside the inner ellipse, RED is "ON"
- To transition from the RED to the GREEN state requires 128 consecutive samples (64 seconds) outside the outer ellipse.
- To transition from the GREEN to the RED state requires the wind vector to enter the inner RED region. The transition to the RED state takes place without any delay, requiring the RED region to be entered in only one 1/2-second sample.

The tower processor output data formats shall be configured as shown on pages 32-64. Runway 1 and 2 are referenced to the two runways served by a tower, runway one always being the lower numbered runway. As an example, tower 1 at O'Hare serves runways 04R and 32L. Runway 1 in the tower processor output data format is 04R and runway 2 is 32L.

The output from each tower processor is serial using the microcomputers USART device such as an 8251 to format and output the data.

Procedures Used for the Vas Tower Program

PUTVASDATA (33)

PUTVASDATA is responsible for writing out the data stored in the VAS$DATA array during the previous cycle. It is called from the MAIN procedure, and calls the SET$TIMER and STOP$TIMER routines to control timeout of the USART. The interrupt procedures, USART$INTERRUPT and TIMER$INTERRUPT are used to restart the processor from the Halt state which is entered after each byte is written to the USART. Processing consists of the following steps:

(1) Compute a checksum on bytes 3 through 7 of the data. The checksum is stored in byte 8. The algorithm exclusive or's each byte with the previous checksum value.

(2) Initialize the USART.

(3) Loop until 27 bytes are sent out or until the USART times out. The timeout interval is 2 milliseconds.

(4) Disable transmit for the USART.

GET$TOWER$DATA (37) - Chart 3, Table 8

GET$TOWER$DATA controls the input of data from the tower sensors. The format of the input data is shown in Table 8. Chart 3 outlines the main logic used by GET$TOWER$DATA. It is called from the MAIN procedure and calls GET$SENSOR$DATA (36) and SELECT$VECTOR (20). Any errors encountered during the reading are stored in VAS$DATA byte 12; the low nibble contains the results of the first attempt and the high nibble the results of the second attempt (if one is needed). If there is an error, the error count is incremented. Eight consecutive error readings are considered a permanent error, and this is flagged in VAS$DATA byte 4. Table 8 shows the logic used to determine the error display action.

GET$SENSOR$DATA (36) - Table 7

GET$SENSOR$DATA reads the data from the sensors using the LARSE interface. The sensor identification is used to compute a checksum to verify that all sensors are read correctly. GET$SENSOR$DATA is called by GET$TOWER$DATA. It calls:

SET$TIMER - set 8 millisecond timeout on LARSE

STOP$TIMER - cancel timeout interval

STORERAWDATA - assemble input data for processing and output

TEST$VOLTAGES - test inputs against tolerance limits to check for voltage failure

TIMER$INTERRUPT and LARSE$INTERRUPT are used to restart the processor when a byte of data is received or when the timeout interval expires. If the read is successful, the procedure returns True; otherwise, it returns False to GET$TOWER$DATA. Table 7 shows the tests applied for determining a good read.

STORERAWDATA (34)

STORERAWDATA converts the input data to a format useful for processing and output. Center tower data is converted to signed word format.

TEST$VOLTAGES (35)

TEST$VOLTAGES is used to test the voltage tolerances of the variables GV, P1, P2, P3. It uses the ABSVAL routine (4) to compute the absolute value of the readings and nominal values. TEST$VOLTAGES returns True if all values are within tolerance, and False if one or more is unreasonable.

SELECT$VECTOR (20)

SELECT$VECTOR controls the selection of the R and THETA values to be used. It returns the value True if an acceptable value of R and THETA are selected for a tower runway or if the tower is the center tower; otherwise, it returns False. SELECT$VECTOR is called from GET$TOWER$DATA. It calls R$SELECT and T$SELECT.

R$SELECT (18) - Table 9

R$SELECT compares the readings for R from each of the three sensors, and selects one to use for later processing. The decision logic for choosing the R is shown in Table 9. The results of the comparison of the R values are returned in VAS$DATA bytes 10 and 11. R$SELECT is called by SELECT$VECTOR. It calls ABSVAL (4) to determine the difference between each pair of R values. R$SELECT returns True if a value is selected; it returns False if the R values do not match.

T$SELECT (19) - Table 10

T$SELECT compares the readings for THETA from each of the three sensors, and selects a value to be used for later processing. The decision logic for choosing the THETA value is shown in Table 10. The results of the comparison of the THETA values are returned in VAS$DATA bytes 10 and 11. T$SELECT is called by SELECT$VECTOR. It calls:

SCALE$THETA (5) - force THETA between 0 and 359 degrees

T$LIMIT (14) - test whether a pair of angles are within 20 degrees of each other, returning True if so; also returns the difference between the values

T$SELECT returns True if a value is selected; it returns False if the THETA values do not match.

PROCESS$TOWER$DATA (47)

PROCESS$TOWER$DATA provides the control for processing the data obtained from the sensors. It is called from MAIN. It checks for a permanent error condition set by GET$TOWER$DATA and, if so, calls DISPLAY$ERROR to set the error conditions and returns. If there is data available, PROCESS$CENTER or PROCESS$RUNWAY is called, depending on the tower identification.

DISPLAY$ERROR (17)

DISPLAY$ERROR sets up the permanent error conditions: R = 88, THETA = 888, GUST = 88, and Red status.

PROCESS$CENTER (38)

PROCESS$CENTER controls processing of center tower data. Since there is no averaging of center tower data, it sets the FIRST$TIME switch off and calls PROCESSMETDATA. PROCESS$CENTER is called from PROCESS$TOWER$DATA.

PROCESSMETDATA (27)

PROCESSMETDATA sets the calculated variables (R, R$BAR, THETA$BAR, GUST, TOWER$R, VAB, VBC and VCA), and calls STORECALDATA (23) to move them to VAS$DATA. Calculations are done bv CALCMETR (26), which converts R to BCD by table lookup, and by CALCMETTHETA (25) which computes THETA in BCD from VAB, VCA and VBC according to the decision rules in Table 11.

PROCESS$RUNWAY (39)

PROCESS$RUNWAY controls the processing of runway data. It is called by PROCESS$TOWER$DATA if the processor gets input from runway tower sensors. It calls PROCESS$SENSOR$DATA to compute R$BAR and THETA$BAR and GUST, and calls NEWSTATUS to determine the Red or Green status for each runway associated with the tower. The runways are processed according to the order of entries in RUNWAY$DATA (see Table 6) starting with the last runway entry for the tower and working forward in the table.

PROCESS$SENSOR$DATA (24) - Chart 4

PROCESS$SENSOR$DATA is the control logic for processing the data obtained from runway tower sensors. Its steps are outlined in Chart 4. It is called by PROCESS$RUNWAY. It calls AVERAGE (21) to determine the running average value of R and THETA, and stores these in R$BAR and THETA$BAR. $\overline{\text{R}}$$BAR is calculated using ROOTSQRT if an unnormalized value of R is used and GET$BCD if a normalized R is chosen. It calls GET$GUST (22) to determine whether there is a value for wind gust, and, finally, calls STORECALDATA (23) to save the values in VAS$DATA.

AVERAGE (21)

AVERAGE maintains three tables with the last 128 readings of R (stored in Z1), and the two linear components of THETA, U and V (stored in U1 and V1). It is called by PROCESS$SENSOR$DATA. It computes values US and VS from the current reading of THETA (using SIN and COS routines and a multiplication routine PROD12X8). It stores the current values in Z1, V1 and U1, and updates the running average by calling AVGSUM (12). The current running average of each of these variables is stored in the zero entry of each array for use by PROCESS$SENSOR$DATA.

AVGSUM (12)

AVGSUM is called by AVERAGE. It has two parameters, SPTR and D. SPTR is the address of an array of 131 words which is used to store data for computing a running average. D is a word whose value is the difference between the next entry to be added to the array and the entry about to be replaced. AVGSUM maintains the current sum of all entries in the array in the two entries 129 and 130. When called, it adds the value of D to this sum, using 24 bit signed arithmetic, and then divides the sum by 128 (using shifts) and returns the new average value. AVGSUM calls the utility routines NEG (3), ABSVAL (4), ADD3 (9) and SUB3 (10).

GET$BCD / ROOTSQRT (15)

These two routines are used to calculate values for GUSTSX (the candidate gust value used by GET$GUST (22)), VDU$INDEX, and to return a BCD value of R$BAR. The routine used depends on whether a normalized or unnormalized value of R is used. The appropriate routine is called from PROCESS$SENSOR$DATA (24).

ARCHTAN (13)

ARCHTAN is used to calculate the angle, given its U and V components. It is called by PROCESS$SENSOR$DATA to calculate the value of THETA$BAR.

GET$GUST (22) - Table 12

GET$GUST determines the current value of the GUST variable. It is called by PROCESS$SENSOR$DATA after a new value of R has been determined to see if this value is a gust. The result of the calculation is stored in the variable GUST. The decision logic for determining gusts is presented in Table 12. A running average of the last four values of R is calculated. If this average exceeds the current value of R$BAR (the average over 128 cycles) by 9 knots, the average is a candidate for being a gust. The routine maintains the two highest gusts in the past 128 samples. The highest is stored in OLD$GUST and the next highest in NEW$GUST. The new candidate is compared with the current values of OLD$GUST and NEW$GUST, and, if higher, displaces the existing values. The values of OLD$GUST and NEW$GUST are then aged, and if either has been in force for 128 cycles it is set to zero. Finally, the variable GUST is set to the BCD value of the current OLD$GUST.

GET$GUST relies on the setting of the variable GUSTSX by the routine GET$BCD or ROOTSQRT (15). GUSTSX is the current value of R$BAR, scaled to compare with the other values of gusts.

STORECALDATA (23)

STORECALDATA sets the values of THETABAR, RBAR, GUST and R in VAS$DATA locations. It is called by PROCESS$SENSOR$DATA and by PROCESSMETDATA.

NEWSTATUS (30) - Chart 5, Table 13

NEWSTATUS determines the Red or Green status of a runway. It is called by PROCESS$RUNWAY. The logic is outlined in Chart 5. Table 13 shows the decision logic for determining Red or Green status. NEWSTATUS first computes the relative wind angle, PHI, for the runway by subtracting the runway orientation from THETA using ADD$ANGLE (16). The value of PHI is forced to the range 0 - 359 by calling ADD$ANGLE, if necessary. CONDX is then called to evaluate the conditions for setting Red or Green. The value returned by CONDX is used to set the status appropriately and, if a change from Red to Green is pending, to increment the Greencount. NEWSTATUS returns the Red or Green condition to PROCESS$RUNWAY.

CONDX (28) - Table 13

CONDX evaluates the conditions for setting Red or Green status and returns a value to NEWSTATUS indicating the actions to be executed. CONDX first calls GET$BAND to compute the index, PHIX, into the table of limits of the Red and Green sectors. This guardband table is named R$RED and R$GREEN (Table 11). GETBAND determines the quadrant and rounds the value of PHI to the nearest 5 degrees. The index is adjusted if the value of PHI is in the second or fourth quadrants because the table contains values for the first quadrant only. CONDX then uses the value of PHIX to determine whether the current R$BAR (scaled and stored in TOWER$R) puts the runway into Red or Green status. Table 13 gives the decision rules for setting status.

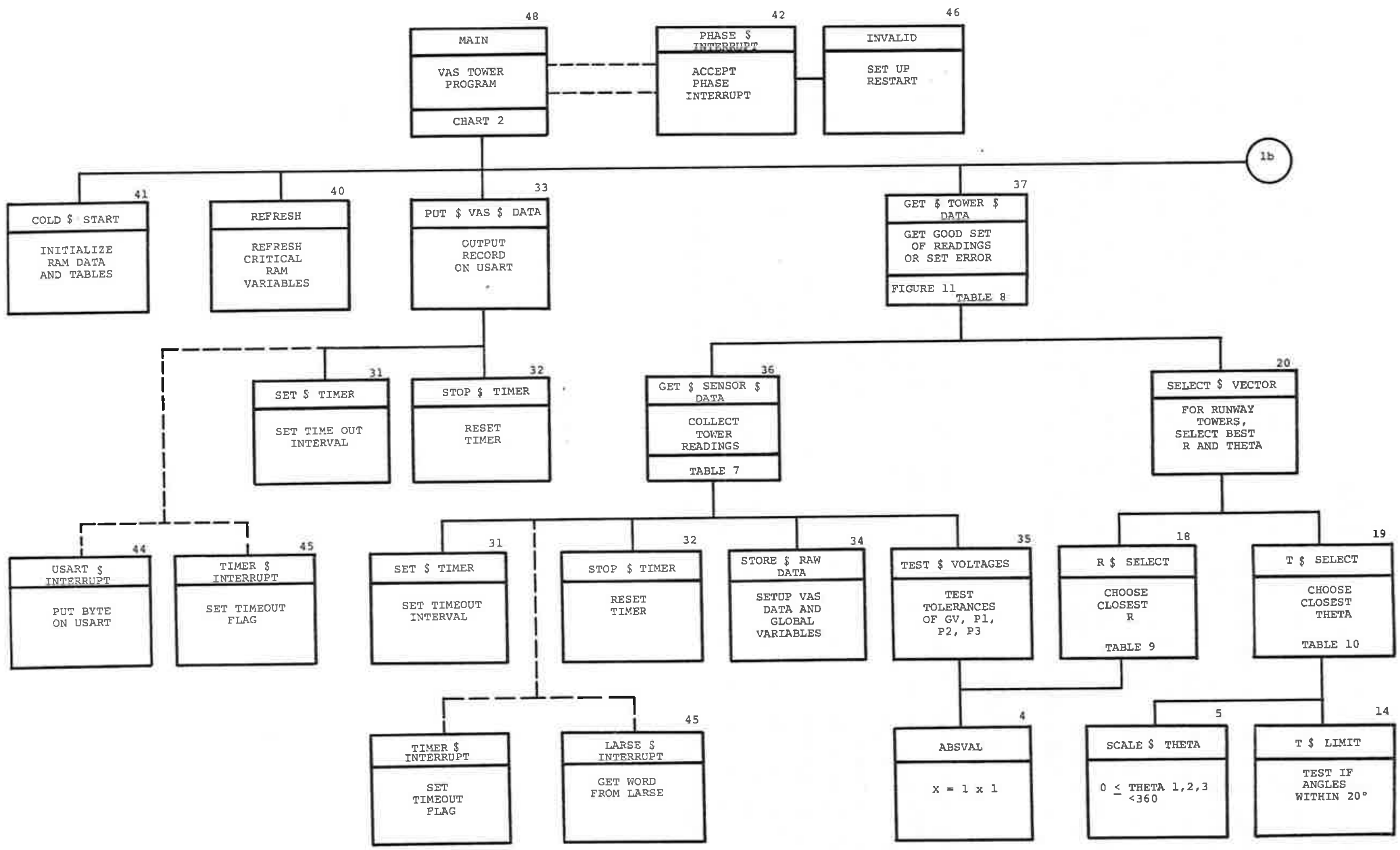


FIGURE 9. VAS TOWER PROGRAM STRUCTURE

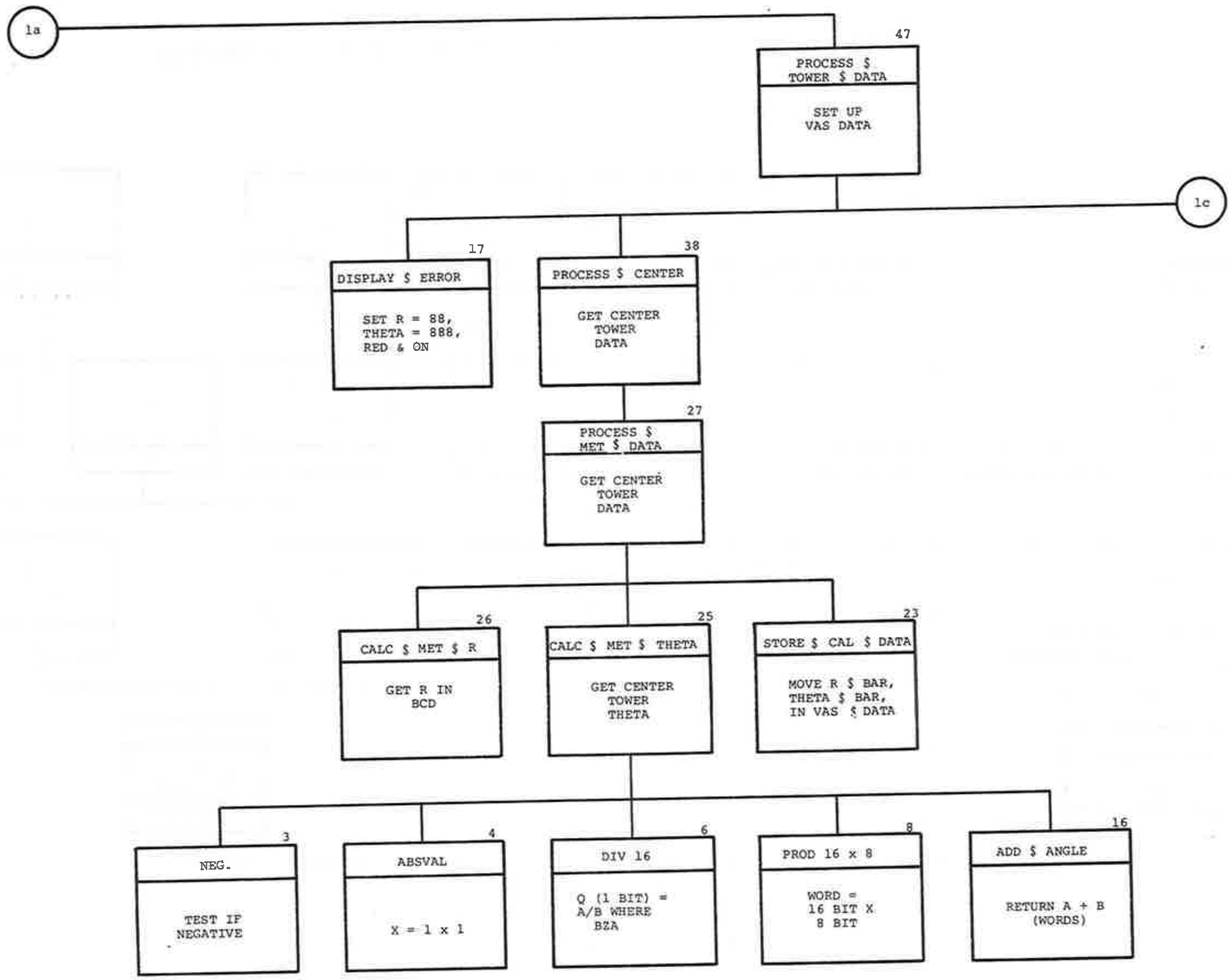


FIGURE 9. VAS TOWER PROGRAM STRUCTURE (CONTINUED)

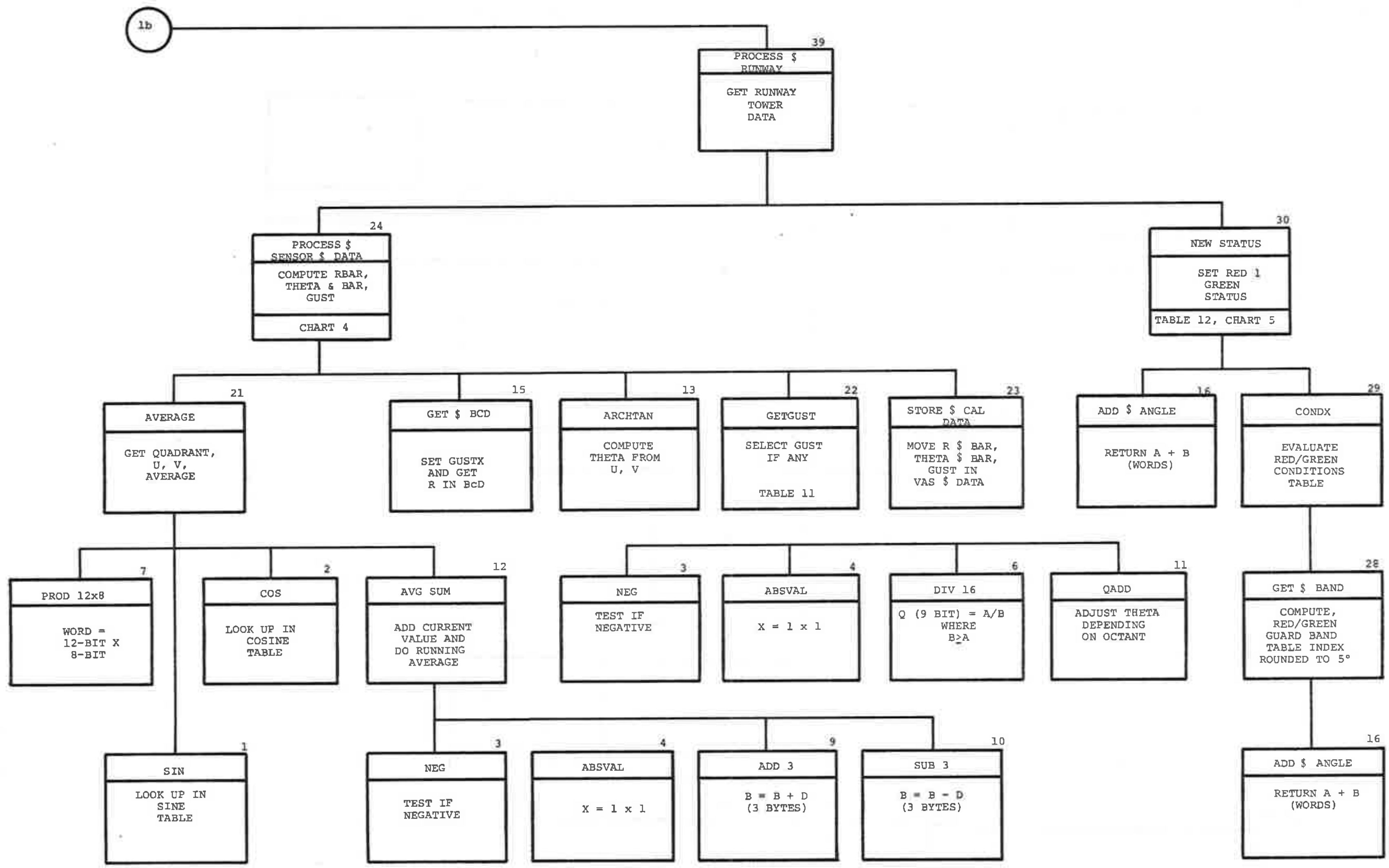


FIGURE 9. VAS TOWER PROGRAM STRUCTURE (CONTINUED)

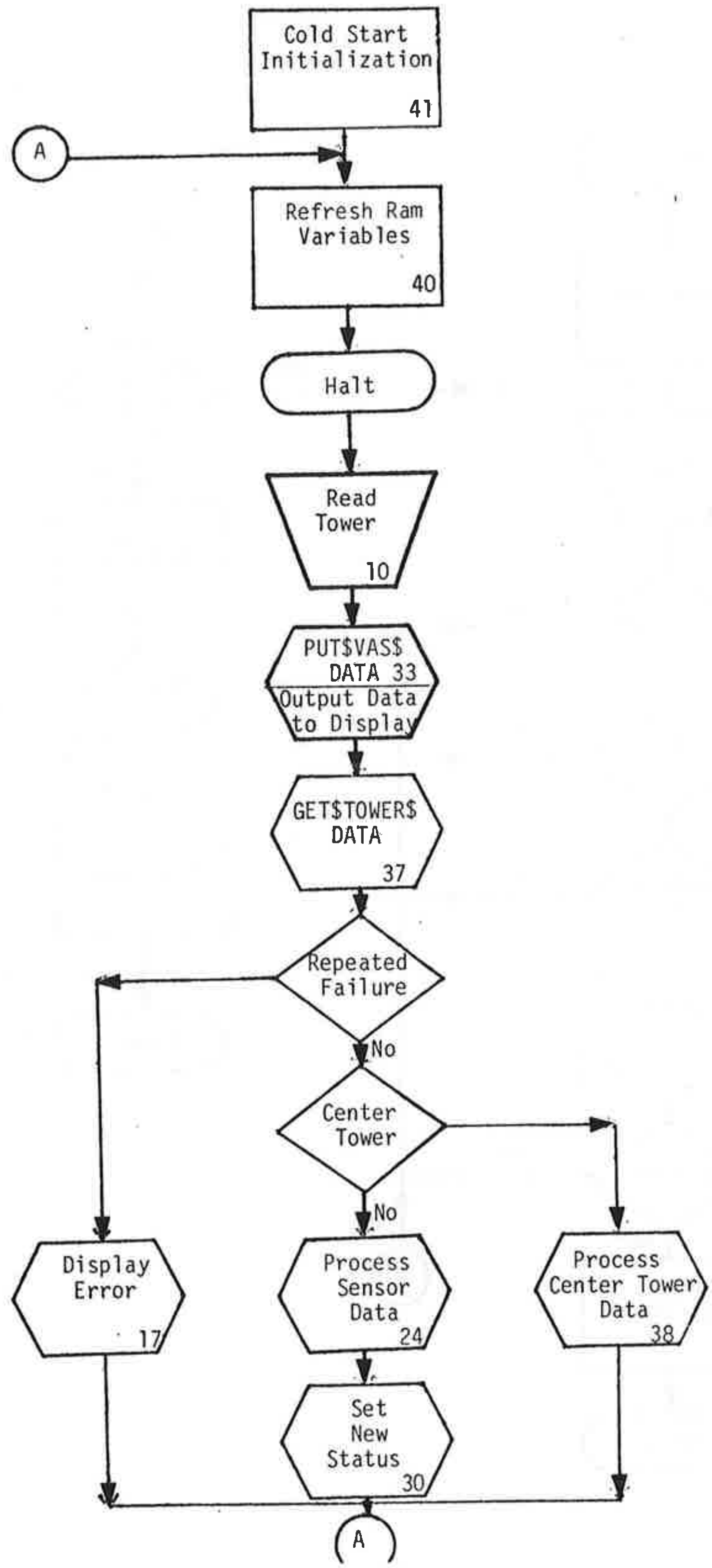


FIGURE 10. VAS TOWER PROGRAM MAIN LOOP

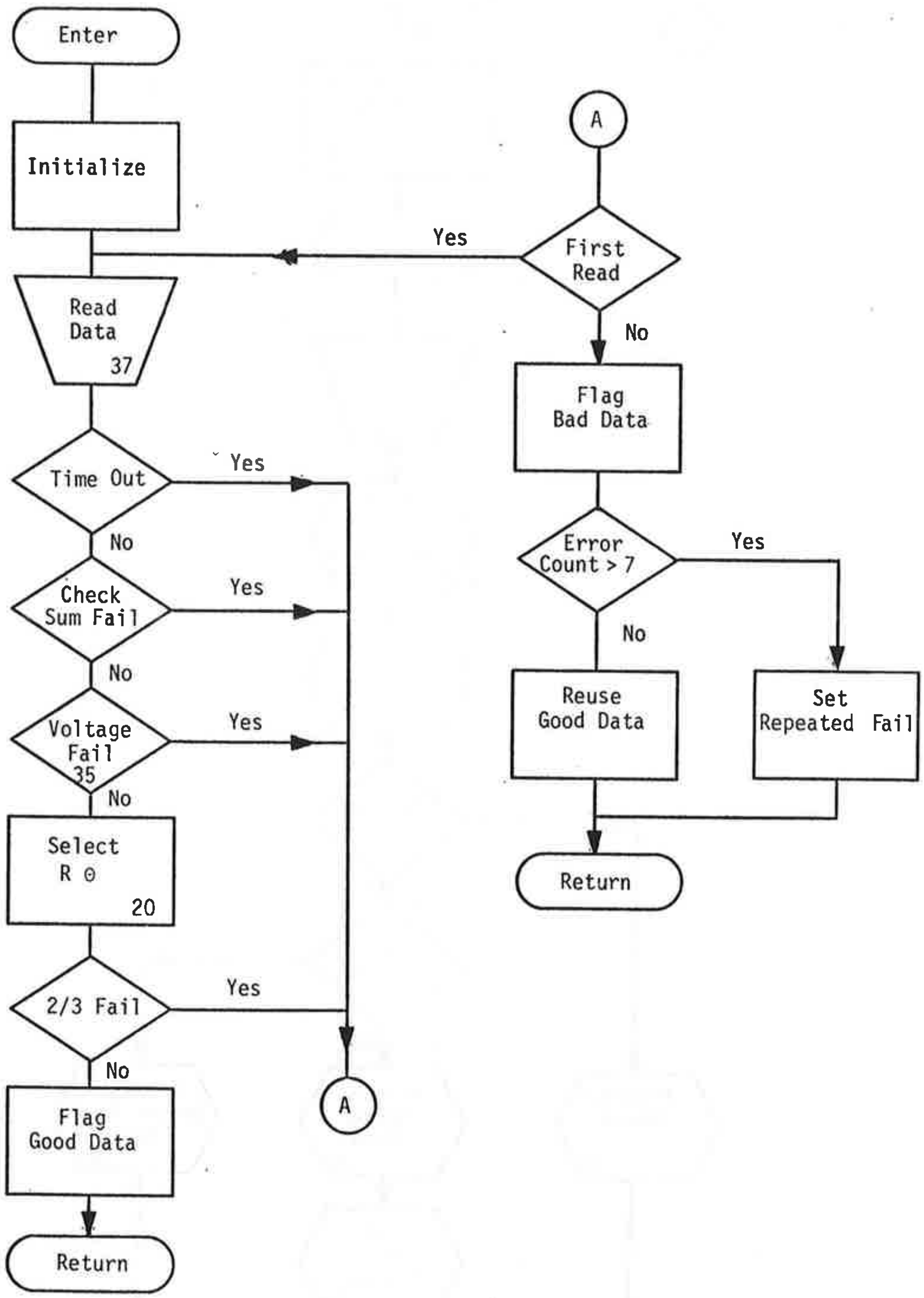


FIGURE 11. GET TOWER DATA

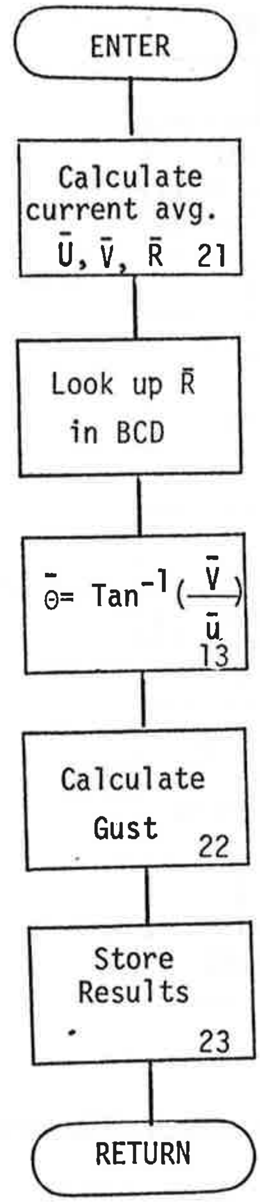


FIGURE 12. PROCESS SENSOR DATA

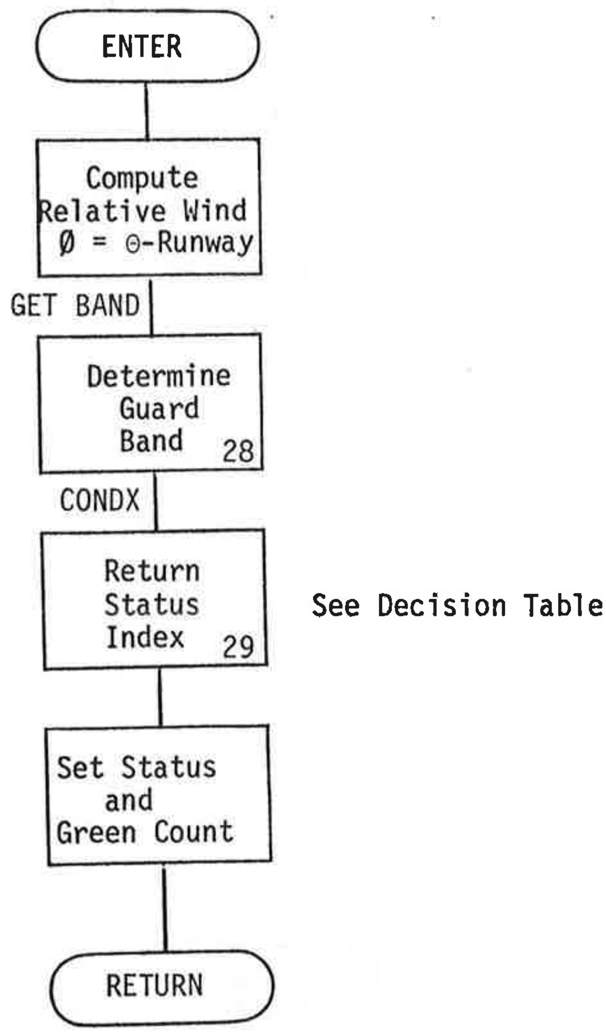


FIGURE 13. GET NEW STATUS (Invoked for each Runway)

TABLE 1 FORMAT OF TOWER PROCESSOR OUTPUT DATA

BYTE	SYMBOLIC	CONTENTS
0	SYN	SYN = 16H
1	SYN	SYN = 16H
2	STX	STX = 02H
3	RW2: G | R ; RW1: G | R ; Tower ID	Runway R/G Flags + Tower ID
4	$\bar{\Theta}$ Units | | f	$\bar{\Theta}$ Units + f = Repeated Failure Bit
5	$\bar{\Theta}$ Hundreds | $\bar{\Theta}$ Tens	$\bar{\Theta}$ Hundreds + $\bar{\Theta}$ Tens
6	$\bar{R}$ Tens | $\bar{R}$ Units	$\bar{R}$ Tens + $\bar{R}$ Units
7	$\bar{G}$ Tens | $\bar{G}$ Units	Gust Tens + Gus .ts
8	Check Sum	Modulo 2 Sum of Bytes 3 - 7
9	MSB R	$\bar{R}$ in Binary where lsb = 1/2 Knot
10	Sensor Select Flags	See Definition
11	Sensor Fail Flags	See Definition
12	Detected Error Code	See Definition
13	MSB R1 LSB	R1 - 8 msbs of Raw Data
14	Θ1	Θ1 - 8 msbs of Raw Data
15	R2	R2 - 8 msbs of Raw Data
16	Θ2	Θ2 - 8 msbs of Raw Data
17	R3	R3 - 8 msbs of Raw Data
18	Θ3	Θ3 - 8 msbs of Raw Data

TABLE 1 (cont'd.)

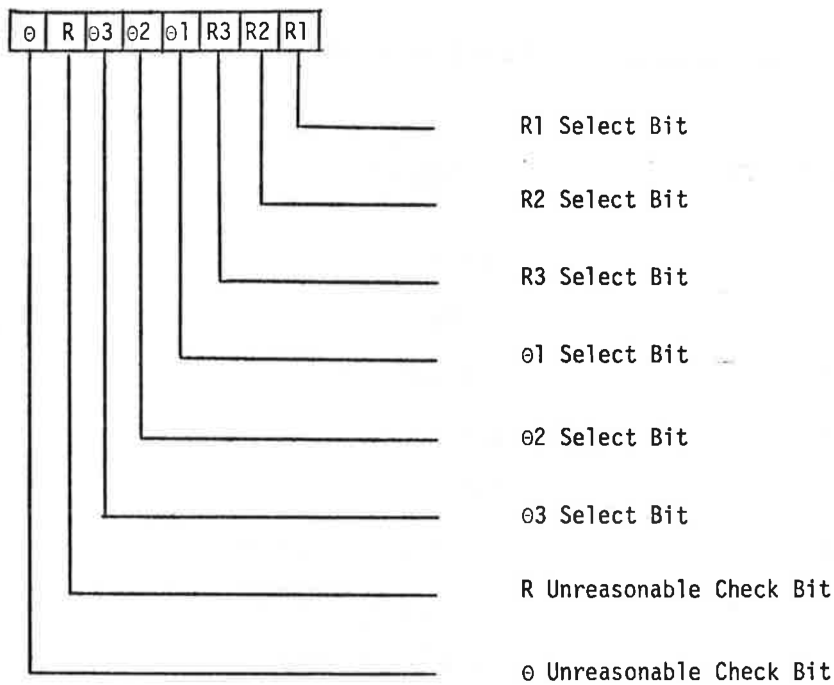
BYTE	SYMBOLIC		CONTENTS
19	msb P1	4.5v	P1 msb
20	P1 lsb | msb P2		P1 lsb + P2 msb
21	P2 lsb		P2 lsb
22	msb P3		P3 msb
23	P3 lsb | msb GV		P3 lsb + GV msb
24	GV lsb		GV lsb
25	ETX		ETX =03H
26	SYN		SYN = 16H

FORMAT EXCEPTION FOR CENTERFIELD TOWER OUTPUT DATA

BYTE	SYMBOLIC	CONTENTS
13	R1	R1 - 8 msbs of Raw Data
14	S1	S1 - 8 msbs of Raw Data
15	S2	S2 - 8 msbs of Raw Data
16	S3	S3 - 8 msbs of Raw Data
17	msb Z	Z - 8 msbs of Raw Data
18	Z lsb | X	Z - 4 lsbs of Raw Data

TABLE 1 (cont'd.)

SENSOR SELECT FLAGS (BYTE 10)



SENSOR FAIL FLAGS (BYTE 11)

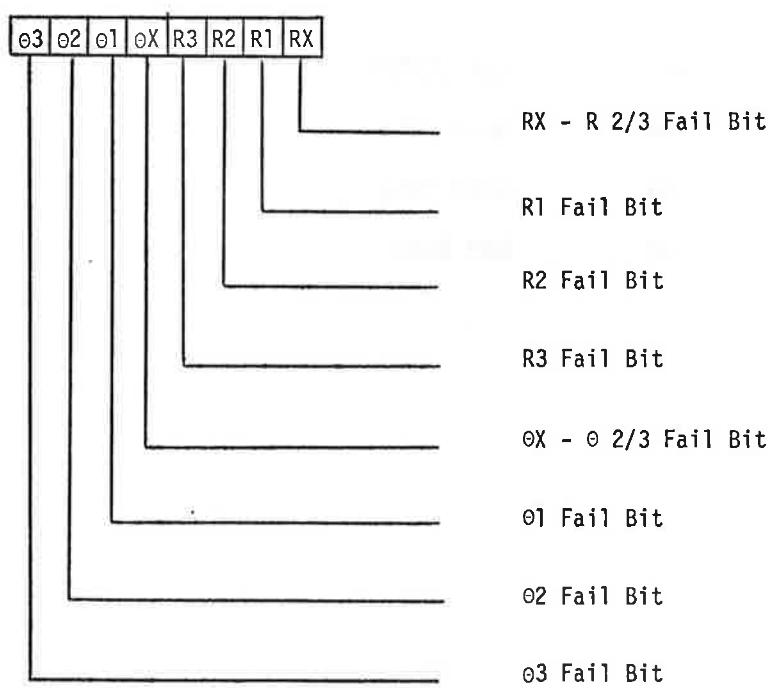
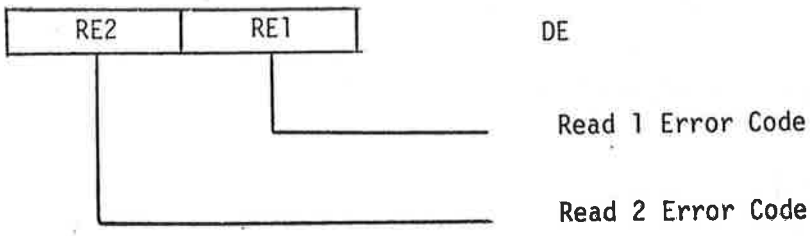


TABLE 1. DETECTED ERROR CODE (BYTE 12) (Cont'd)



READ ERROR CODE	FAILURE
0	No Error
1	Time Out
2	Check Sum ≠ 55
3	R 2/3 Fail
4	Θ 2/3 Fail
5	P1 ≠ 4.5 ± 0.400V
6	P2 ≠ 2.5 ± 0.005V
7	P3 ≠ 1.0 ± 0.150V
8	GV ≠ 0.0 ± 0.050V

RE2	RE1	DATA STATUS
0	0	Good Data
0	>0	Good Data
>0	>0	Bad Data

TABLE 2 FORMAT OF SENSOR INPUT DATA
RUNWAY MET TOWERS (1-7)

CHANNEL	SENSOR ID	SYMBOL	MEASUREMENT	MSB
1	0001	R1	Wind Magnitude - Center	64 Knots
2	0010	Θ1	Wind Direction - Center	256°
3	0011	R2	Wind Magnitude - Left	64 Knots
4	0100	Θ2	Wind Direction - Left	256°
5	0101	R3	Wind Magnitude - Right	64 Knots
6	0110	Θ3	Wind Direction - Right	256°
7	0111	P1	+4.5V : Precision Reference	2.500V
8	1000	P2	+2.5V : ±5V DC Power Supply	2.500V
9	1001	P3	±1.0V : ±15V DC Power Supply	2.500V
10	0000	GV	0.0V : System Ground	2.500V

INPUT DATA FORMAT FROM LARSE RECEIVERS

INPUT 0: [msb] bits 15 – 8

INPUT 1: [lsb | ID] bits 7 – 4 – 0

TABLE 2. FORMAT OF SENSOR INPUT DATA CENTERFIELD MET TOWER (8) (cont'd.)

CHANNEL	SENSOR ID	SYMBOL	MEASUREMENT	MSB
1	0001	R1	Wind Magnitude	64 Knots
2	0010	S1	Synchrodata 1	
3	0011	S2	Synchrodata 2	
4	0100	S3	Synchrodata 3	
5	0101	Z	Centerfield Ground Reference	2.500V
6	0110	(Spare)		
7	0111	P1	+4.5V : Precision Reference	2.500V
8	1000	P2	+2.5V : ±5V DC Power Supply	2.500V
9	1001	P3	+1.0V : ±15V DC Power Supply	2.500V
10	0000	GV	0.0V : System Ground	2.500V

TABLE 3. VAS TOWER PROCESSOR INTERRUPT ASSIGNMENTS

LOGICAL LEVEL	VECTOR	PRIORITY	FUNCTION
0	0	0	Reset 0 (RSTO)
1	+8	1	Phase Interrupt
2	+16	2	Larse End of Word (Input)
3	+24	3	USART End of Word (Output)
4	+32	4	Timer 1 (Larse Time Out)
7	+56	7	Reset 7 (Invalid OP Code)

TABLE 4. VAS TOWER PROCESSOR INPUT/OUTPUT ASSIGNMENTS

DEVICE	DEVICE ADDRESS	I/O	MODE	FUNCTION
8255	E4	Input	1	Sensor Data lsb + id)
8255	E8	Input	1	Sensor Data (msb)
8255	E7	Output		Port A Control
8255	EB	Output		Port B Control
8251	EC	Output		Display Output (USART)
8251	ED	Output		USART Control
8259	DA	Output		ICW1, OCW2
8259	DB	Output		ICW2/2, OCW1
8259	DA	Input		Read Int. Req. or Status Reg.
8259	DA	Input		Read Mask Reg.
8253	DF	Output		Timer Mode Control
8253	DC	Output		Set Timer 0
8253	DD	Output		Set Timer 1
8255	E5	Input	0	Tower ID

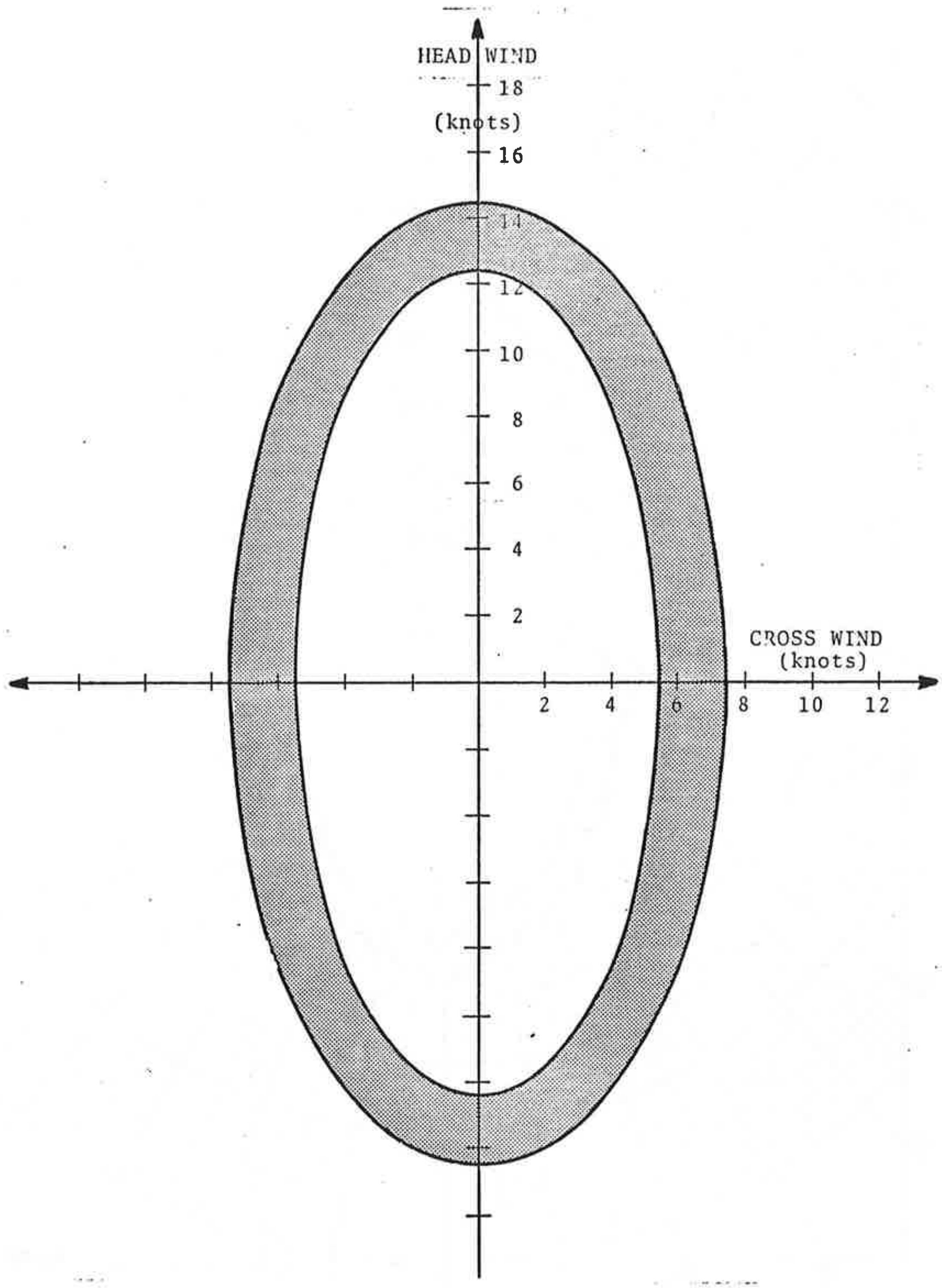


FIGURE 14. GENERAL VAS ALGORITHM

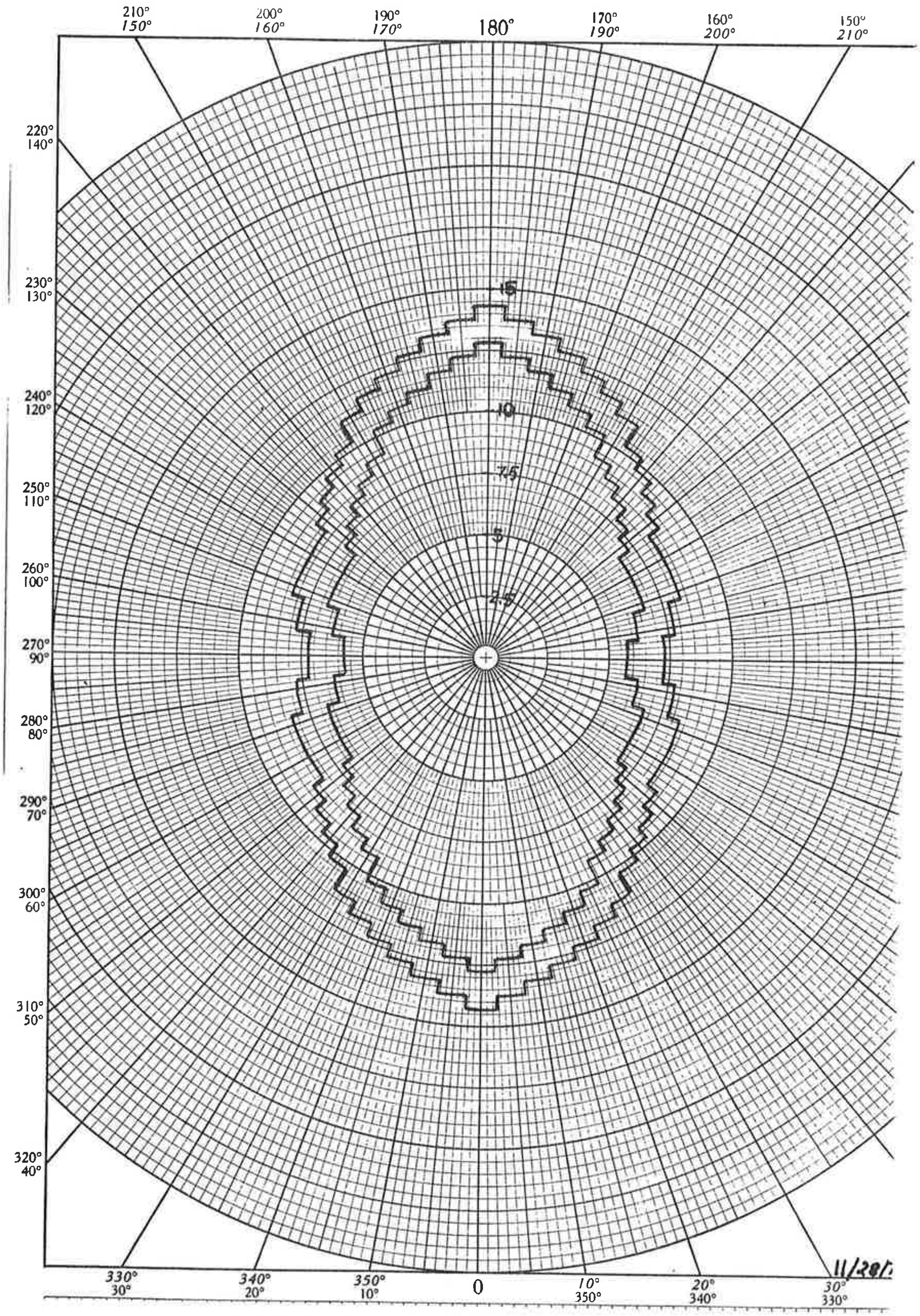


FIGURE 15. ACTUAL VAS IMPLEMENTATION

TABLE 5. VAS ELLIPSE

Θ	"RED" $\overline{R}$<Rnom.	Δ G→R	"GREEN" $\overline{R}$>Rnom.	Δ R→G	Δnom G→R	Δnom R→G
-2.5°-2.5°	13.0	12.75	14.0	14.25	12.5	14.5
2.5°-7.5°	12.5	12.25	13.5	13.75	12.0	14.0
7.5°-12.5°	12.0	11.75	13.0	13.25	11.5	13.5
12.5°-17.5°	11.5	11.25	12.5	12.75	11.0	13.0
17.5°-22.5°	11.0	10.75	12.0	12.25	10.5	12.5
22.5°-27.5°	10.5	10.25	11.5	11.75	10.0	12.0
27.5°-32.5°	9.5	9.25	11.0	11.25	9.0	11.5
32.5°-37.5°	9.0	8.75	10.0	10.25	8.5	10.5
37.5°-42.5°	8.5	8.25	9.5	9.75	8.0	10.0
42.5°-47.5°	8.0	7.75	9.0	9.25	7.5	9.5
47.5°-52.5°	7.5	7.25	8.5	8.75	7.0	9.0
52.5°-57.5°	7.0	6.75	8.0	8.25	6.5	8.5
57.5°-62.5°	7.0	6.75	8.0	8.25	6.5	8.5
62.5°-67.5°	7.0	6.75	8.0	8.25	6.5	8.5
67.5°-72.5°	7.0	6.75	8.0	8.25	6.5	8.5
72.5°-77.5°	6.5	6.25	7.5	7.75	6.0	8.0
77.5°-82.5°	6.5	6.25	7.5	7.75	6.0	8.0
82.5°-87.5°	6.0	5.75	7.0	7.25	5.5	7.5
87.5°-92.5°	6.0	5.75	7.0	7.25	5.5	7.5

VAS ELLIPSE VALUES R = 0.5 KTS INCREMENTS

Θ = 5° INCREMENTS

TABLE 6. TOWER RUNWAY ASSIGNMENTS

TOWER	RUNWAY INDEX	APPROACH RUNWAYS	RUNWAY ORIENTATION*
1	0	04R	9960H
	1	32L	9680H
2	2	04L	9960H
	3	09R	9910H
3	4	09L	9910H
	5	14R	9860H
4	6	14L	9860H
5	7	18	9820H
	8	22R	9780H
6	9	27R	9730H
	10	32R	9680H
7	11	22L	9780H
	12	27L	9730H

* Runway Orientation in Complement BCD Decimal Address

.: $\emptyset = \bar{\Theta}$ + Runway Orientation

TABLE 7. VAS TOWER ACCEPT INPUT DATA DECISION

	RULE								
CONDITION	1	2	3	4	5	6	7	8	9
Larse Time Out	N	Y							
Check Sum = 55	Y		N						
P1 = 4.5 ± .400V	Y			N					
P2 = 2.5 ± .025V	Y				N				
P3 = 1.0 ± .150V	Y					N			
GV = 0.0 .050V	Y						N		
R 2/3 Fail	N							Y	
Θ 2/3 Fail	N								Y
ACTION									
Good Data	X								
Set Error Count = 0	X								
Execute Read Error		X	X	X	X	X	X	X	X

TABLE 8. READ ERROR DECISION-GET$TOWER$DATA

	RULE		
CONDITION	1	2	3
Read Error	Y	Y	Y
First Read	Y	N	N
Error Count > 7		N	Y
ACTION			
Retry Read Data	X		
Flag Bad Data		X	X
Add 1 to Error Count		X	
Reuse Last Good Data		X	
Set Repeated Fail Bit			X
Set R = 88			X
Θ = 888			X
Gust = 88			X
Execute Error Status			X

TABLE 9. R SELECTION DECISION

CONDITION	RULE 1	2	3	4	5	6	7	8	9
R1 : R2 Match	Y	Y	N	Y	N	N	N		N
R1 : R3 Match	Y	N	Y	N	Y	N	N		N
R2 : R3 Match		Y	Y	N	N	Y	Y		N
R2 $\leq$ R3						Y	N		
Selected R < 2								Y	
ACTION									
Select R1	X	X	X	X	X				
Select R2						X			
Select R3							X		
Set Selected R = 1 Knot								X	
Set R1 Select Bit	X	X	X	X	X				
Set R2 Select Bit						X			
Set R3 Select Bit							X		
Set R1 Fail Bit						X	X		
Set R2 Fail Bit					X				
Set R3 Fail Bit				X					
Set R 2/3 Fail Bit									X

Note: Rn : Rm match means $|Rn - Rm| \leq 5$ knots

TABLE 10. Θ SELECTION DECISION

	RULE										
CONDITION	1	2	3	4	5	6	7	8	9	10	11
R 2/3 Fail											Y
Selected R < 5	Y	Y	Y	N	N	N	N	N	N	N	
ΔΘ12 : Minimum	Y										
ΔΘ13 : Minimum		Y									
ΔΘ23 : Minimum			Y								
Θ1 : Θ2 Match				Y	Y	Y	N	N	N	N	
Θ1 : Θ3 Match				Y	N	N	Y	Y	N	N	
Θ2 : Θ3 Match					Y	N	Y	N	Y	N	
ACTION	0	1	2								
Bypass Θ Select											Y
Select Θ1				X	X	X	X	X			
Average Θ1-Θ2	X										
Average Θ1-Θ3		X									
Average Θ2-Θ3			X						X		
Set Θ1 Select Bit	X	X		X	X	X	X	X			
Set Θ2 Select Bit	X		X						X		
Set Θ3 Select Bit		X	X						X		
Set Θ1 Fail Bit									X		
Set Θ2 Fail Bit								X			
Set Θ3 Fail Bit						X					
Set Θ 2/3 Fail Bit										X	

Note: Θn : Θm match means $|\Theta n - \Theta m| \leq 20°$

TABLE 11. THETA ZONE SELECTION DECISION RULES FOR CENTER-FIELD TOWER

CONDITION	RULE 1	2	3	4	5	6
Vab	+	−	−	−	+	+
Vbc	+	+	+	−	−	−
Vca	−	−	+	+	+	−
ACTION						
To	0	60	120	180	240	300
V_0	Vca	Vbc	Vab	Vca	Vbc	Vab
V_1	Vbc	Vab	Vca	Vbc	Vab	Vca
V_2	Vab	Vca	Vbc	Vab	Vca	Vbc

Note:

$$THETA = T_0 + 60 \times \frac{|V_1|}{|V_0|}$$

TABLE 12. GUST CALCULATION DECISION LOGIC

CONDITION	RULE 1	2	3	4	5	6	7	8	9
$\overline{G} > \overline{R} + 9$	Y	Y	Y	Y	Y	N	N	N	N
$\overline{G} >$ OLD$GUST	Y	N	N	N	N				
G > NEW$GUST		Y	Y	Y	Y				
OLD$GUSTIME = 0		N	Y	N	Y	Y	N	Y	N
NEW$GUSTIME = 0		Y	Y	N	N	Y	Y	N	N
ACTION									
OLD$GUST = $\overline{G}$	X								
OLD$GUSTIME = 128	X								
NEW$GUST = $\overline{G}$		X	X	X	X				
NEW$GUSTIME = 128		X	X	X	X				
Decrement OLD$GUSTIME	X	X		X			X		X
Zero OLD$GUSTIME			X		X	X		X	
Decrement NEW$GUSTIME				X	X			X	X
Zero NEW$GUSTIME		X	X			X	X		
OLD$GUST = NEW$GUST					X			X	
OLD$GUSTIME = NEW$GUSTIME					X			X	
Zero NEW$GUST					X			X	
Zero NEW$GUSTIME					X			X	
GUST = OLD$GUST	X	X	X	X	X	X	X	X	X

TABLE 13. RED/GREEN DISPLAY DECISION

	RULE					
CONDITION	1	2	3	4	5	6
$\overline{R}$ Inside Ellipse 1	Y	-	-	-	-	-
$\overline{R}$ Outside Ellipse 2		Y	Y	Y	-	-
$\overline{R}$ Middle Zone					Y	Y
Previous Status						
GREEN		On	Off	Off	On	Off
RED		Off	On	On	Off	On
GREEN Count $\geq$ 16			Y	N		
ACTION	R		G		R/G	
New Status						
GREEN	Off	On	On	Off	On	Off
RED	On	Off	Off	On	Off	On
Increment GREEN Count				X		
Reset GREEN Count	X					
CONDX Return Code	0	2	2	1	3	3

TABLE 14. TOWER PROCESSOR PROCEDURES REFERENCE

1. SIN
2. COS
3. NEG
4. ABSVAL
5. SCALE$THETA
6. DIV16
7. PROD12X8
8. PROD16X8
9. ADD3
10. SUB3
11. QUADD
12. AVGSUM
13. ARCHTAN
14. T$LIMIT
15. GET$BCD
16. ADD$ANGLE
17. DISPLAY$ERROR
18. R$SELECT
19. T$SELECT
20. SELECT$VECTOR
21. AVERAGE
22. GET$GUST
23. STORECALDATA
24. PROCESS$SENSOR$DATA
25. CALCMETTHETA
26. CALCMETR
27. PROCESSMETDATA
28. GET$BAND
29. CONDX
30. NEWSTATUS
31. SET$TIMER
32. STOP$TIMER
33. PUTVASDATA
34. STORERAWDATA
35. TEST$VOLTAGES
36. GET$SENSOR$DATA
37. GET$TOWER$DATA
38. PROCESS$CENTER
39. PROCESS$RUNWAY
40. REFRESH
41. COLD$START
42. PHASE$INTERRUPT
43. LARSE$INTERRUPT
44. USART$INTERRUPT
45. TIMER$INTERRUPT
46. INVALID
47. PROCESS$TOWER$DATA
48. MAIN

3.3.3.2 Clock Board Program. The clock program implementation shall be as shown in the following pages. The implementation is required in order to enable a VAS configuration with up to eight (8) microcomputers. The specific information included in the following pages is for the purpose of clarifying the design approach for using a single board (identical to the tower processor) computers as the system clock.

The clock generates the 8 interrupts for up to 8 microprocessors as well as the common 4800 Hz clock for the data output devices located on each microprocessor.

3.3.3.3 "OR" Board. An "OR" board shall be designed and used to combine the microcomputer outputs into a single data stream which is distributed over wire pairs to the VAS displays located in the TRACON and CAB. As shown in Fig. 19, the OR board block diagram, data from the individual microcomputers are input to line receivers which, if necessary, change signal levels. In order to prevent the output of a failed microcomputer from disabling the data output lines, a counter and decoder shall be utilized to enable the input from each microcomputer during its allotted time slot. The data inputs shall be combined into a single data stream in the OR circuit and output to the VAS displays, including the 4800-Hz clock using differential line drivers. The line driver outputs shall be TTL level signals.

3.3.3.4 Microcomputer and Modem Receiver Power Supplies. Each modem receiver and each microcomputer shall be powered by individual power supplies, in order to prevent a power supply failure from disabling the entire VAS. The exception to the above requirement is the use of a single power supply to supply the system clock and OR board.

All power supplies shall have overvoltage protection with foldback, short circuit-protection, and remote sensing for the high current sources, specifically the +5V to the microcomputers.

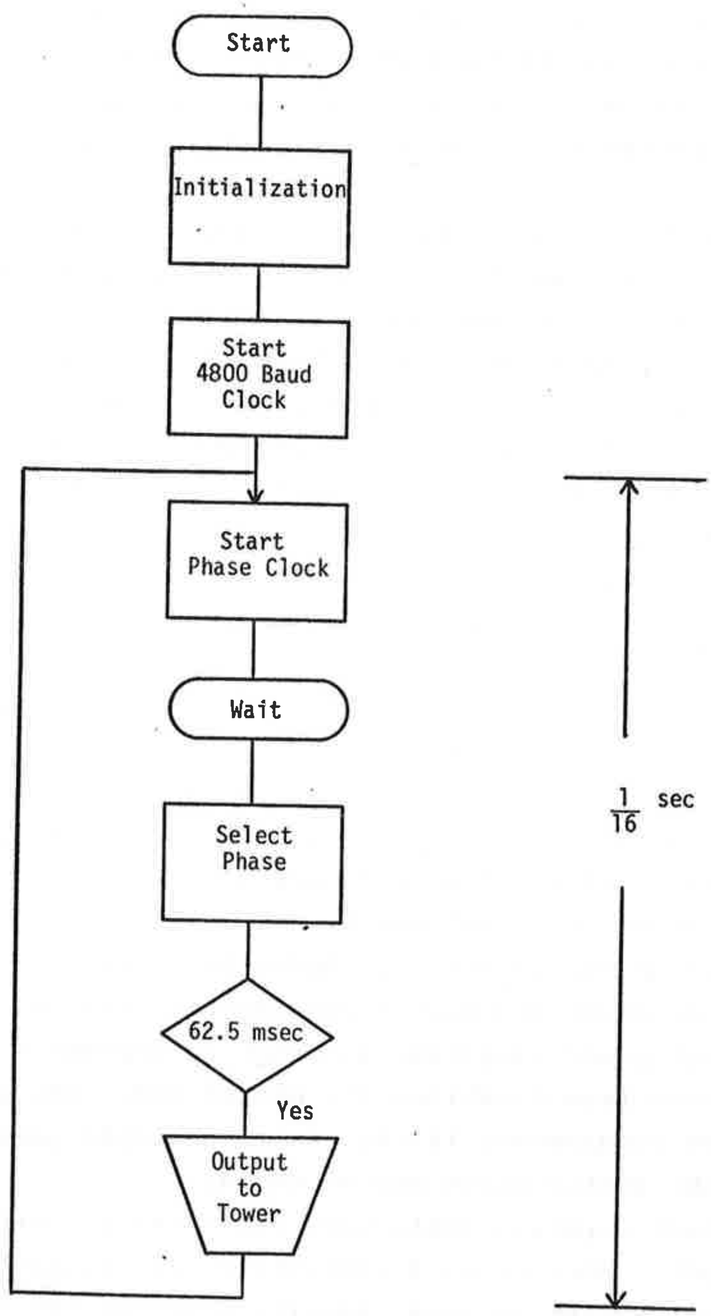


FIGURE 16. CLOCK BOARD PROGRAM

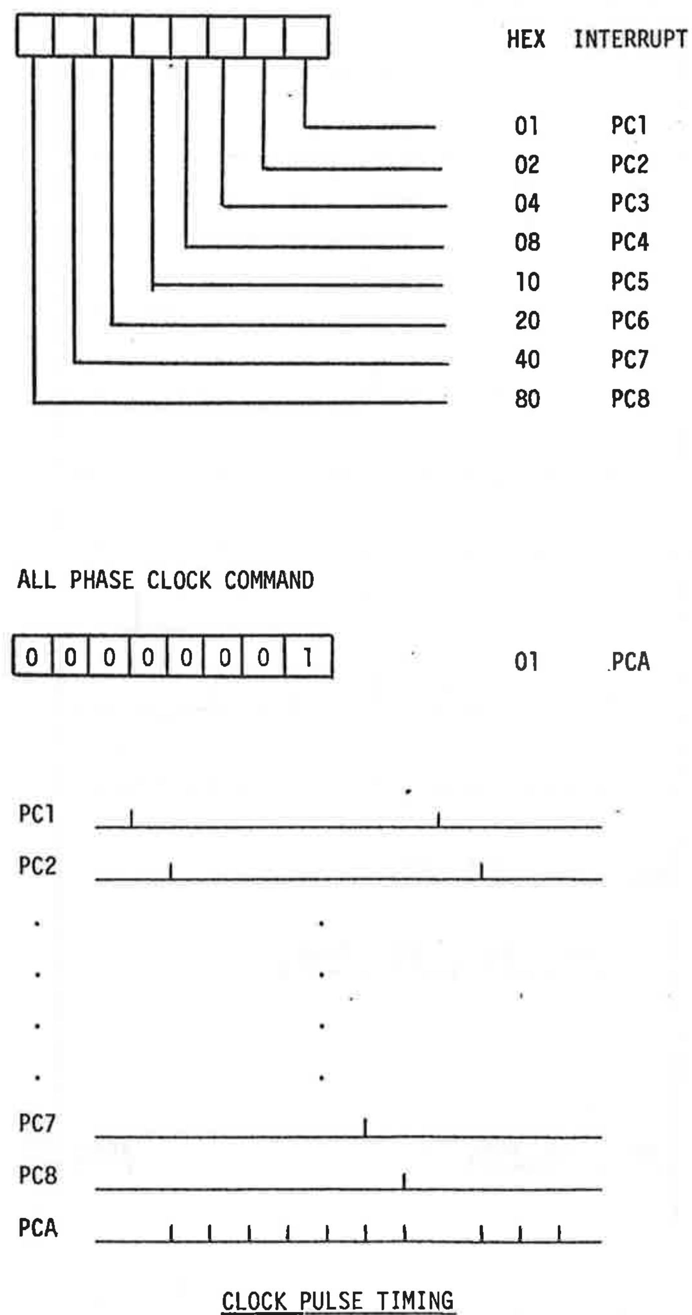


FIGURE 17. FORMAT OF CLOCK BOARD OUTPUT

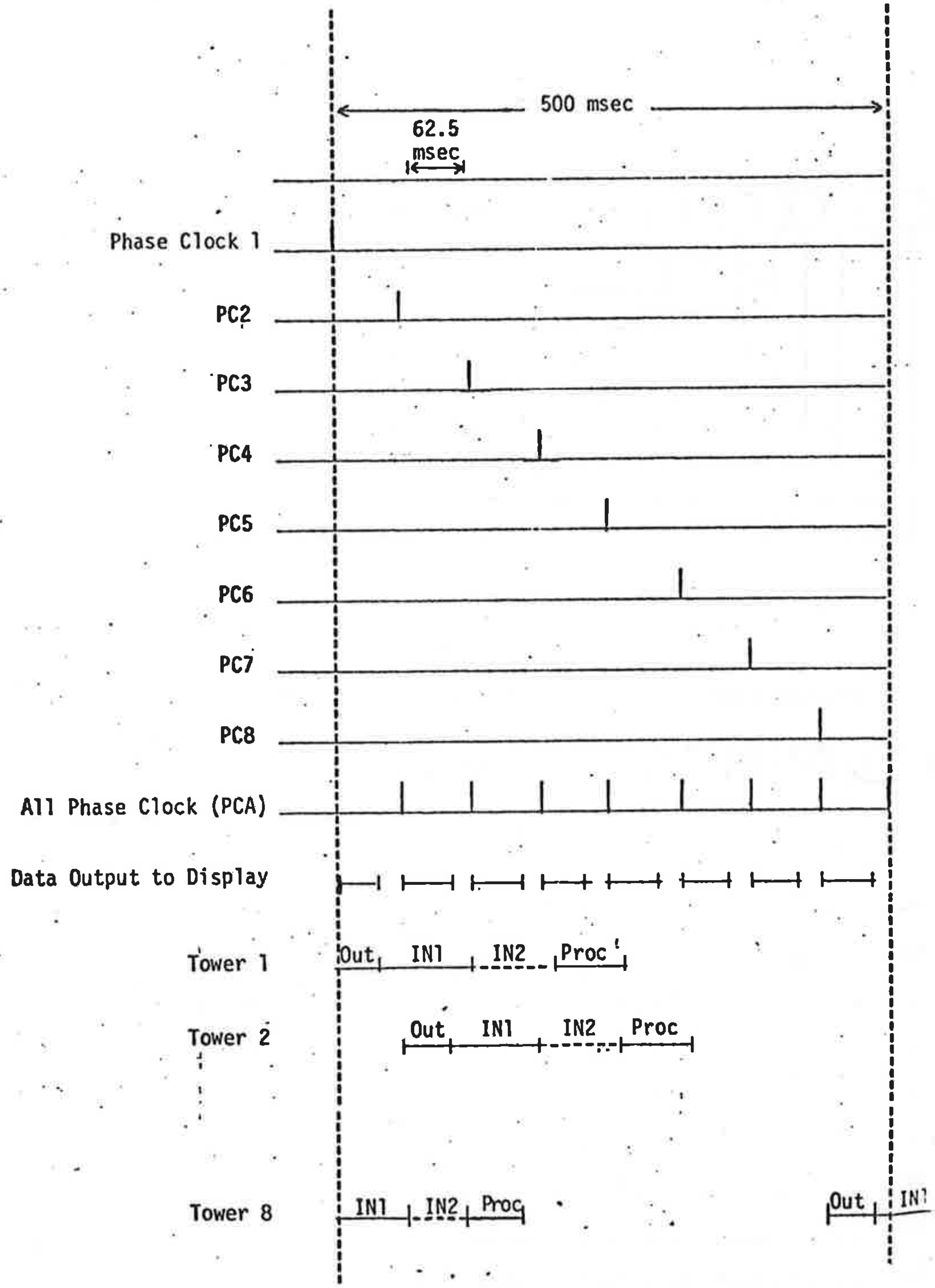


FIGURE 18. SYSTEM TIMING

TABLE 15. CLOCK BOARD INTERRUPT ASSIGNMENTS

LOGICAL LEVEL	VECTOR	PRIORITY	FUNCTION
0	0	0	RESET
1	+8	1	PHASE INTERRUPT (TIMER 1)
2	+16	2	—
3	+24	3	—
4	+32	4	—
5	+40	5	—
6	+48	6	—
7	+56	7	INVALID OP CODE

TABLE 16. CLOCK BOARD INPUT/OUTPUT ASSIGNMENTS

LOGICAL UNIT	DEVICE	DEVICE ADDRESS	I/O	MODE	FUNCTION
0	8255	E4	OUTPUT	0	8 PHASE INTERRUPTS
1	8255	E8	OUTPUT	0	lsb = ALL PHASE
2	8255	E7	CONTROL		GROUP 1 CONTROL
3	8255	EB	CONTROL		GROUP 2 CONTROL
4	8253	DF	REGISTER		TIMER CONTROL
5	8253	DE	BAUD RATE		4800 SYNC
6	8253	DC	TIMER 1	0	PHASE CLOCK
7	8259	DA	REGISTER		COMMAND
8	8259	DB	REGISTER		BLOCK ADDRESS

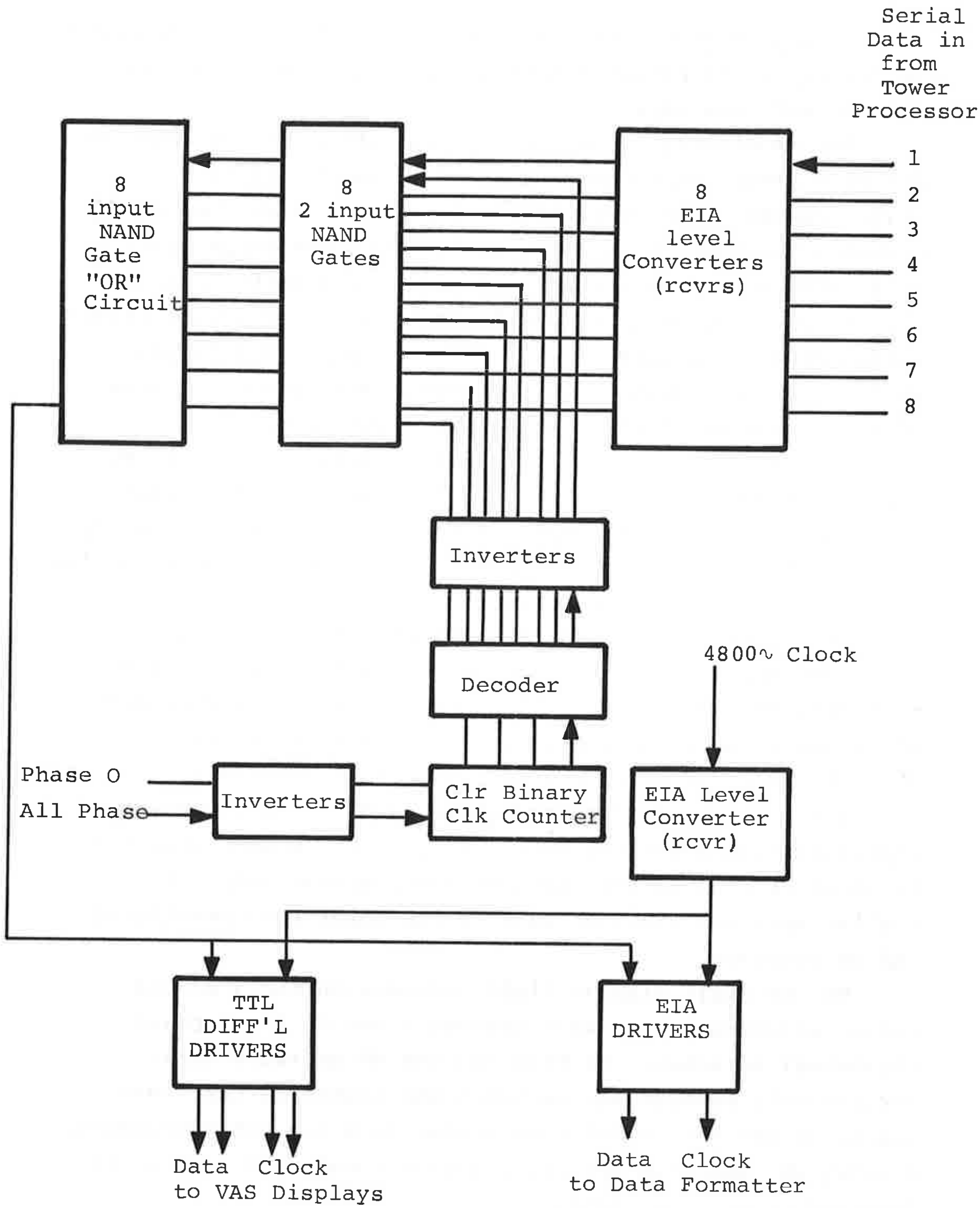


FIGURE 19. OR BOARD BLOCK DIAGRAM

3.3.4 VAS Displays. The VAS shall be provided with two types of displays, the Runway Monitor (RM) display and the System Monitor (SM) display.

The RM display, shown in Fig. 20, shall be designed for use by a local controller and shall display data for a single runway. The controller inputs via the thumbwheel switches the type of information he wants displayed, i.e., wind parameters from the arrival end of a specific runway and the corresponding RED/GREEN condition, or the wind information from the departure end of the runway. The display thereafter shall select the processed data from the corresponding tower and display it to the controller.

The SM display, Fig. 21, shall be designed for use by the TRACON and CAB supervisors. The display shall provide in summary form all meteorological tower outputs, the runway ends to which they pertain, the allowable (RED, GREEN) landing separations, and system failures if any.

Since both the SM and RM units will be located in the CAB where the displayed data may have to be viewed in bright sunlight, the choice of display must allow for easy viewing of the data under these high ambient light conditions and shall be easily read from a distance of up to 15 ft.

3.3.4.1 Runway Monitor Display (RM). A RM display implementation using the Intel 8080A microcomputer chip set is shown in Fig. 22 for illustrative purposes only. A similar approach shall be used to implement the operational VAS RM displays.

The RM shall display field information for a single runway selected by the user through a set of front panel thumbwheel switches. To this end the RM software shall continuously service the switches and lights on the front panel, accept the serial data stream from the VAS processors, display current data for the selected runway and respond to detected error conditions.

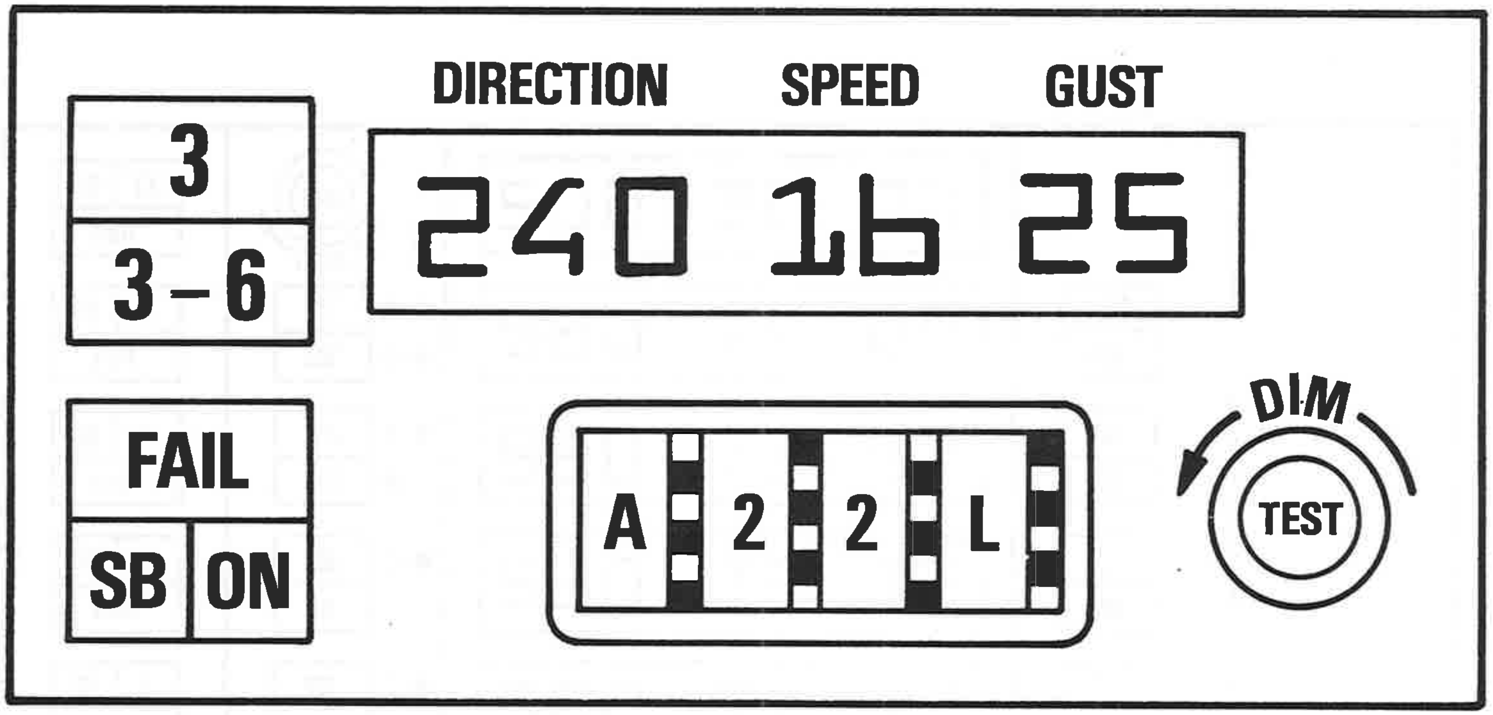


FIGURE 20. VAS RUNWAY MONITOR

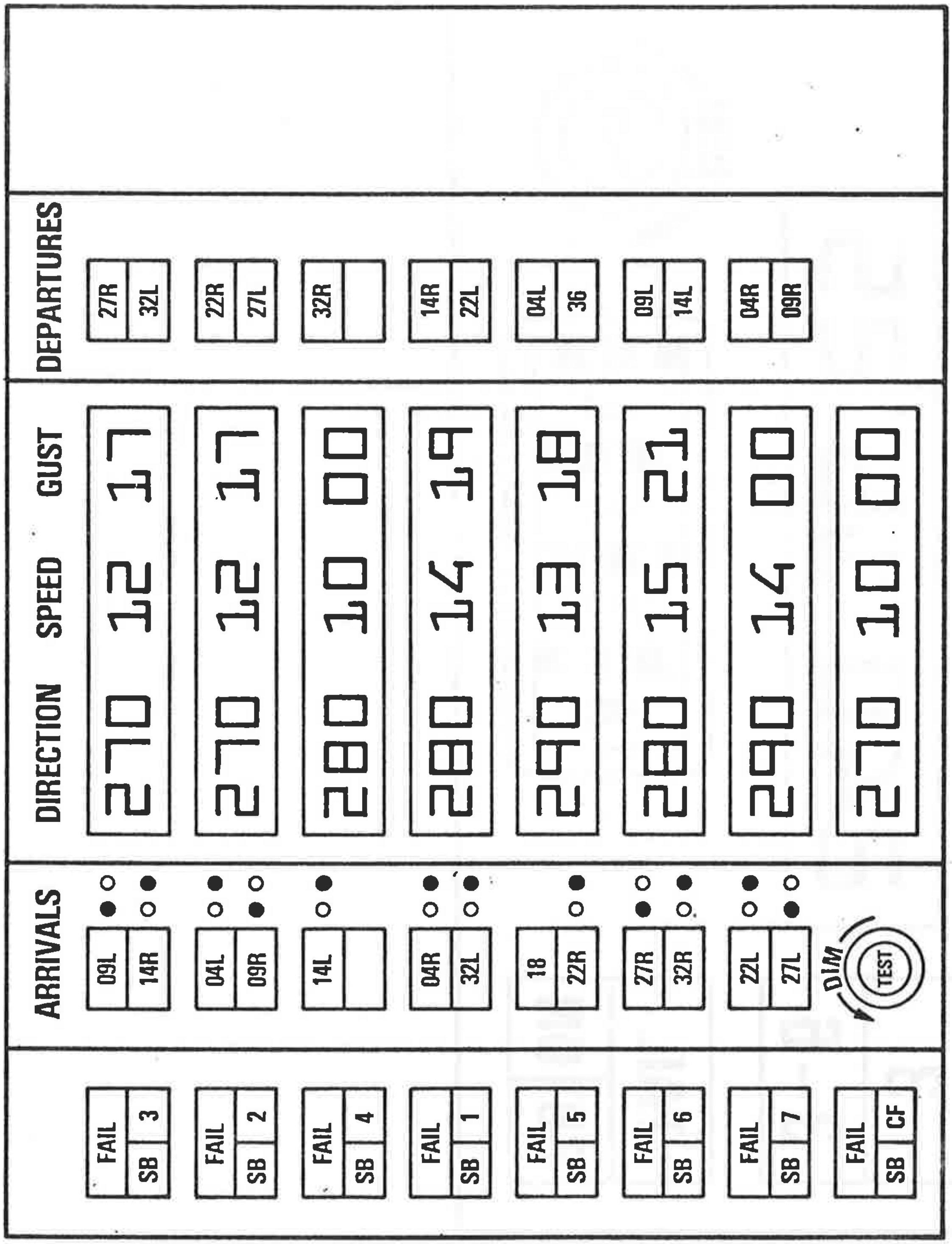


FIGURE 21. VAS SYSTEM MONITOR

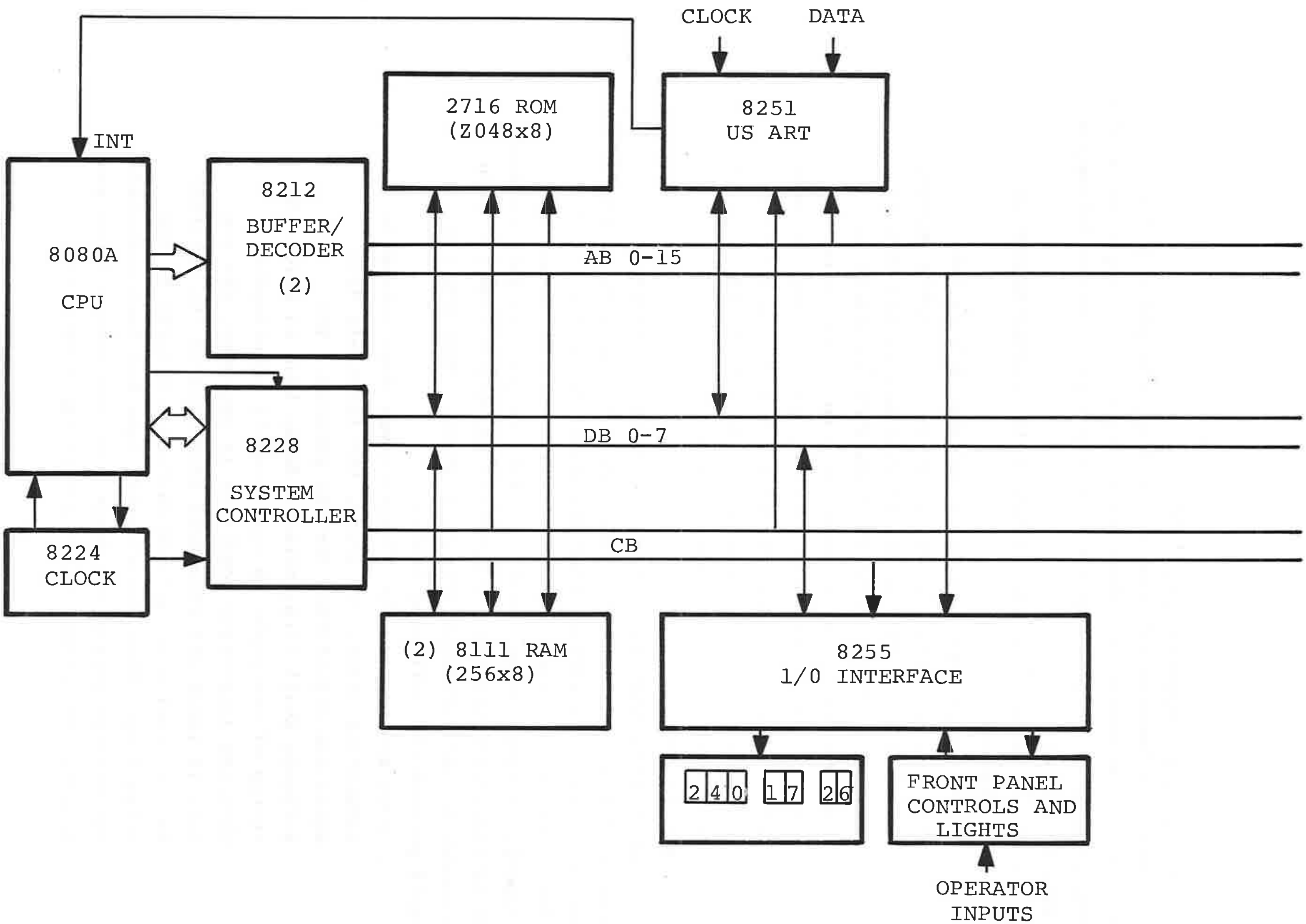


FIGURE 22. BLOCK DIAGRAM, RUNWAY MONITOR

A. Front Panel Switches and Lights

When the monitor is first powered up, the program shall initialize the system and then shall loop continuously through the main program sequence. The sequence shall perform the following tasks in order:

- Input and process the status of the runway selection thumbwheels.
- Input and process the status of the TEST switch.
- Input and process the status of the ON/STANDBY Switch.
- Output (ON or OFF) to the front panel lights (ON, SB, FAIL, RED, GREEN, DISPLAY, BLANKING) according to the above switches or detected error conditions.
- Enter a delay loop to await the next interrupt request from the USART. When an interrupt has been accepted and serviced, the program shall recycle to the beginning of the main sequence and continue.

B. VAS Data Stream

The USART periodically issues a hardware interrupt request (when it detects the SYN, SYN, STX sequence) to the microprocessor, signifying that the data stream for the next field tower is available for processing. The processor when properly initialized and enabled, shall respond to this request by automatically transferring program execution from the main sequence to the interrupt service routine. This routine shall perform the following tasks:

- Input and process the 27-byte tower data stream in sequential order. Of these, the first six data bytes are significant for the program. The software shall first enter a delay loop in which the status of the USART is continuously interrogated. When the data-ready condition is detected, the new byte is input and processed according to its position in the input sequence and execution returns to the delay loop. When the eleventh byte has been accepted, the program exists the input loop and interrogates and modifies the status flags set in the main program according to any detected error conditions. If the status permits and if there is a match between the requested runway and the current tower, the new information for that runway shall be displayed on the RM data display.

C. <u>Data Display</u>

Runway data available for display include the GREEN and RED lights, and numeric wind direction, speed and gust information. The wind parameter data when latched, are displayed when the display BLANKING status is not on.

Data for the selected runway shall be displayed when the RM is in the ON Mode and no error conditions apply. When the RM is powered up it shall be in the STANDBY Mode and remain there until the user presses the ON/SB switch. Each depression of the ON/SB switch thereafter shall change the RM Mode between STANDBY and ON.

The FAIL light is an indication of an error condition flagged by the VAS tower microcomputer in the second data byte. When the FAIL bit is detected, both the RED and GREEN lights shall be turned off and the data display blanked (BLANKING Status is ON).

In the STANDBY mode, only the SB light is on, all others shall be OFF, the data display Blanked. However, the data collection, processing and updating shall continue as usual.

In the ON Mode and with no error conditions, the ON light shall be on, the data display unBLANKED and the RED/GREEN conditions displayed. When an error condition occurs, the ON light shall remain ON, but the data display and the RED/GREEN indicators shall be blanked. The FAIL light is also turned on only if the "repeated failure" data bit is set by the VAS tower microcomputer. Should the source of the error condition disappear, the software shall provide for automatic recovery and a renewal of the current data display for the selected runway.

The TEST mode shall override all other system modes. For as long as the user depresses the TEST switch, all panel lights shall be turned on and the data display shall display all 8's. When the TEST switch is released the RM shall revert to its previous status.

The PANEL lights which serve to illuminate the thumbwheel switches shall always be on.

D. Error Conditions

The detectable errors in the system fall in the categories of data errors (check sum error, repeated failure bit set) and transmission errors (loss of interrupt, loss of a tower, loss of data). The former errors are discovered in the processing of the data bytes, the latter through software time out loops. The VAS tower processors transmit data to the RM in half-second cycles; the RM receives data from a different tower every sixteenth second (for an 8 tower system) and any given tower is processed every half second. The action taken on detection of an error shall be as follows:

- Loss of Interrupt: as described before, the last part of the main program sequence shall involve a delay loop during which the next interrupt request from the USART is awaited. The loop shall count down a period of 10 seconds. If no interrupt request is flagged in this time, the RM program enters the STANDBY Mode continuing the main program loop until interrupt service is restored. When interrupts reappear, the user must enter the ON mode manually.

For each of the following conditions, the system response shall be as described below for the ON mode: The ON light remains on but all data lights are blanked. Also for the repeated failure bit error only, the FAIL light shall be turned on. Note that in the STANDBY Mode errors are still detected but no action is taken.

- Loss of data: as described before the interrupt service routine acquires each byte of the incoming data stream by cycling through a delay loop until the data ready bit is output by the USART. If this does not occur after an elapsed time of 5 milliseconds, the following three actions shall be taken: the current interrupt service is dismissed without further input, the last good data are displayed without updating, and an internal twenty-cycle bad data flag is decremented. If this type of time-out persists through the servicing of 20 consecutive interrupts, the RM program enters the error mode and remains there until these time-outs cease to occur.

- Loss of a tower: the first byte of the data stream contains the tower identification number. If for twenty consecutive interrupts this ID number does not match the tower requested by the thumbwheels, the system enters the error mode and remains there until the correct tower is again flagged.
- Check-sum error: The sixth byte of the data stream for a given tower is the odd parity check-sum of the previous five bytes. Processing of the data shall involve forming the running check sum of the first five bytes and comparing this to the check sum byte transmitted by the VAS tower microcomputer in byte six. If they don't match, two actions shall be taken: the last good data are "coasted" as above and a twenty-cycle (10-second) bad check sum flag is decremented. If the check-sum continues bad for 20 consecutive cycles of the selected runway, the RM program shall enter the error mode and remain there until check-sum errors cease to be detected.
- Repeated Failure bit: bit zero of the second byte of the data stream for each tower is set or reset by the VAS tower microcomputer according to the criteria for acceptability of meteorological tower data as detailed

in section 3.3.3.1. If this bit is set for the selected runway, the RM program shall immediately enter the error mode and remain there until good data is again accepted. This special error condition shall be indicated by turning on the FAIL light and blanking the data display and RED/GREEN Lights. All other error conditions which imply that the data stream is bad or absent shall override the repeated failure bit error.

E. Additional RM Display Requirements

In order to display the CF sensor data, the required input shall be 00. Thus, if the user sets the thumbwheel switches to A00 or D00, the RM with display the NWS CF sensor data. The RED and GREEN lights are BLANKED for this input.

Since the available space for the VAS displays is limited, particularly in the CAB, the maximum RM display size is limited to a 6.5" width, a 3.5" height and a 6" depth. The RM power supply is separate from the display head and must be designed for separation distances of up to ten (10) ft. All critical voltages, particularly the +5V supply shall be designed for remote sensing at the display head. The supply shall contain overvoltage protection and current limiting on all outputs, and shall contain fusing and the power ON/OFF switch.

In order to facilitate viewing of the displays by the controllers standing in front of the slanted surface consoles, the display head shall either incorporate a tilting capability or bezels to incline the display to the mounting surface.

The selected data display units and their associated driver/decoder shall have the capability to display in Hexadecimal format. (This requirement is in anticipation of future expansion of the system. Thus, the FAIL condition could be displayed as all F's on the data display, freeing up the FAIL light indicator for another function.)

3.3.4.2 System Monitor Display (SM). The System Monitor Display shall be implemented in the same manner as the RM display described in the previous section. It shall be a microprocessor-based design utilizing the same chip set as that selected for the RM. Although not required in the present application, the SM shall include 4096X8 ROM and 1024X8 RAM for future expansion of the system.

The SM shall display information from all VAS towers on a single front panel display arrangement. Up to eight (8) data lines may be required (seven VAS towers, one NWS center field sensor), the configuration dependent on the particular airport runway configuration. At any time, the user may request display of any combination of towers, of none or of all. For the selected VAS tower, the RM shall indicate the one or two arrival or departure runways serviced by the tower, the RED/GREEN conditions for each arrival runway and the measured wind parameters. The SM software services all switches and lights on the display panel, continuously accepts the serial data stream from the VAS tower microcomputers, displays current data for all runways and responds to the detection of error conditions.

A. Front Panel Switches and Lights

When the monitor is first powered up, the SM software shall perform a one time system initialization and then loop continuously through the main program sequence. The sequence shall perform the following tasks in order:

- Input and process the status of the TEST switch.
- Input and process the status of the eight tower ON/STANDBY switches.
- Output (ON or OFF) to the eight sets of front panel lights (ON, STANDBY, FAIL, RED, GREEN, RUNWAY, and BLANKING) according to the above switches, or to detected error conditions.
- Enter a delay loop to await the next interrupt request from the USART. When an interrupt has been

accepted and serviced, the program shall recycle to the beginning of the main sequence and continue.

B. <u>VAS Data Stream</u>

The USART periodically issues a hardware interrupt request to the display monitor signifying that the data stream from the next field tower is available for processing. The monitor processor, when properly initialized and enabled, shall respond to this request by automatically transferring program execution from the main sequence to the interrupt service routine. This routine shall perform the following tasks:

- Input and process the 27-byte tower data stream in sequential order. Of these, the first six data bytes are significant for the SM program. The software shall first enter a delay loop in which the status of the (USART) data interface is continually interrogated; when the data-ready condition is detected, the new byte is input and processed according to its position in the input sequence, and execution returns to the delay loop. When the eleventh byte has been accepted, the program shall exit the input loop, and: Interrogate and modify the status flags set in the main program sequence according to any detected error conditions. If the status permits, the new information for the current tower shall be displayed on the monitor front panel.

C. <u>Data Display</u>

Data available for display for the various runways include the GREEN (three-mile) or RED (three-to-six mile) separation lights, and numeric wind direction, speed and gust information placed on data display. This latter data is displayed (illuminated) when the BLANK status goes false. The FAIL light is an indicator of an error condition flagged by the VAS tower processor in the second data byte.

- In the STANDBY mode, only the STANDBY light shall be on. The data displays are BLANKED and all other indicator lights for that tower shall be out. (It should be noted, however, that data collection, processing and updating continues as usual.) On initial power-up, all tower displays are in the STANDBY mode and shall remain there until the user switches them ON.
- In the ON mode, and with no error conditions, the ON light is on, the data display is unBLANKed, and the RED/GREEN data are displayed.
- Under an error condition, the ON light remains on, but the data lights are now BLANKed. In addition, the FAIL light shall be turned on if the error condition results from the "repeated failure" data bit being set. Should the source of the error disappear, the software shall provide for automatic recovery and renewed data display.
- The TEST mode shall override all other system modes. For as long as the user depresses the TEST switch, all panel lights shall be turned on and the data display shall display all "8"s. When the TEST switch is released, the monitor shall revert to its previous status.
- The RUNWAY lights, which merely serve to illuminate the runway legends, shall always be on.

D. <u>Error Conditions</u>

The detectable errors in the system fall in the categories of data errors (check-sum error, repeated-failure bit set) and transmission errors (loss of interrupt, loss of tower, loss of data). The former errors are discovered in the processing of the data bytes, the latter through software time-out loops and sequential tower counting. The VAS tower microcomputers transmits data from up to 8 VAS towers in sequence to the display monitor in half-second full cycles;

the monitor thus samples a different tower every sixteenth second, and any given tower every half-second. The action taken on the detection of the various possible errors shall be as follows:

- Loss of interrupt: As described above, the last part of the main program sequence involves a delay loop during which the next interrupt request from the VAS processor is awaited. The loop counts down a period of 10 seconds, the equivalent of 20 full cycles of the data stream. If no interrupt request is flagged in this time, the SM program enters the STANDBY mode and remains there, continuing the main program loop until interrupt service is restored. When interrupts reappear, the user must re-enter the ON mode manually.

  For the following error conditions, the system response shall be as described above for the ON mode. The ON light remains on, but all data lights are BLANKED. The FAIL light is also turned on when the repeated-failure bit is set. (Note that in the STANDBY mode, errors shall still be detected, but no further action shall be taken.)
- Loss of a tower: The first byte of the tower data stream contains the tower identification number, and the towers are sampled sequentially by number; any breaks in the sequence thus indicates a silent tower. If, for twenty consecutive full cycles, the tower remains silent, the system shall flag an error condition for that tower. In the interim, the last good data from the tower are "coasted" and remain on the display.
- Loss of data: As described above, the interrupt service routine acquires each incoming data byte by

cycling through a delay loop until the hardware data-ready flag goes true. At a normal data rate of 1.67 milliseconds/byte, a maximum period of 5 milliseconds shall be allowed for the next byte to appear. If it does not appear, the following three actions shall be taken: the current interrupt is dismissed without further input of data, the last good data for the current tower are "coasted" as above, and again a 20-cycle bad-data counter is updated for that tower, to end in either an error condition or the return to normal operation.

- Check-sum error: The sixth byte of a tower data stream is the odd-parity check-sum of the previous five bytes. A running check-sum of these five bytes shall be formed and compared to the check-sum byte as it comes in. If there is non-agreement, action taken shall be as above with loss of data: display "coasted" over 20 cycles or until check-sums agree again.
- Repeated failure bit: Bit zero of the data stream for each tower is set by the VAS tower microcomputer if its criteria for acceptability of the tower data are not met. In this event, an error condition is flagged immediately (no 20-cycle "time-out"), and the FAIL light is turned on as well as the data display blanked. (Note that the repeated-fail bit is itself data to the SM program. Thus all other error conditions, which imply that the data stream is bad or absent, shall override this error.)

E. <u>Additional SM Display Requirements</u>

The maximum size of the SM display shall be limited to a width of 15", a height of 10.5" and a depth of 8". The above size limitation is for the display and electronics portion only, exclusive of the necessary power supplies which may be located at a distance from the display head.

If the power supplies are located separately, their design shall allow separations of up to 10 ft. by providing remote sensing on all critical voltages. All voltage outputs shall have overvoltage protection with foldback and short circuit protection. The power supply shall include fuses or circuit breakers and the ON/OFF switch for the SM display.

3.3.5 VAS Maintenance Subsystem. The VAS installation shall include a maintenance subsystem shown in the block diagram form in Fig. 22. The main function of the maintenance subsystem shall be to monitor the operating condition of the VAS, alert maintenance personnel to any system failures, display and record the VAS outputs and collect and record VAS failure records.

3.3.5.1 Data Formatter (DF). The Data Formatter function shall be implemented using the same microcomputer unit as that selected for the VAS tower microcomputers similar to the Intel SBC 80/20 in combination with an SBC 116 I/O and memory expansion board, the latter required in order to accommodate the larger program and large I/O requirements of this subsystem. The functions the DF is required to perform are shown in Fig. 23, and are discussed in detail in the following paragraphs. A Multi-tasking Operating System shall be developed to enable the DF to perform these multiple tasks.

3.3.5.2 Data Logging on Tape. The VAS data stream output by the VAS tower microcomputers shall be an input to the DF which shall combine it with the Time Code Generator output and log it on 9-track magnetic tape using the tape format shown on page 89 . The format is shown for an eight (8) tower VAS (the CF sensor is assigned the position of Tower #8).

The above function shall be implemented using standard

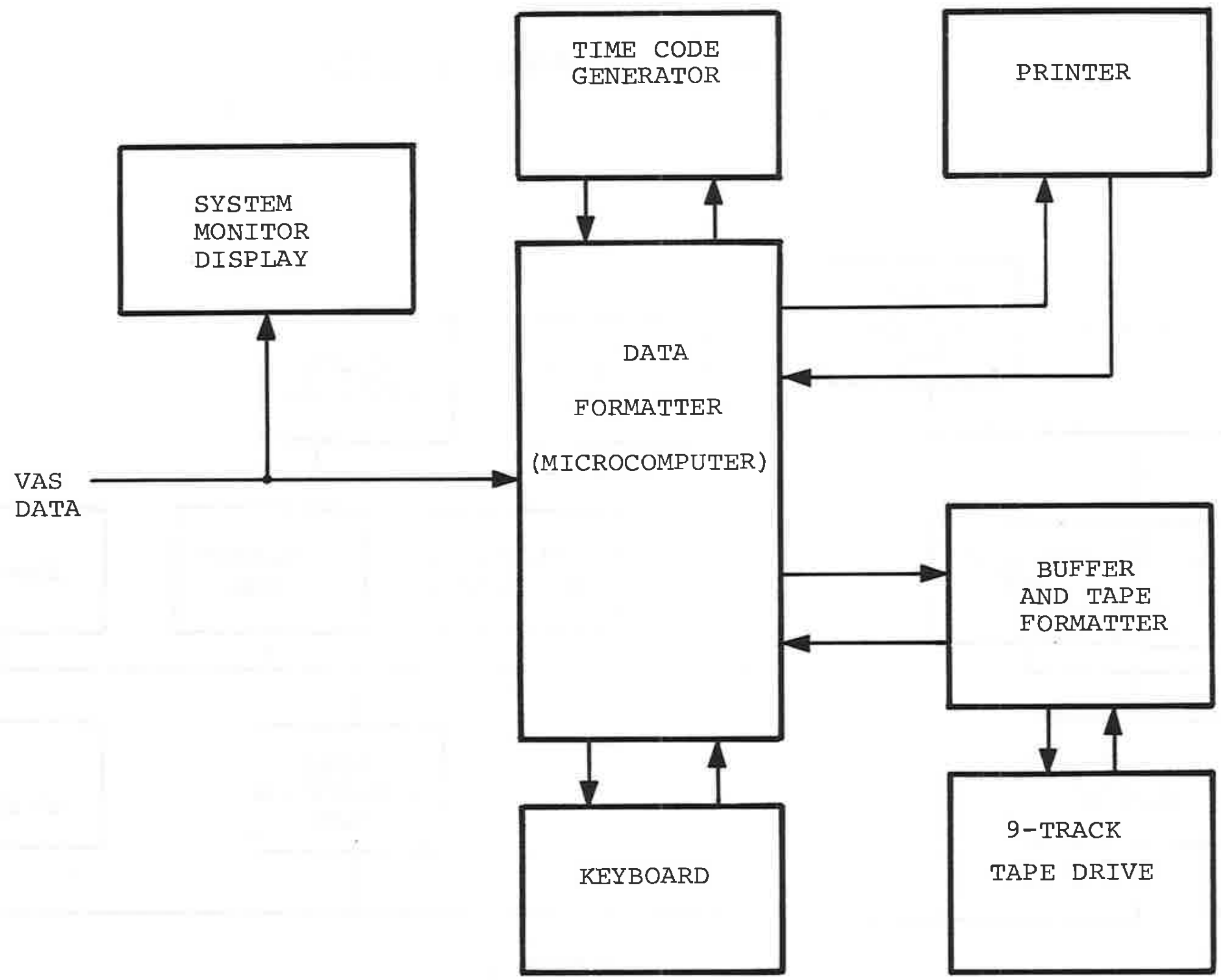


FIGURE 23. BLOCK DIAGRAM, VAS MAINTENANCE SUBSYSTEM

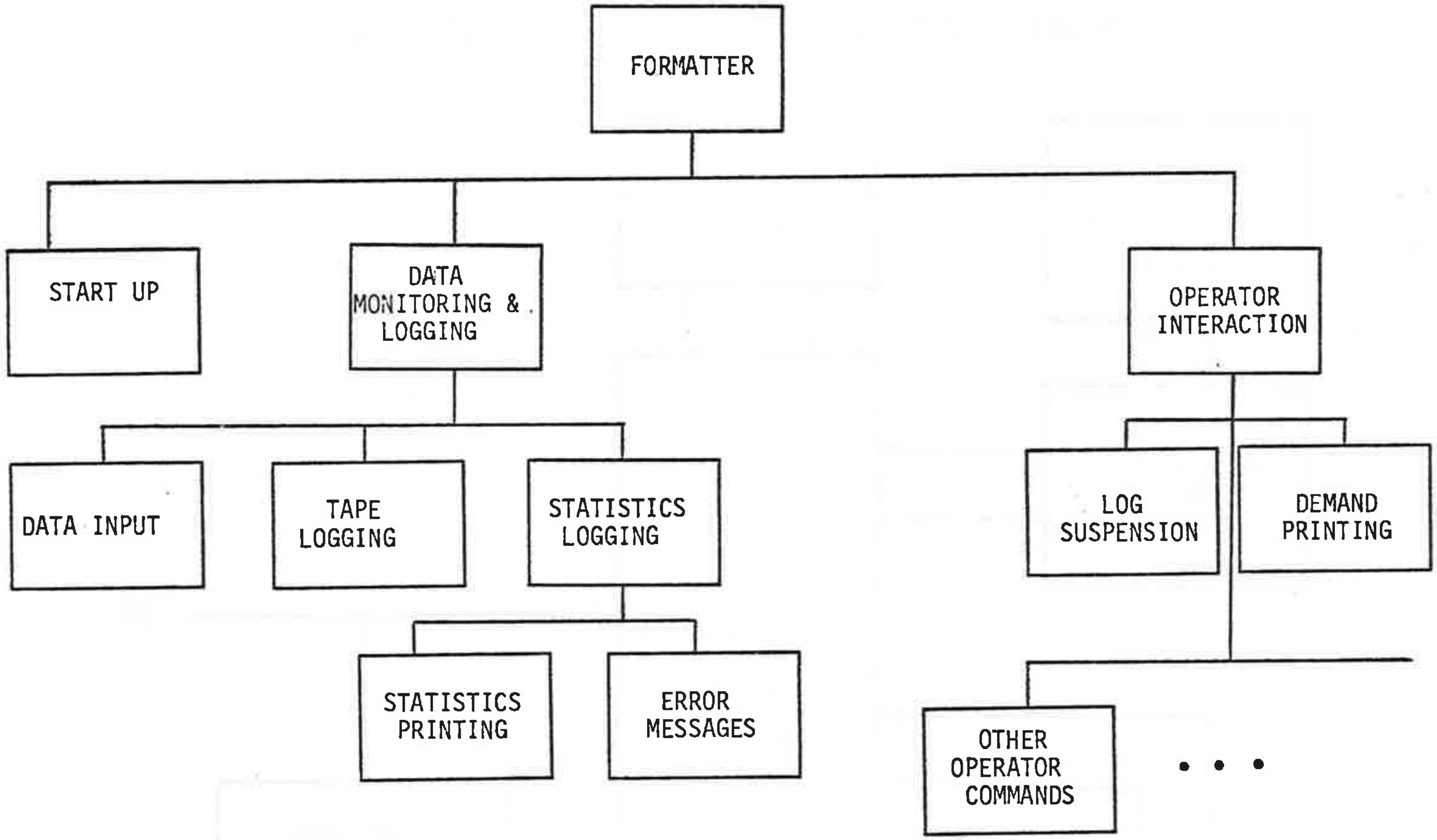


FIGURE 24. FORMATTER FUNCTIONS

MAG. TAPE

9 Track, 800 BPI, NRZI
Format for each block of data

BYTE	7		0	Description
1	MOT		MOU	Time -- Month Tens & Units -- BCD
2	DYT		DYU	" Day " " "
3	HRT		HRU	" Hour " " "
4	MNT		MNU	" Minute " " "
5	SCT		SCU	" Second " " "
6	$\bar{R}$ Tens		$\bar{R}$ Units	Tower 1 Display Data Sample 1
7	Θ Hundreds		Θ Tens	
8	$\bar{G}$ Tens		$\bar{G}$ Units	
9	RW2: G R	RW1: G R	Tower ID	Runway R/G Flags, Tower ID
10	Ø Units		F	Repeated Failure Bit
11	$\bar{R}$ Tens		$\bar{R}$ Units	Tower 2 Display Data Sample 1
12	$\bar{\Theta}$ Hundreds		$\bar{\Theta}$ Tens	
⋮	⋮	⋮	⋮	
2044	RW2: G R	RW1: G R	Tower ID	Tower 8 Display Data Sample 51
2045	Ø Units		F	

1 Block contains 25.5 Sec. of Data.
A 2400 foot tape contains 64.5 Hrs. of Data.

FIGURE 25. FORMATTER OUTPUT DATA FORMAT

commercial equipment similar to the Kennedy Model 9000, 9-track, 800 BPI, NRZ, 25 IPS tape transport together with the Model 9217B/2048 Buffer and Model 9218-1 Tape Formatter. A Chrono-Log Model 70241-612 Time Code Generator is an example of a real time clock suitable for this task. Operator commands to initiate and terminate data recording shall be as follows:

Command Syntax	Name	Function
ST	Start Tape	Start logging of data on tape
EF	End File	Stop logging data on tape. Write file mark.

3.3.5.3 Statistics Logging and Error Messages. The DF shall collect error statistics and generate a printed record of the accummulated data. The record shall be printed on a standard commercial "silent" printer similar to the NCR 260-2 KSR Thermal Printer. This unit shall also include the keyboard required for operator inputs to the DF, discussed in the subsequent section

Hourly Error Statistics

Error statistics shall be collected for the current hour and current day. At the end of each hour, the statistics for the hour shall be optionally printed (see the HS and NH commands) and the hour counters reset to zero. At the end of each day, the statistics for the day shall be optionally printed (see the DS and ND commands) and the day counters reset to zero.

Error counters shall be 16 bits in size and shall contain values up to 64,535. Error counts in excess of 64,535 shall be lost; the counter shall remain at 64,535.

The statistics that will be collected shall be listed as shown in the following pages. There shall be separate counters for each tower.

Only non-zero counters shall be displayed with each non-zero counter identified by the mnemonic shown in the table.

An example of the hourly statistics output shall be as follows:

```
B01 06/15/77 10:00:01 HOURLY ERROR STATISTICS
    TOWER 1
    BCE/0015 R2F/00123 GV1/0093
    TOWER 6
    R2F/01045
```

The output has the following meaning:

- 'B01' is a message I.D.
- '06/15/77' is the date
- '10:00:01' is the time
- 'TOWER 1' specifies the following statistics are for tower 1
- 'BCE/00015...' indicates that there have been 15 block check errors, 123 R2 fail errors, and 93 GV-out-of-range errors for tower 1 in the last hour
- 'Tower 6' specifies the following statistics are for tower 6
- 'R2F/01045' indicates that there have been 1045 R2 fail errors for tower 6 in the last hour.

There was no output for towers other than 1 and 6 indicating that there were no errors for these towers.

An example of a daily statistics print out shall be as follows:

```
B02 06/10/77 00:00:03 DAILY ERROR STATISTICS
    TOWER 1
    BCE/00100 R1F/01016 R2F/03441 GV1/00100
```

HOURLY/DAILY STATISTICS

SOURCE IN TOWER OUTPUT DATA STREAM			COUNTER
BYTE	BITS	DESCRIPTION	MNEMONIC
8	7-0	Checksum Error in Display Data	BCE
11	7		
	6	R1 Fail	R1F
	5	R2 Fail	R2F
	4	R3 Fail	R3F
	3		
	2	θ1 Fail	T1F
	1	θ2 Fail	T2F
	0	θ3 Fail	T3F
12	3-0	Read Error 1	
		Time Out	TO1
		Check Sum ≠ 55	CS1
		R 2/3 Fail	RX1
		θ 2/3 Fail	TX1
		P2 ≠ 4.5±0.400V	P11
		P1 ≠ 2.5±0.005V	P21
		P3 ≠ 1.0±0.150V	P31
		GV ≠ 0.0±0.050V	GV1
12	7-4	Read Error 2	
		Time Out	TO2
		Check Sum ≠ 55	CS2
		R 2/3 Fail	RX2
		θ 2/3 Fail	TX2
		P2 ≠ 4.5± 0.400V	P12
		P1 ≠ 2.5± 0.005V	P22
		P3 ≠ 1.0± 0.150V	P32
		GV ≠ 0.0± 0.050V.	GV2

Repeated Failure Error Messages

When the formatter detects the repeated failure bit (Byte 4, Bit Ø of the tower output) it prints out a message of the form:

```
B03 MM/DD/YY HH:MM:SS TOWER X REPEATED ERRORS. LAST 16 ERROR CODE PAIRS ARE:
    XX/YY XX/YY XX/YY XX/YY XX/YY XX/YY XX/YY XX/YY
    XX/YY XX/YY XX/YY XX/YY XX/YY XX/YY XX/YY XX/YY
```

The sixteen fields of the form XX/YY are pairs of mnemonics representing the error codes contained in byte 12 of the tower output data; XX represents Read Error 1; YY represents Read Error 2. The codes are listed below:

ERROR MESSAGE CODES

XX,YY - Read Error 1, Read Error 2 (Byte 12)

Error Code (Numerical)	Error Code MNEMONIC	Failure
0	NE	No Error
1	TO	Timeout
2	CS	Checksum $\neq$ 55
3	RX	R2/3 Fail
4	TX	θ2/3 Fail
5	P1	$P2 \neq 4.5 \pm 0.400V$
6	P2	$P1 \neq 2.5 \pm 0.005V$
7	P3	$P3 \neq 1.0 \pm 0.150V$
8	GV	$GV \neq 0.0 \pm 0.050V$

The sixteen fields represent the sixteen pairs of error codes detected previous to the detection of the repeated failure bit (the formatter stores the last 16 pairs of error codes for each tower).

Following is an example of this type of output:

```
B03 06/20/77 13:01:20 TOWER 4 REPEATED ERRORS: LAST 16 ERROR CODE PAIRS ARE:
    RX/RX RX/RX RX/RX RX/RX RX/RX RX/RX RX/TX TX/TX
    TX/TX RX/RX RX/RX RX/RX RX/RX RX/RX RX/RX RX/RX
```

This message indicates that previous to the detection of the repeated error condition there were:

- 6 pairs of R2/3 fail errors followed by
- an R2/3 fail error followed by a θ2/3 error followed by
- 2 pairs of θ2/3 fail errors followed by
- 7 pairs of R2/3 fail errors.

If all 16 preceding error pairs were identical and in each error pair both errors are the same, a condensed message shall be printed as follows:

B04 06/20/77 13:01:20 TOWER 4 REPEATED ERRORS: RX

This message indicates that for tower 4 the last 16 failures were due to pairs of R2/3 errors.

For a given tower, a repeated failure error message shall be output no more than once a minute.

Printout of statistics shall be enabled or disabled by operator commands via the keyboard. The command inputs shall be as follows:

COMMAND SYNTAX	NAME	FUNCTION
HS	Hourly Statistics	Print hourly error statistics
NH	No Hourly Statistics	Do not print hourly error statistics
DS	Daily Statistics	Print daily error statistics
ND	No Daily Statistics	Do not print daily error statistics
EM	Error Messages	Print error messages
NE	No Error Messages	Do not print error messages

3.3.5.4 Diagnostic Printout. The DF shall at the request of the operator print out diagnostics for each tower. Diagnostic printouts will be requested by an operator to trace the activity at a given tower in real time. In order to operate in real time, 12 characters of information shall be printed for each block of input received from a tower. Six groups of 12 characters each shall be printed on a line. Groups shall be separated by a "/".

The command for initiating diagnostic printing shall be as follows: DG, Tower ID, Diagnostic Type. Example: The command DG ␣ 2 ␣ 5 request the DF to print out Type 5 diagnostics for Tower 2. Diagnostic printing shall be stopped by typing the carriage return key.

Diagnostic mode printout shall not interfere with normal tape logging and error statistic printing. Hourly and daily error statistic printing (if enabled) shall interrupt diagnostic mode printing. Repeated error message printing, however, shall be inhibited during diagnostic printout.

There shall be seven (7) types of diagnostic outputs which can be requested. The format of each type is shown on pages 97-103 along with an example.

3.3.5.5 Messages. The table on the following page lists the messages which shall be output by the Data Formatter. Each message contains a unique identifier which will help define the action taken.

3.3.6 VAS Console. The VAS electronics shall be housed in standard FAA NAS consoles. A sample arrangement of the VAS electronics components in two consoles is shown in Fig. 24. Its salient features are:

A. The CF sensor monitoring electronics are contained in the VAS console. This arrangement shall not be assumed to be a standard for all VAS installations. As some, the CF monitoring electronics may be separated by a considerable distance from the VAS console, requiring the use of modems.

B. The console shows ten (10) microcomputer power supplies. This is a requirement for a seven tower VAS installation. The CF sensor is counted as the eighth tower. Power supply number 9 powers the microcomputer clock and "OR" board. Power supply number 10 supplies power to the Data Formatter.

A01	MM/DD/YY HH:MM:SS FORMATTER RESET
A02	MM/DD/YY HH:MM:SS TAPE DRIVE OFFLINE
A05	MM/DD/YY HH:MM:SS INPUT DATA TIMEOUT
A10	MM/DD/YY HH:MM:SS PRINTER TIMEOUT
B01	MM/DD/YY HH:MM:SS HOURLY ERROR STATISTICS
B02	MM/DD/YY HH:MM:SS DAILY ERROR STATISTICS
B03	MM/DD/YY HH:MM:SS TOWER X REPEATED ERRORS LAST 16 ERROR CODE PAIRS ARE: XX/YY XX/YY XX/YY XX/YY XX/YY XX/YY XX/YY XX/YY XX/YY XX/YY XX/YY XX/YY XX/YY XX/YY XX/YY XX/YY
B04	MM/DD/YY HH:MM:SS TOWER X REPEATED ERRORS:XX
B05	MM/DD/YY HH:MM:SS TOWER X TYPE Y DIAGNOSTIC INFO:
X01	INVALID COMMAND
X02	INVALID TOWER I.D.
X03	INVALID TYPE
X04	TAPE ERROR

DIAGNOSTIC PRINTOUT

TYPE 1 — DISPLAY VARIABLES

FORMAT

12 columns

TOWER ID $\bar{R}$ $\bar{\theta}$ RW1 RW2 FAIL

Variable	Code	Meaning
ID	1-8	Tower I.D.
$\bar{R}$	00-99	$\bar{R}$ (decimal)
$\bar{\theta}$	000-999	$\bar{\theta}$ (decimal)
RW1, RW2	0	None
↓	1	$\bar{G}R$ Runway Status
	2	$G\bar{R}$ Runway Status
	3	GR Runway Status
FAIL	F	Repeated Failure Light ON
↓	0	Repeated Failure Light OFF

EXAMPLE *

312 205 11 0/312 205 11 0/312 205 11 0/312 205 11 0/312 205 11 0/312 205 11 0
312 205 11 0/312 205 11 0/312 205 11 0/312 205 11 0/312 205 11 0/312 205 11 0

In the above example:

- ID=3 - Runway 1 Status=$\bar{G}R$
- $\bar{R}$=12 - Runway 2 Status=$\bar{G}R$
- $\bar{\theta}$=205 - Repeated Fail Light is not on

*For the sake of simplicity, in the examples all 12 character groups are identical

DIAGNOSTIC PRINTOUT

TYPE 2 — WIND SPEED VARIABLES

FORMAT

12 columns

R1 , R2 , R3 , $\bar{R}$, RSRFRU

Variable	Code	Meaning
R1	00-FF	R1(Hex)
R2	00-FF	R2(Hex)
R3	00-FF	R3(Hex)
$\bar{R}$	~~00-99~~	$\bar{R}$ Decimal
RS	0, 1, 2, 3	Selected R (0 if 2/3 Fail)
RF	0, 1, 2, 3	R Fail

EXAMPLE *

1A1B1D24 100/1A1B1D24 100/1A1B1D24 100/1A1B11D24 100/1B1B1D24 100/1B1B1D24 100
1C1B1C24 100/1C1B1C25 100/1C1B1C25 100/1D1C1C25 100/1D1C1D25 100/1D1C1D25 100

In the above example:

- R1=10 - The selected R is R3
- R2=12 - There is no R1, R2, or R3 fail condition
- R3=11 - $\bar{R}$ is not unreasonable
- $\bar{R}$=11

*For the sake of simplicity, in the examples all 12 character groups are identical

DIAGNOSTIC PRINTOUT

TYPE 3 — WIND DIRECTION VARIABLES

FORMAT

12 columns

θ1 θ2 θ3 $\bar{\theta}$ θSθFθU

Variable	Code	Meaning
θ1	00-FF	θ1(Hex)
θ2	00-FF	θ2(Hex)
θ3	00-FF	θ3(Hex)
$\bar{\theta}$	000-999	$\bar{\theta}$(Decimal)
θS	0, 1, 2, 3	Selected θ(0 if 2/3 Fail)
θF	0, 1, 2, 3	θ Fail

Example*

0A1B2300712X/0A1B2300712X/0A1B2300712X/0A1B2300712X/0A1B2300712X/0A1B2300712X
0A1B2300712X/0A1B2300712X/0A1B2300712X/0A1B2300712X/0A1B2300712X/0A1B2300712X

In the above example:

- θ1=0A - Selected θ=1
- θ2=1B - No $\bar{\theta}$ Fail Error
- θ3=23 - θ is unreasonable
- $\bar{\theta}$=007

*For the sake of simplicity, in the examples all 12 character groups are identical

TYPE 4 — MISCELLANEOUS VARIABLES

FORMAT

```
   12 columns
 XX  YY  Ḡ
```

Variable	Code	Meaning
XX	Error Mnemonic	
YY	Error Mnemonic	
$\bar{G}$	00-99	Gust (Decimal)

EXAMPLE *

```
R2 R2 23   /R2 R2 23   /R2 R2 23   /R2 R2 23   /R2 R2 23   /R2 R2 23   /
R2 R2 23   /R2 R2 23   /R2 R2 23   /R2 R2 23   /R2 R2 23   /R2 R2 23   /
```

In the above example:

- There are repeated R2 Fail errors
- $\bar{G}$=23

*For the sake of simplicity, in the examples all 12 character groups are identical

DIAGNOSTIC PRINTOUT

TYPE 5 — MISCELLANEOUS VARIABLES

FORMAT

```
   12 columns
|___________________________|

 __P1__  __P2__  RE1 RE2
|      ||      | |_|_|
```

Variable	Code	Meaning
P1	000-FFF	P1(Hex)
P2	000-FFF	P2(Hex)
RE1, RE2	0-8	Detected Error Codes

EXAMPLE*

```
01F 20D 00  /01F 20D 00  /01F 20D 00  /01F 20D 00  /01F 20D 00  /01F 20D 00  /
01F 20D 00  /01F 20D 00  /01F 20D 00  /01F 20D 00  /01F 20D 00  /01F 20D 00  /
```

In the above example:

- P1=01F
- P2=20D
- There are no errors detected.

*For the sake of simplicity, in the examples all 12 character groups are identical

DIAGNOSTIC PRINTOUT

TYPE 6 — MISCELLANEOUS VARIABLES

```
|_______12 Columns_______|
   P3       GV    RE1 RE2
|_____|  |_____|  |_|_|
```

Variable	Code	Meaning
P3	000-FFF	P3(Hex)
GV	000-FFF	GV(Hex)
RE1, RE2	0-8	Detected Error Codes

EXAMPLE*

```
123 ABC 00  /123 ABC 00  /123 ABC 00  /123 ABC 00  /123 ABC 00  /123 ABC 00  /
123 ABC 00  /123 ABC 00  /123 ABC 00  /123 ABC 00  /123 ABC 00  /123 ABC 00  /
```

In the above example:

- P3=123
- GV=ABC
- There are no errors detected.

*For the sake of simplicity, in the examples all 12 character groups are identical

DIAGNOSTIC PRINTOUT

TYPE 7 — CENTER TOWER VARIABLES

FORMAT

```
 12 Columns
R1 S1 S2 S3
```

Variable	Code	Meaning
R1	00-FF	R1(Hex)
S1	00-FF	S1(Hex)
S2	00-FF	S2(Hex)
S3	00-FF	S3(Hex)

EXAMPLE*

```
1B031F1A   /1B031F1A   /1B031F1A   /1B031F1A   /1B031F1A   /1B031F1A
1B031F1A   /1B031F1A   /1B031F1A   /1B031F1A   /1B031F1A   /1B031F1A
```

In the above example:

- R1=1B
- S1=03
- S2=1F
- S3=1A

*For the sake of simplicity, in the examples all 12 character groups are identical

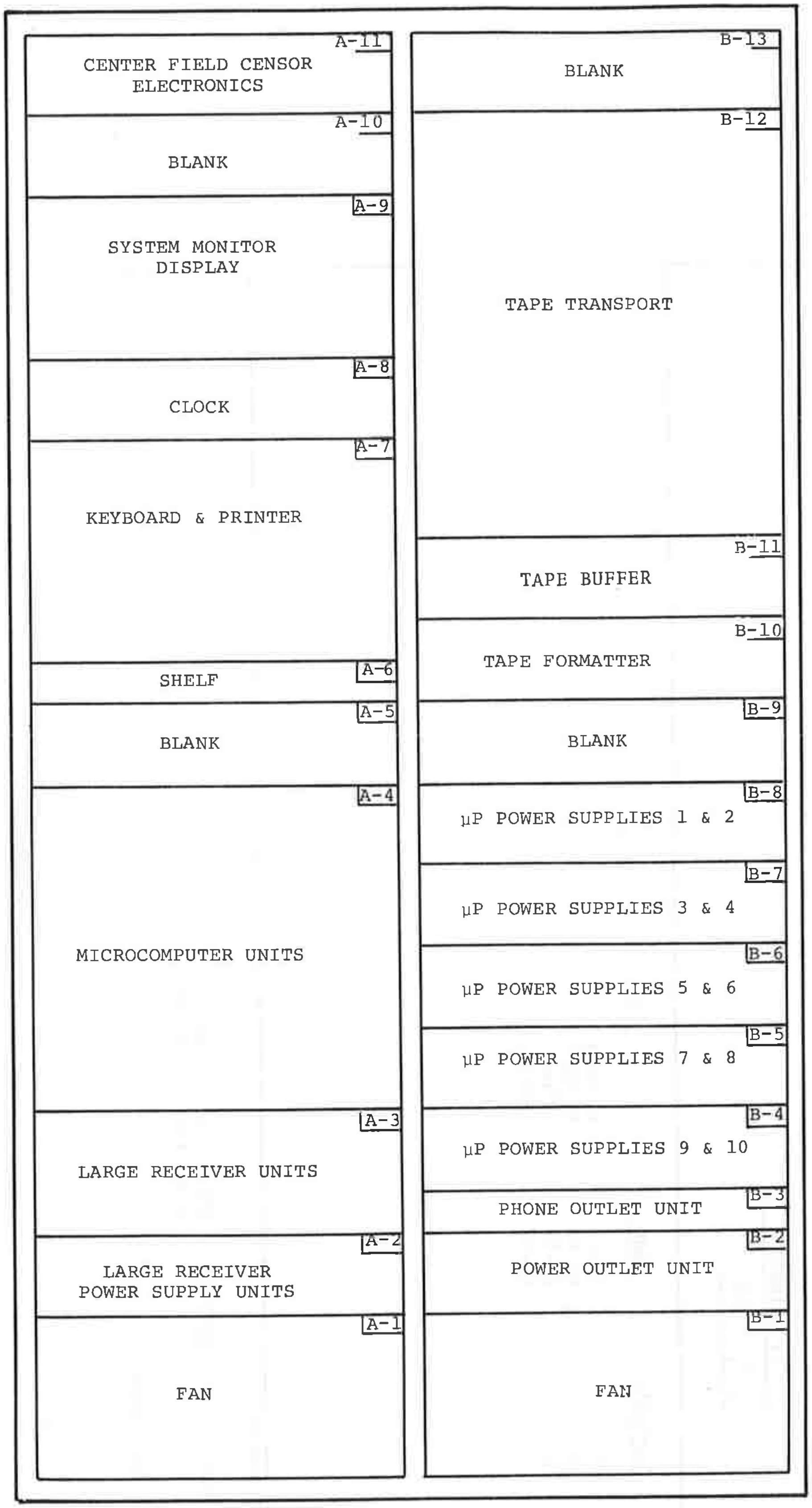


FIGURE 26. VAS ELECTRONICS CONSOLE

C. The phone outlet unit (B-3) provides direct lines from the VAS console to each of the VAS towers in the field, permitting direct conversations between maintenance personnel performing calibration or maintenance work on a meteorological subsystem and personnel monitoring system performance using the VAS Maintenance Subsystem. The VAS equipment shall include the communication equipment required to communicate between the VAS console and the meteorological towers.

D. A standard-rack mounted power outlet panel (B-2) shall be supplied to provide convenience outlets for test equipment.

3.4 Logistics. Each VAS site shall be equipped with a complete set of test and calibration equipment which shall enable the maintenance personnel to test, repair and recalibrate the VAS and any of its subsystems or components.

3.4.1 Sensor Test Fixture. The contractor shall provide a sensor test fixture which shall enable an operator to completely test and calibrate the VAS meteorological (wind speed and direction) sensors. The fixture shall have the capability to perform the following functions:

A. Test the sensor's wind speed output at 5 KTS, 15 KTS and 50 KTS.

B. Test the sensor's wind direction output from 0° to 360° in 10° increments.

C. Test the wind speed and direction thresholds.

D. Test the sensor electronics unit which translates the wind speed and direction transducer outputs into the scaled DC voltage outputs.

3.4.2 Meteorological Tower Test Unit. A Meteorological Tower Test Unit shall be provided which permits an operator to completely test and calibrate a VAS meteorological tower at the tower itself. The test unit shall perform the following functions:

A. The test unit shall have the necessary adaptor cables required to connect the three wind magnitude and direction sensors mounted on the tower to the unit. The outputs from all three speed and direction sensors shall be displayed simultaneously using digital readouts suitable for both day and night viewing. The digital display shall be scaled in knots and degrees corresponding to the actual sensor outputs. Use of this portion of the test system will allow an operator to perform a comparison check of all three tower sensor outputs, observing their performance independent of the tower mounted electronics unit.

B. The test unit shall be capable of simultaneously generating three (3) sets of signals corresponding to the outputs of the three tower sensors. By connecting these test unit outputs to the tower mounted electronics in lieu of the 3 actual sensors an operator shall be able to input known wind magnitude and direction signals to the electronics in order to test their operation. The test unit shall include a digital voltmeter to read the scaled DC outputs (2.5V = 64KTS = 256°), verifying the performance of the sensor transducer to DC voltage translator electronics.

The unit shall also generate signals corresponding to the outputs of the NWS CF sensor, which when input to the CF sensor monitoring electronics, will allow the checkout of that unit's operation.

C. The test unit shall be capable of accepting the output from the modems (VAS tower electronics or CF sensor monitoring electronics), process the data and display it to the operator via suitable digital displays. When used on a VAS tower, the unit shall display simultaneously the 3 wind speed and direction sensor outputs in knots and degrees and (using a seventh digital display and a selector switch) the outputs from channels 7 through 10. When used with the CF sensor electronics, the unit shall display the CF output in knots and degrees. When used with the simulator section described in Section B above, it will permit the complete checkout of a set of tower electronics at the tower site.

In summary, the Tower Test unit shall enable an operator to perform the following tasks:

- Observe the direct outputs from all three VAS tower sensors or the CF sensor.
- Simulate the outputs from the three VAS tower sensors and the CF sensor.
- Decode and display the outputs of the tower modem. Thus, the tower electronics outputs can be checked using known inputs. Also the VAS tower and CF sensor lines can be checked at the input to the VAS console using the test unit capabilities described in Section C.

3.4.3 Microcomputer Test Unit. The microcomputer test unit shall consist of two parts:

A. A data simulator which duplicates the data stream from a VAS tower or the CF sensor to the microprocessor. The unit shall permit an operator to set in three values of R and three values of θ (or the voltages corresponding to the CF Sensor outputs when simulating that unit) and the inputs corresponding to the voltage inputs to multiplexer channels 7-10. Using this unit, an operator will be able to input known values of R and θ into the microprocessor, generate R or θ failures, 2 out of 3 R or θ failures, powers supply failures, A/D failures, etc.

B. The microcomputer test unit shall contain the capability to test a VAS microcomputer either in the VAS console or at a separate test (bench) stand. The unit shall be capable of testing the performance of the microprocessor, to locate faults. A microprocessor test system offered by either the microprocessor vendor or a commercial source shall be considered an acceptable unit. Thus, if the Intel SBC 80/20 microprocessor is selected for the VAS, the Intel MDS system or the Tektronics 8000 system shall be an acceptable test set.

3.4.4 Display Test Unit. A Display Test Unit shall be provided to generate test inputs to the RM & SM Displays. The unit shall permit an operator to set in the Tower ID, RED/GREEN for each runway $\overline{R}$, $\overline{\Theta}$ and G values, set the Repeated Failure Bit, or introduce a check Sum Failure.

The use of the above unit together with the microcomputer test system described in (3.4.3) shall enable a qualified operator to isolate display faults, effect repairs and test the unit.

4. QUALITY ASSURANCE PROVISIONS

4.1 Quality Control Provision. - The contractor shall provide and maintain a quality control program in accordance with FAA-STD-013. All tests and inspections made by the contractor shall be subject to Government inspection. The term "Government Inspection", as used in this specification, means that an FAA representative will witness the contractor's testing and inspection, and will carry out such visual and other inspections as deemed necessary to assure compliance with contract requirements. Tests shall be conducted at the Contractor's plant or test facility and at the Contractors expense. All test facilities, instrumentation connection and personnel necessary to conduct the tests required by this specification shall be furnished by the Contractor.

4.1.1 Classification of Tests. - The classes of tests which are required to be accomplished on the Vortex Advisory System are as follows:

- Preliminary Tests
- Design Qualification Tests
- Production Tests
- Reliability Demonstration Test
- Maintainability Demonstration Test

4.1.2 Test Procedures. - The contractor shall submit to the contracting officer at least, 60 days in advance of the proposed dates of the first test, test plans showing the procedures for all classes of tests specified including samples of the data sheets to be used for recording the results.

4.2 Contractor's Preliminary Tests. Prior to the time the contractor notified the Government that the initial production system is ready for inspection, and to demonstrate readiness for inspection, he shall make one complete set of all tests excluding reliability and maintainability tests. These preliminary tests shall be made on one production system or on one prototype (preproduction) model. The contractor's preliminary tests do not constitute any of the regular design qualification tests, or production tests required by the referenced general specifications.

4.2.1 Preliminary Test Data. The contractor shall submit to the Government contracting Officer a certified copy of the test data covering all the contractor's preliminary tests. This test data may be submitted along with the proposed test procedures and forms under FAA-STD-013, but, in any case, the test data shall be submitted not less than 10 working days in advance of the date set for inspection pursuant to paragraph 4.2.2.

4.2.2 Notification of Readiness for Inspection. After a submission of the preliminary test data, and when the contractor has one or more production systems completed, i.e., equipments produced to meet all specification requirements, he shall notify the Government Contracting Officer in writing that he is ready for Government inspection. Such notification shall be given in time to reach the Contracting Officer not less than five work days before the contractor desires inspection to start.

4.3 Design Qualification Tests. - The following tests (and verification) shall be made on a regular production system selected by the FAA representative.

Rating verification of parts and materials (4.3.1)
Other general specification tests (4.3.2)
Other design qualification tests in this specification 4.3.3

4.3.1 Rating Verification of Parts and Materials. - Measurements or calculations, or both, shall be made in order to establish that the electrical and electromechanical parts, wire and insulating materials used in the equipment will not be subjected to voltage, currents, power dissipation, and temperature in excess of the derated values permitted by applicable specification requirements.

The following is a basic list of parts and materials to which the foregoing applies, other electrical and electromechanical parts used in the system shall also be subject to the foregoing:

Capacitors	Relays	Connectors
Crystals	Resistors	Semiconductor Devices
Fuses	Switches	(Transistors, Rectifiers
Insulators	Transformers	Diodes, Displays, etc.)
Insulating Materials	Wire	
Motors		

4.3.2 Other General Specification Tests. - Tests shall be made in order to establish that the requirements of the following paragraphs of FAA-G-2100/1 wherever applicable, are being met:

Ground potentials 1-3.5.9.2 to 1-3.5.9.3

AC line input resistance to ground (service conditions of temperature and humidity) 1-3.6.3

Circuit protection (at minimum line voltage in service conditions range) 1-3.7

Performance requirements and tolerances specified in parts 3,4 and 5 of FAA-G-2100 where such parts are applicable.

4.3.3 Other Design Qualification Tests. - The tests shall include an end to end VAS performance evaluation test. To meet this requirement the contractor shall establish a test station consisting of a minimum of two (2) VAS meteorological towers, sensor and electronics, the VAS console, and a minimum of two (2) SM and six (6) RM displays. A minimum of 20,000 ft. of signal cable shall be used to connect the VAS towers to the VAS console and a minimum of 500 ft. of cable shall be used to connect the VAS displays to the console.

Tests shall include but not be limited to verification of the correct operation of the sensors, sensor electronics, microprocessors ($\overline{R}$, $\overline{\theta}$, $\overline{G}$, RED, GREEN computations, failure detection) display operation, operation of the data formatter, data recording and the diagnostic, failure and statistics printout. In general, it shall be a comprehensive test which insures proper operation of all portions of the VAS.

4.4 Production Tests. - A complete set of tests shall be performed at normal test conditions on each completed system to establish conformance with the specification requirements. The system configuration to be tested shall be as defined in paragraph 4.3.3 above.

4.5 Reliability Demonstration Tests. - A reliability demonstration shall be performed using one or more production systems as defined in paragraph 4.3.3 above, in accordance with the contractors approved test plan. The test shall be conducted continuously with no allowable repairs or shutdowns.

4.6 Maintainability Demonstration Test. - A maintainability demonstration shall be performed on a production system. The MTTR shall be 30 minutes and the maximum corrective maintenance downtime shall be 2 hours.

5. PREPARATION FOR DELIVERY

5.1 General. - Preservation, packaging and packing, and marking shall be in accordance with the requirements of Specification MIL-E-17555. Levels of protection as defined in FED-STD-102 shall be as specified by the procuring activity.

5.2 Preservation and packaging. - Each VAS complete with five (5) sets of instruction books, shall be packaged in accordance with the Level C requirements of Specification MIL-E-17555. Each packaged unit shall be individually marked for identification and stocking.

5.3 Packing. Items preserved and packaged as above, shall be packed in exterior type containers, selected from appropriate tables of MIL-E-17555, conforming to the applicable levels of packing specified. The shipping containers shall be marked in accordance with the procurement documents.

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