

CARGO SECURITY FIELD TEST

FINAL REPORT

Volume II: Technical Description

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Volume II: Technical Description

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SUMMARY

The Cargo Security Field Test Program conducted for the Law Enforcement Assistance Administration had as its objective the evaluation of a cargo security system in terms of its impact on cargo theft and the operational utilization of cargo vehicles.

Earlier phases of the overall Cargo Security program had identified the magnitude and distribution of cargo losses within the trucking industry, had established that the pickup and delivery segment of the industry suffered the preponderance of losses, and, with the cooperation and participation of cognizant security officers, had determined that continuous surveillance of vehicle location and status would provide the most cost-effective method of countering theft. A pilot test program was instituted to assess system feasibility and to identify the requirements for an operational system. This program was completed in 1976 and established the system operational requirements for the Field Test Program.

The Field Test Program was designed to evaluate system performance with a total of 40 pickup and delivery trucks operating within a 400-square-mile area of the Los Angeles basin. The program consisted of two phases: (1) the design, development, deployment and checkout of an improved cargo security system, and (2) the evaluation of its impact on cargo operations. To assess the feasibility of sharing common system elements between multiple users, a primary cost consideration in a fully operational system, the 40 vehicle units were equally divided between two independent trucking operations.

The design of the system incorporated the necessary improvements identified during the pilot test program, and was comprised of an automatic vehicle location subsystem deploying signals from commercial broadcast stations and a limited number of proximity units, a vehicle sensor and processing subsystem, a communications subsystem, a data processing subsystem, and display subsystem, all linked by a common communications subsystem.

The overall system was deployed in the Los Angeles test area, and its capability to provide real-time reporting of vehicle location and status and an audit trail of vehicle movements was demonstrated during the system checkout phase of the program.

A non-technical problem, namely the unavailability of a clear mobile radio channel in the test area, precluded completion of system acceptance testing and the initiation of the formal field evaluation, (the checkout phase had been conducted using a radio channel for which an experimental license was obtained; however, during final checkout, it was found that operation on the channel caused interference with regularly licensed users in Southern California,) and the program was terminated by LEAA.

From a technical viewpoint, the state-of-the-art of vehicle monitoring was materially advanced by the successful development and demonstration of the system. Implementation of the system provided an active demonstration of the multi-user, wide-area-coverage capacity of the AVM system and the capability for determining vehicle location using commercial AM broadcast transmissions. The development and subsequent operation of a dedicated, common, mobile radio digital communication link for multiple users was proven via-

ble and to be operationally acceptable from an end-users standpoint. Further, the design and implementation of a sophisticated, combined data-base-driven and event-driven data processing system which operated in a distributed processing environment was completed.

The technical accomplishments and the findings of the system design, development, deployment and checkout phase may be summarized as follows:

- o Vehicle Location System

- oo A wide-area coverage Automatic Vehicle Location (AVL) system was developed which operated over a 400-square-mile area (an area greater than the sum of the areas covered by all previously developed AVL systems).
- oo A very accurate, repeatable, and economical AM Phase signal tracking sensor/receiver was developed.
- oo A differential navigation system combining two location technologies was developed.
- oo Certain aspects of the external environment resulted in location errors beyond the specified limits and additive augmentation should be incorporated if the system is to realize its full potential in accurately determining vehicle location in an urban environment.

- o Sensor System

- oo The use of combinatorial logic for detected sensor information in the vehicle demonstrated that false alarms could be minimized while maintaining a full capability of detecting significant events.
- oo The low-cost, off-the-shelf sensors used in the system require that reasonableness criteria logic be in-

corporated to preclude the possibility of generating false data.

oo The environment of the installed sensors is hostile.

oo The operational value of the cargo compartment intrusion sensor is questionable.

o Communications System

oo A single channel, multi-user, digital, mobile radio communication system was developed and successfully implemented.

oo The system operated on a truly non-interference basis with the normal trucking operation.

oo A dedicated clear channel is needed for successful system operation. Additional preventive measures and protection are required to combat deliberate disablement of the communications antenna.

oo Communication coverage in the trucking company yard is unique to each installation, and special measures may be required to provide reliable operation at those specific locations.

o Base Station/Dispatch Station System

oo An event-driven dispatch display system which operates five devices over a single telephone line communications link was developed.

oo A simple, comprehensive, user-oriented, interactive dispatch display and recording/printout system was developed.

oo A transaction history and vehicle recent history re-

cording algorithm and recall procedure was developed to provide security personnel with a log of vehicle activity.

- oo A street data base algorithm, digitizing method, real-time nearest intersection look-up algorithm and vehicle in-route/out-of-route algorithm was developed to provide alphanumeric display of vehicle location and route status to the nearest of over 30,000 intersections and 40 truck routes in the 400-square-mile area.

As a consequence of these findings, and the limited operational experience gained on the program, the following recommendations are made:

- o The AM Phase-Lock vehicle location system should be augmented using a microprocessor and odometer sensors to eliminate location inaccuracy due to excessive localized grid warpage resulting from environmental factors.
- o The sensor and communications system should be upgraded to account for the hostile environment, and the operational utility of certain sensors should be re-evaluated.
- o A dedicated clear channel is mandatory for the common communications link.
- o The dispatcher station should be upgraded from a human factors standpoint.
- o The system should be capable of automatic recovery from a power failure.
- o Planning for future installations should include consideration of vehicle conditions from an electrical stand-

point for evaluation of communications coverage at individual freight yards, and installation and operational implications resulting from the trend towards the use of semitrailers for pickup and delivery operations.

- o The utility of the system when trucks are in the freight yard should be re-evaluated by potential users.
- o Because of the special relationship between drivers and dispatchers, consideration should be given to routing all theft-related data to the security personnel, with only location and driver initiated alarm data being presented to the dispatcher.

CHAPTER I. INTRODUCTION

This volume presents a technical description of the Cargo Security System Field Test Hardware, Fabrication, Installation, and Maintenance Program (the Program). The Program activities were performed by Gould Information Identification Inc. (Gould I³) under a subcontract issued by The Aerospace Corporation. The program was sponsored by the National Institute of Law Enforcement and Criminal Justice, Law Enforcement Assistance Administration (LEAA), United States Department of Justice. The scope of the program encompassed the system design, system upgrade, system fabrication, testing, installation and checkout at designated field sites, maintenance for the duration of the program and hardware removal and test site restoration at program completion.

The system design was based on an upgrade of the brassboard system previously developed in the Cargo Security Development Program. The current Program consisted of designing, manufacturing, and installing equipment in 20 trucks at each of two trucking companies and included associated dispatch system, data processing and recording equipment.

The hardware/software system consisted of sensors mounted in trucks, location sensing electronics, a base station and two remote dispatch stations. The system was intended to provide a means for vehicles to automatically transmit potential theft alert conditions and locations to the trucking company dispatchers. With this information, the dispatchers would be able to interpret the conditions and notify local law enforcement agencies of the potential theft and the location to allow preventive action to be taken, when applicable.

The system was further designed to provide the trucking companies with a means of improving the efficiency of fleet operations, and thus to create an additional incentive for its use.

A typical sequence of events and an illustration of the use of the system hardware and software as developed under this program is presented in Figure 1-1. The occurrence of cargo theft is depicted in the figure in the upper left-hand corner. The theft is detected via the sensor at the cargo compartment door. Vehicle location is automatically determined through the use of the automatic location system equipment (exemplified in the figure by signpost transmitters). Security status and vehicle location data are transmitted via the system mobile radio for display at the trucking firm's dispatch station. The dispatcher observes the displayed data, assesses the problem and telephones the local police dispatcher who activates the police response.

A. Field Test Program Background and Overview

Cargo theft in the United States has reached a serious level. Organized crime and individual thefts have caused annual cargo losses in the billions of dollars. In recognition of this problem, The Aerospace Corporation conducted an extensive operations research study during fiscal year 1974 to pinpoint the magnitude and major source of these losses. The results of that study indicated that the biggest single factor in trucking operations is local pick-up and delivery. It was found that the authorized truck provides the most frequently used tool for cargo theft. A preliminary concept feasibility study of the practicality of a Cargo Security System was conducted. Based on the feasibility study results, a subcontract was let to Hoffman Electronics Corporation (subsequently

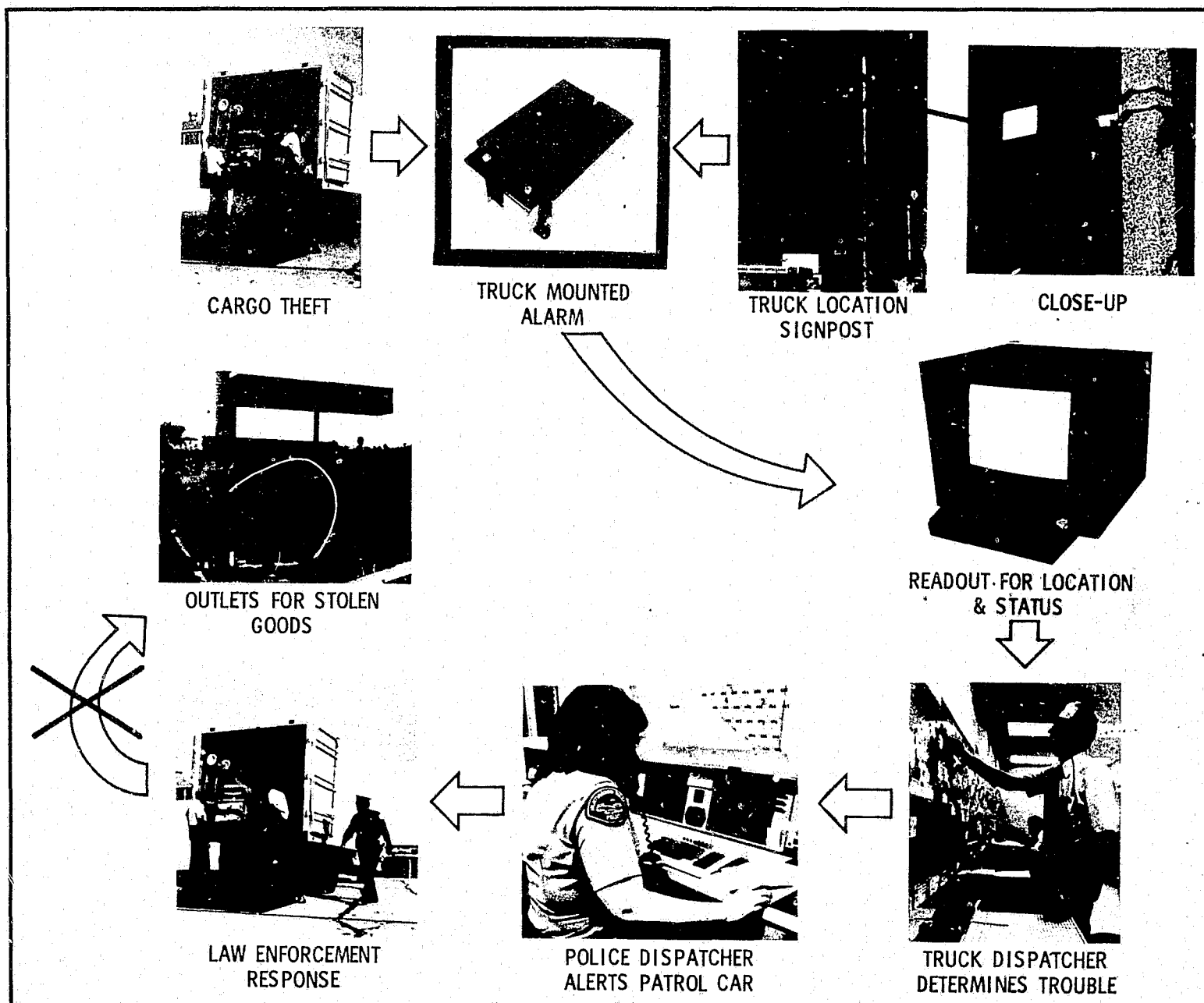


FIG. 1-1 CARGO SECURITY SYSTEM EVENTS

Gould I³) for the development and pilot test of a brassboard version of a Cargo Security System. The development system consisted of 331 direct proximity signpost transmitters, a complete base station, six vehicle units and a complement of sensors.

The successful results of pilot test program were the basis of this Program. The Program involved providing two separate trucking companies with the capability of monitoring the operation of their own cargo trucks for the purpose of detecting incidents of cargo theft and determining vehicle location and operational information. In addition, the system included the capability for off-line playback of day-to-day cargo truck operations in terms of location changes and status changes. The data and information generated during the Program was to be used for off-line analysis of operation and assessment of user acceptance and system effectiveness. The basic location technology used in the Program was Hybrid AM Phase-lock. This approach offered the potential for a very low cost wide area coverage capability. The basic technique was demonstrated (with some recommended modifications) during the Cargo Security System Pilot Test Program. The hybrid portion of the system consisted of differential navigation between reset signposts. The vehicle units transmitted status and location data via an integral common communications link.

The Program was conducted during a 20-month period beginning in February 1977, and extending through September 1978. The results of the program together with a description of the hardware and software are summarized in this volume.

B. Report Format

The material in this volume is organized into five chapters. Following this introductory chapter, this volume presents four technical chapters as follows:

- Chapter 2: System Description - The Field Test Cargo Security System hardware and software are summarized by subsystem.
- Chapter 3: System Results - The key accomplishments of the field test program are described along with an evaluation of results.
- Chapter 4: Areas For Improvement - System improvements are identified for the four subsystems.
- Chapter 5: Summary of Results and Recommendations - The major findings of the field test program are summarized and the resulting recommendations are presented.

CHAPTER 2. SYSTEM DESCRIPTION

The Cargo Security System provides for the following: (1) real-time surveillance of vehicle location and status, (2) display of incipient theft situations and individual vehicle status to the appropriate fleet dispatcher, and (3) data recording of individual vehicle histories for use by security personnel. The system includes:

- o A location support element which provides a controlled electromagnetic grid to support location determination.
- o A vehicle element which senses, processes and outputs data from the location support equipment and the vehicle status sensors.
- o A base station element which provides overall system control and processes data from the vehicle and the dispatch station equipment.
- o A dispatch station element which provides for the display and printout of vehicle data.
- o A communications element which provides the data transmission paths between all system elements.

A. System Operational Modes

The system, illustrated in Figure 2-1, has two modes of operation which are enabled automatically or by dispatcher selection.

Normal Mode. During normal business operations, i.e., when the trucks are engaged in the loading and delivery of cargo. In this mode, the dispatcher is provided with the following display data and hardcopy outputs.

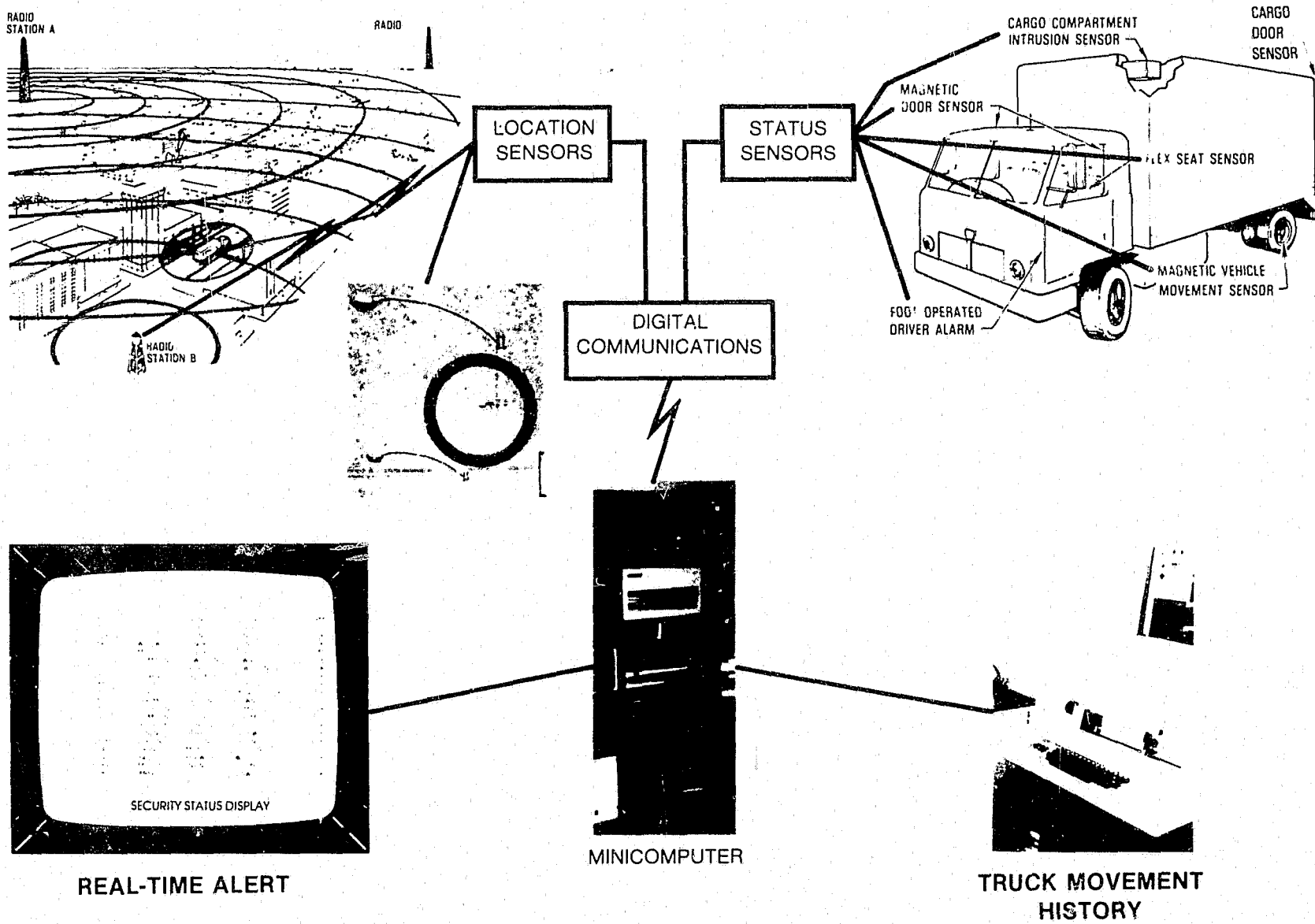


FIG. 2-1 CARGO SECURITY SYSTEM

- o A system status display (Route Status) describing the location and status of all trucks and an indication of alarm or potential theft situations is the primary system display. Vehicle location and status data on the display is updated whenever a significant predetermined sequence of sensor actuations is detected. Data transmissions are normally initiated by the vehicle upon occurrence of any of the above events. However, a supplemental base-station-initiated interrogation to verify communications and vehicle system integrity also provides location and status change data.
- o A specific vehicle status display (Security Status) provides the dispatcher with detailed sensor status information as well as location information. Supplementary data (e.g., license plate number, truck identifier, appropriate law enforcement jurisdiction, etc.) is displayed to assist the dispatcher in responding to an abnormal situation.
- o A printed copy of display information provides the dispatcher with all the significant data relative to an alert or alarm condition, including sensor status, vehicle location and time of occurrence. This information also serves as a permanent record of fleet operations.

After Hours Mode

Outside normal business hours, a vehicle is loaded and parked either within its freight yard or another known location. The after hours mode of the system provides for the real-time detection of attempts to steal or to enter the vehicle with alarm data presented

on a separate display located in the security guard area.

In both operational modes, the system records events occurring at each vehicle and provides a capability for the retrieval of up to three days of individual vehicle histories. The vehicle history data includes delivery and non-delivery stops, route entry/exit, a mileage summary, and all detected alert and alarm conditions.

B. System Architecture

To meet the operational requirements at minimum cost, the system is organized as a distributed data processing network linked by common communications channels. Referring to Figure 2-2, preliminary processing of source data (location and sensors) is performed within each vehicle unit in accordance with processing protocols established by the base station. Bi-directional data transfers between each vehicle unit and the base station are accomplished via a common radio communication link. Second stage processing and combining of source data from each vehicle is performed within the base station to yield location and alarm/alert information in a common format. Base station control processing provides for the processing of individual vehicle data by vehicle affiliation for any necessary communication with vehicle units and for handling data requests from the dispatch stations. These dispatch stations incorporate processing elements to handle communications with the base station and to format the individual displays in accordance with local commands.

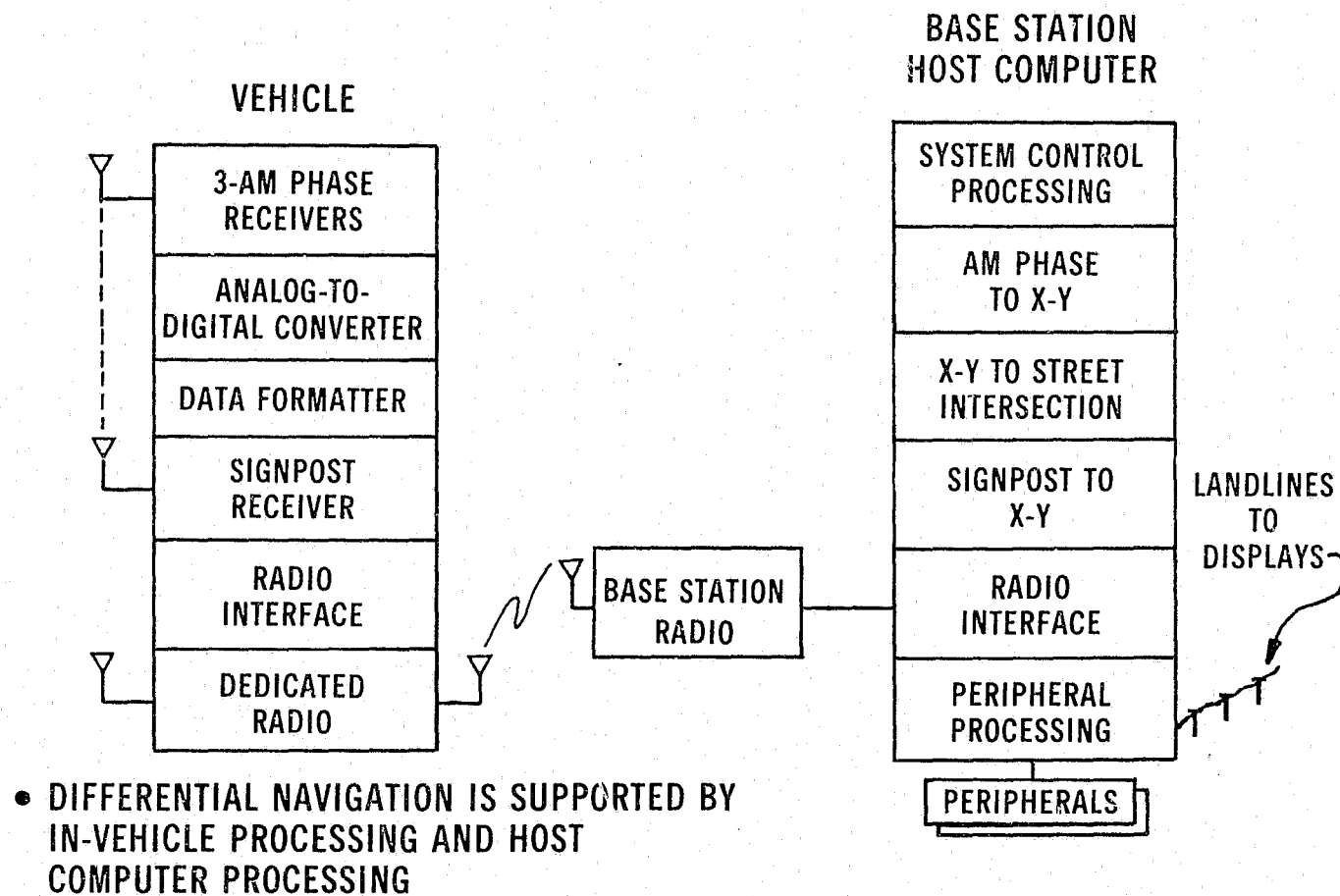


FIG. 2-2 DISTRIBUTED PROCESSING

The system elements and their interfaces are depicted in Figure 2-3.

A controlled electromagnetic environment comprised of phase stabilized commercial broadcast transmissions and low-power proximity units is employed as the primary source of vehicle location data. Three local broadcast stations, with a suitable spatial distribution, are phase synchronized and proximity units installed on utility poles at approximately two-mile intervals throughout the operational area to provide location data.

Within each vehicle unit, separate receivers are employed for detection of broadcast signals and proximity unit transmissions. The broadcast receivers process the received signals to generate phase comparison data unique to the specific location of the vehicle. Similarly, when the vehicle enters an area covered by a proximity unit, the coded address of that unit (unique to a specific installation site) is detected and processed. Both sets of location-related data are routed to the vehicle's control unit for subsequent transmission to the base station.

Also contained within each vehicle subsystem is a group of sensors for detection of door openings, intrusion, vehicle motion, driver alarm, ignition key operation, seat occupancy, and any attempts to disable the system by severing sensor wiring or gaining access to the vehicle unit electronics. The sensor data is routed to an on-board processor which provides data filtering by means of a programmable combinatorial logic operation, such that only pre-determined sensor combination actuation sequences are recognized by the system and transmitted to the central processor.

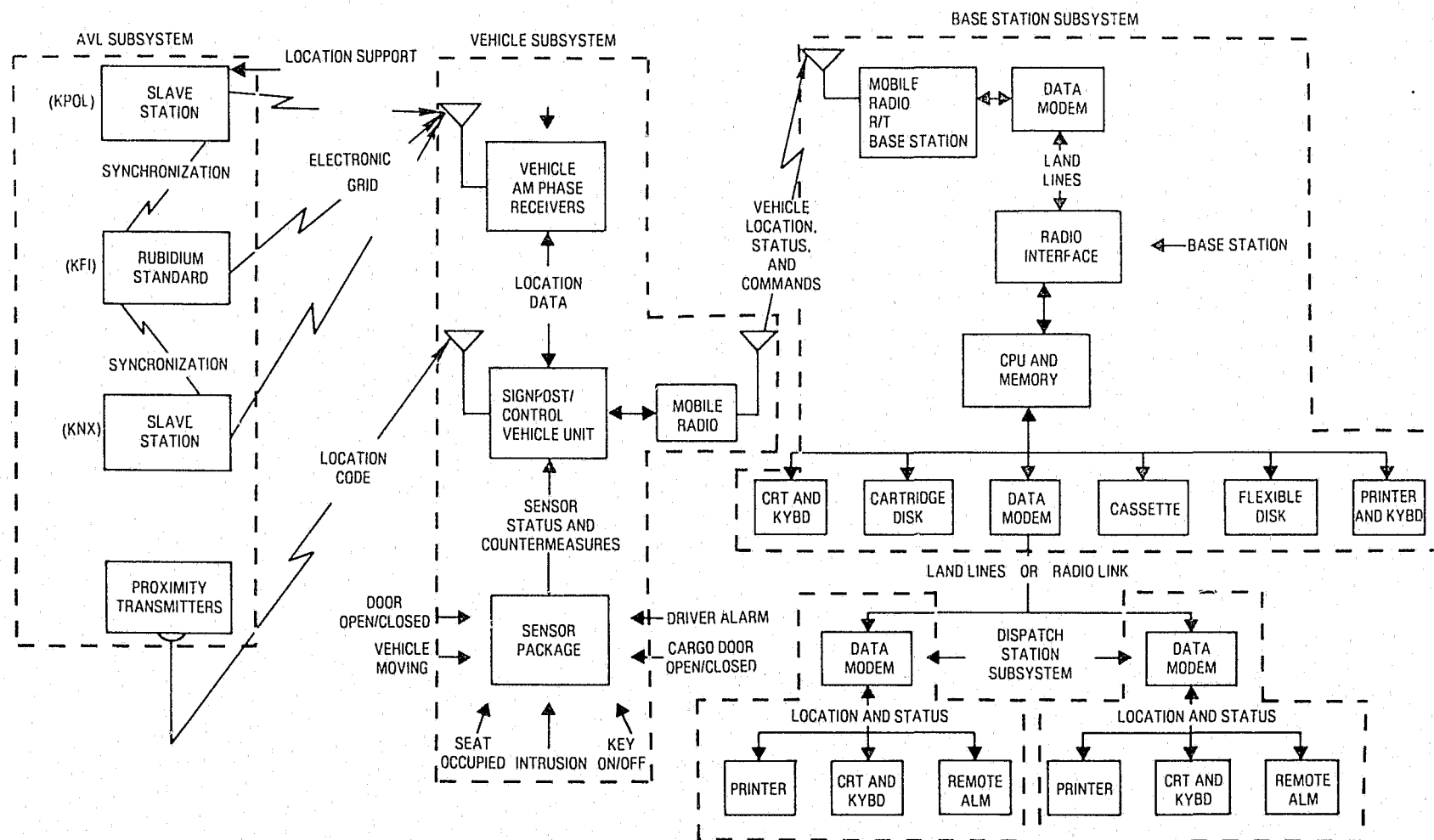


FIG. 2-3 CARGO SECURITY SYSTEM - FIELD TEST CONFIGURATION

The vehicle control unit interfaces with the mobile communications equipment and data transmissions to the base station are initiated by the vehicle unit upon occurrence of specified events (predetermined sensor actuations, receipt of a proximity unit signal, predefined changes in broadcast signal phase, etc.), or in response to an interrogation from the base station. The communications interface section of the control unit handles communications protocol, error detection, channel contention and transmission control.

A dedicated radio communications system shared by all vehicles in the system provides for independent digital data transmission between vehicles and the central base station. Vehicle transmissions are comprised of location related and filtered sensor data. The transmissions are initiated by the occurrence of a specified "event" at a vehicle or in response to a base station interrogation. Transmissions from the base station to individual vehicles include acknowledgement of vehicle data transmissions, interrogations to verify vehicle integrity, modification of the combinatorial logic patterns in the vehicle sensor processor and reset of vehicle location registers. The radio communications subsystem is comprised of commercial land-mobile radio equipment operating on a dedicated UHF channel.

The base station subsystem includes the communications interface with the vehicles, provides for processing of location and filtered sensor data, is used to generate data bases describing the geographic location and status of each vehicle, partitions the data on a fleet basis, provides the interfaces with the dispatch subsystems located at the individual trucking company locations, and maintains

the overall timing and control of the system. Associated peripheral devices provide for system control, program and data storage and recording of system transactions.

Each trucking company is equipped with a dispatch subsystem for the display and printout of associated vehicle data. Communication between each dispatch subsystem and the base station subsystem is by means of dedicated land lines provided by the local telephone company. Each display subsystem can access and display/printout the associated vehicle location and status data. The primary display employed for normal operations (overall status or individual vehicle status) presents color-keyed data for use by the dispatcher. Data selection is accomplished via an alphanumeric keyboard. In the after-hours mode of operation, sensor data is presented on a dedicated display installed in the security guard area. A printer is installed for the purpose of logging events or for the recall of individual truck histories.

C. Basic System Operation

The basic system function is that of acquiring two types of source data (location and sensors) at each vehicle and processing these data to provide a display of vehicle status and location. The system is essentially comprised of a location processing function and a control data processing function, a data retrieval function and a control function.

1. Location. The location system is a hybrid technology comprised of a differential hyperbolic navigational grid formed by commercial broadcast stations (AM Phase-Lock) and proximity transmitter units used for the initialization and reset of vehicle location. The location system functions are performed by location support elements, receiver processors at each vehicle and software algorithms (and supporting data bases) in the common base station.

a. AM Phase. The basic operation of the AM Phase-lock location system is that of receiving and comparing phase stabilized carrier signals from three commercial broadcast stations and the conversion of the resultant hyperbolic lines of position to a standard coordinate system. The location support element for the AM Phase-lock system is comprised of a frequency standard installed in one station and special purpose receiver/exciter unit installed in the other two selected stations to provide a triad of phase-stabilized carrier signals. In each vehicle unit, a receiver/processor unit strips off the modulation sidebands from the incoming broadcast signals, converts the resultant carriers to a common frequency, and compares the phases of two carrier pairs. The output of this receiver/processor unit consists of two counters,

the contents of which describe the number of hyperbolic "lane crossings (in either an increasing or decreasing direction) for each station pair from an arbitrary zero reference point. This reference point is reestablished each time the vehicle passes a proximity unit. The lane count data in each register is made available to the vehicle data control unit for transmission to the base station via the common radio channel. Additionally, to preserve data integrity a transmission of lane count data is initiated whenever a counter rollover is experienced. Within the base station the first level of computation is conducted in AM Phase coordinates. Lane count data received from the vehicle is used to increment or decrement registers which are initially loaded with the absolute AM Phase coordinates of the zero references in the vehicle unit. The contents of these registers thus represent the absolute phase coordinates of each vehicle. The second level of processing provides for the conversion from the AM Phase coordinates to geographic coordinates. This conversion algorithm uses the AM Phase coordinates in conjunction with data base information describing the location and carrier frequency of each broadcast station and the origin/scaling of the selected geographic coordinate system. An auxiliary processor compares this vehicle location data with a data file describing the boundaries of the authorized vehicle operating area for alert detection. The final processing level converts the geographic coordinate data to street intersection information and employs a data base which describes street segments in geographic coordinates to determine the nearest street intersection to the derived vehicle coordinates.

b. Proximity. Proximity units are low power transmitters emitting a unique code and are employed in this system to initialize or reset the location of each vehicle. The location support element consists of these transmitters installed at preselected sites throughout the test areas. A special configuration of proximity transmitters is employed for depot initialization and mode change control. In the vehicle unit, the proximity unit receiver is employed to detect and verify the validity of the received code in transmission (the detection range is preset to approximately 150 feet from the transmitter) and receipt of a valid signal initiates a data transmission to the base station and the establishment of a new zero reference point for the AM Phase-Lock system. At the base station, the proximity unit code is used in conjunction with the proximity unit data base to derive the absolute AM Phase coordinates of that specific proximity transmitter. This data is employed to update the previously described absolute vehicle AM coordinate registers. Detection of the special proximity configuration also initiates a mode change via the system control function.

2. Sensors. The vehicle sensor group provides signals in the form of contact closures, voltage level changes, and pulse data to the vehicle unit which provides for data filtering and transmission control in the normal mode of operation and for alarm transmission control in the after-hours mode. In the vehicle unit, incoming sensor data is conditioned to eliminate transients and then inputs to a processor which employs a random access memory (RAM) to detect predetermined combinations of sensor activations, and to initiate a data transmission when these criterion have been met. The contents of the RAM, i.e., the combinatorial criteria and the

inhibiting of data from any specific sensor) are loaded from the base station via the radio communication link whenever the vehicle is placed in the normal mode of operation. In the after-hours mode of operation the actuation of any sensor initiates a transmission to the base station. Within the base station the filtered sensor data is examined to determine its priority (i.e., alarm/alert) and entered into a vehicle status file. Certain sensors data (e.g., cargo door open) are combined with location data to determine if an alarm condition should be declared.

3. Data Retrieval. Two dispatch stations provide for retrieval, formatting and display of individual vehicle status and location data. A microprocessor and associated memory located within the primary display provide for system control of storage of vehicle data thus limiting the communications channel to data update. Request for data on an individual vehicle or fleet basis are routed from the dispatch station keyboard via the microprocessor to the base station which accesses the current vehicle data files and returns updated information to the microprocessor. Local memory is updated as appropriate and the updated information is routed to the requested display and/or printer.

4. Control. Control of the system is organized on a two tier basis: within each local unit (i.e., vehicles, dispatch stations) an independent control function provides for priorities, data transmissions, and auxiliary processing; overall system management is controlled by the base station processor. The system is designed for fully automatic operation.

a. Mode Control. When a vehicle which is in the after-hours mode exits the depot, detection of signals from the special

proximity unit configuration installed at the exit initiates a data transmission by the vehicle to the base station. Receipt of this special code initiates a mode change control process which provides for loading (via the radio channels) of the RAM in the vehicle unit processor and the initiation of the vehicle location and status files. When the vehicle returns to the depot, detection of the special signals and their transmission to the base station results in a command to the vehicle unit enabling an orderly shut-down of nonessential functions in transition to the after-hours mode of operation.

b. Communications Control. Control of the communications channel (radio and landline) is primarily under the control of the local units and organized on an event/demand basis. However, the base station maintains a general supervisory role and has provisions for override or supplemental control as required. Each vehicle controller initiates a data transmission when a predetermined event (e.g., detection of sensor combination, receipt of valid proximity unit data, counter rollover, etc.) occurs within the vehicle unit and when communications protocol requires an acknowledgement to a base station command. The controller also includes provisions for detection of channel occupancy by another or the base station and for automatic retransmission of unacknowledged data blocks. The base station radio communications control acknowledges vehicle transmissions and also provides for automatic polling of specific vehicles on a demand basis. The dispatch station processors provide for the accessing of data from the base station via the landline links and for the control of the data flow within the dispatch station element.

D. Location Support Equipment

This section contains descriptions of each hardware element of the CSS location support subsystem. Operational characteristics are described and, where appropriate, physical features are provided. This includes descriptions of the AM Phase-lock radio station equipment and proximity location signposts.

1. AM Phase Location Equipment. The AM Phase-lock location net, shown in Figure 2-4, is described in this section in terms of its hardware features.

The AM Phase-lock electronic grid is generated by locking the carrier frequencies of three AM broadcast stations to a fixed reference. This reference is established by installing one radio station (KFI) with a rubidium frequency standard (Tracor Model 308A modified) and locking the other two frequencies to this stabilized frequency (in phase only). The electronic equipment which provides this synchronization was provided as government-furnished equipment (GFE) to this program, and was modified to operate with the higher power output required by the air transformer coupled exciter stage of station KPOL.

The three AM broadcast station carrier signal frequencies are 1540 KHz, 1070 KHz, and 640 KHz (corresponding to radio stations KPOL, KNX, and KFI, respectively). The 640 KHz frequency signal (master station with rubidium standard) was detected and amplified by the two slave units (Time and Frequency Technology Model 713 modified) at station KNX and KFI. The operating sensitivity of the slave receivers is approximately 25 microvolts. The slave unit receiver channel employs limiting amplifiers, phase-locked filtering, and TTL level digital frequency division to the 10 KHz (the lowest

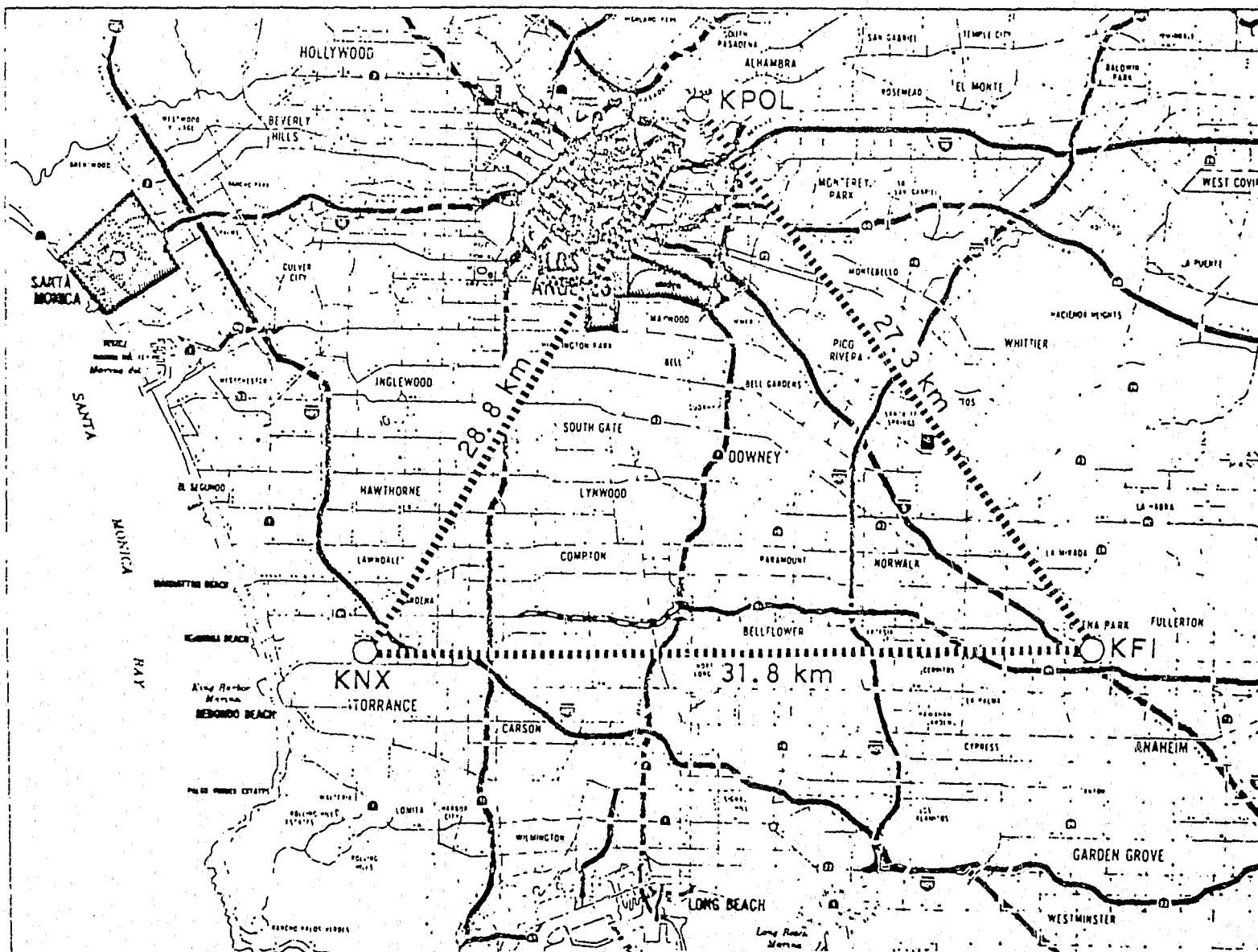


FIG. 2-4 PARTICIPATING AM RADIO STATIONS

common subharmonic of the three AM stations). This signal is then multiplied to obtain 1540 KHz and 1070 KHz respectively to obtain the phase-locked carrier frequencies for the slave stations and is used directly as the input to the broadcast transmitter exciter stage in lieu of the built-in crystal oscillator.

The signpost units were standard Gould I³ proximity RF signpost transmitters. 331 of these units were GFE to this program and installed at approximately two mile intervals throughout the test are (Figure 2-5). A summary of the physical and operation features of the signpost transmitter is provided in Table 2-1

Each signpost transmitter radiated a pre-assigned, hardwired, unique binary coded signal in the 27 MHz frequency band at a relatively low repetition rate (1.5 Hz) with an average radiated power of approximately 300 microwatts. Each long life (i.e., 5 years minimum) battery operated signpost transmitter operated as a low power device under Part 15 of the FCC rules.

Figure 2-6 presents the signpost transmitter omnidirectional radiated field as a function of range from the transmitter. The rapid decay in field strength in the near-field (70-100 feet radius) provides a steep gradient through which a complete street intersection (typically 40-100 feet) was covered. In the far-field, the field gradient is less severe, approaching the 1/2 free space dependency. The manner in which this gradient is used to create a location region reset is to use a threshold detector in the vehicle unit set at a nominal 150' range R.

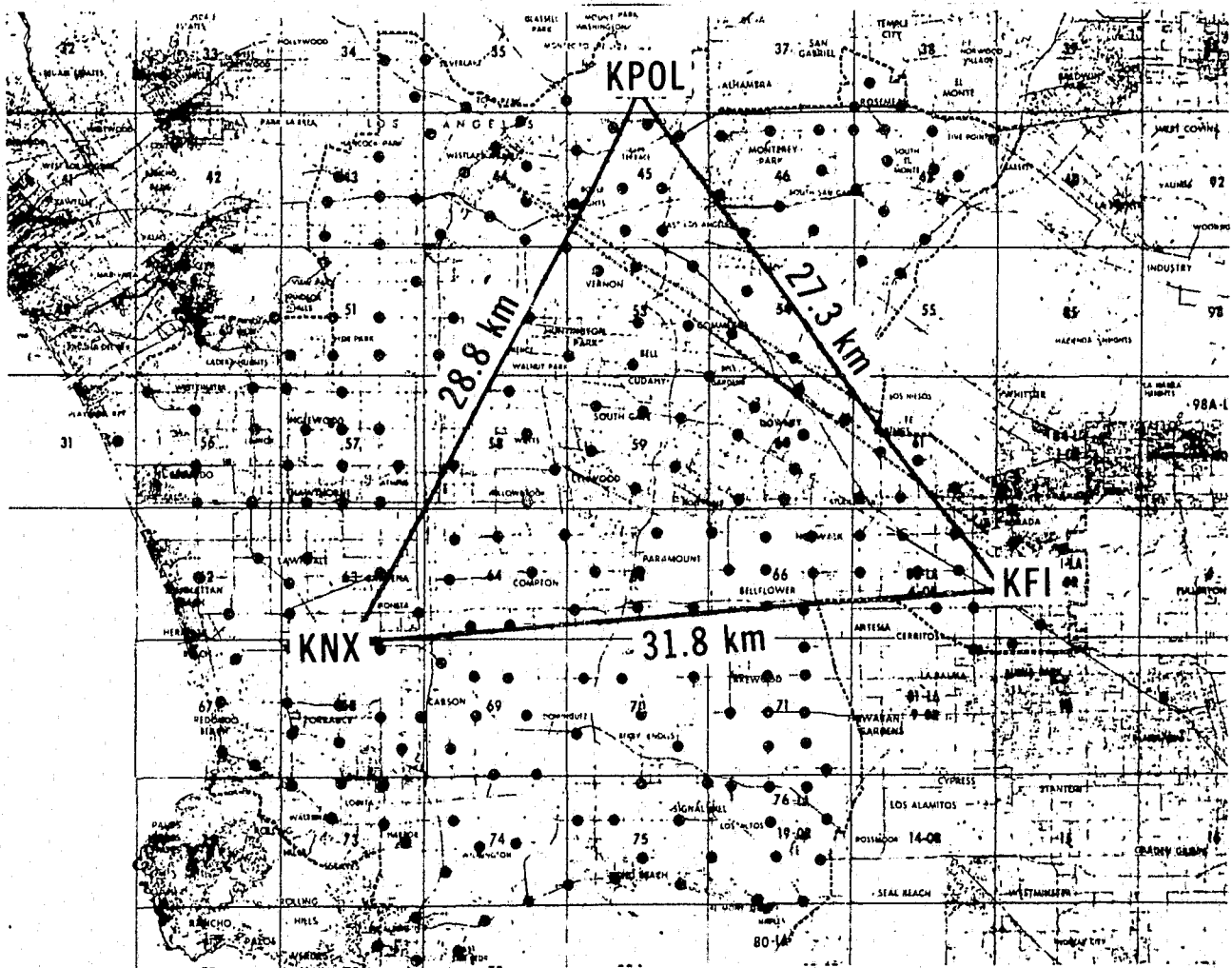


FIG. 2-5 SIGNPOST LAYOUT OVER THE TEST AREA

TABLE 2-1 SIGNPOST TRANSMITTER DESIGN FEATURES

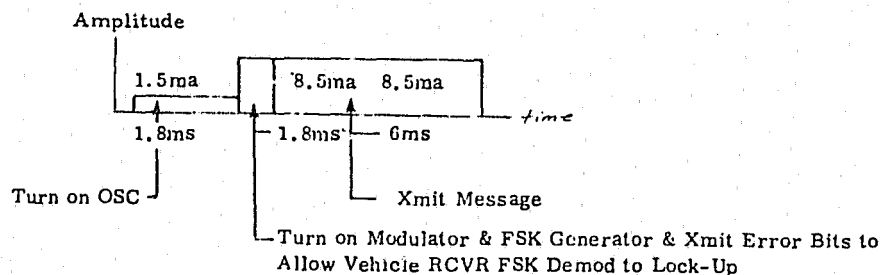
Physical	Operational
• Case and Mounting Material Selected for 20-yr Life • Long Life Lithium Battery (5-yr minimum design) • Low Cost Installation Using Standard Brackets • Light Weight (< 5 lbs) • Small Size Allows Installation Flexibility	• Low Power RF Meets FCC Requirements • 16-bit Code Allows 65,000 Unique Locations • Duty Cycle ≤ 0.012 • Not Affected by Electrical Power Failures

Communication Method -- Coherent FSK With Repeated bit - bit

Data Rate -- 11.6k bits/sec

Transmitted Bandwidth -- 45 kHz

Transmitter Timing



Duty Cycle -- 0.012

Battery Capacity -- 10 AM

Average Current Drain = $0.012 \times 8.5 + 75 \mu\text{a} = 177 \mu\text{a}$

Battery Life = $\frac{10 \text{ AM}}{177 \mu\text{a}} = 56,497 \text{ hours}$ $\frac{56,497}{8,760} = 6.45 \text{ years}$

Average Radiated Power -- 0.3 MW

Signpost PRF = 1.5 Hz

Antenna Gain -- -14 dBI

Transmitter Frequency -- $f_c = 27.095 \text{ MHz}$

FSK Frequencies -- $f_{ml} = 9.5 \text{ kHz}$ $f_{mh} = 14.25 \text{ kHz}$

Message Length -- (16 information bits + 16 bit complements + 2 error bits) $\times 2 = 68 \text{ bits}$

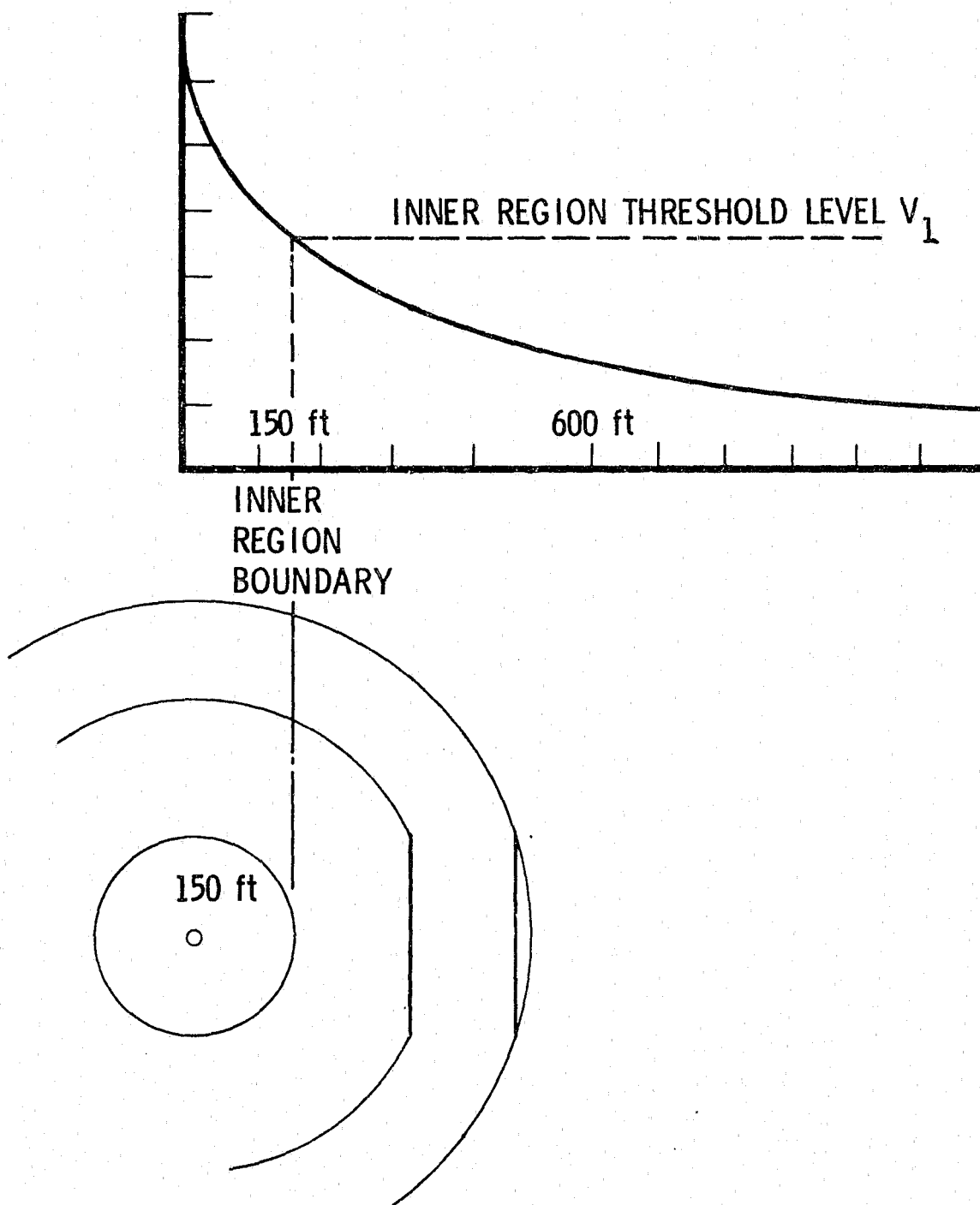


FIG. 2-6 THRESHOLD DETECTION GENERATES RESET

The basic electrical design of the RF signpost transmitter is shown in Figure 2-7. All digital and RF components are installed on a single PC card which includes the antenna tuning coil. The antenna coax is soldered to the PC card tuning coil. For maximum reliability, there are no connectors in the entire signpost and all connections are soldered. All components are conformally coated, the battery pack is sealed by the manufacturer, and the antenna is stainless steel.

E. Vehicle Equipment

The vehicle equipment provides for the sensing and acquisition of raw location and vehicle event data, local data processing, and bi-directional radio communication with the base station.

The principal elements of this equipment are depicted in the block diagram of Figure 2-8 and their functions may be summarized as follows:

(i) Sensors

These devices detect vehicle events such as door openings, vehicle movement, etc., and route the data to a data control unit. In parallel with these individual sensors, a second group of countermeasure sensors detects any attempt to interfere with vehicle system operation.

(ii) AM Phase Receiver

This receiver/processor provides detection and phase comparison between two pairs of broadcast signals and routes this data to a data control unit.

(iii) Signpost/Control Unit

This unit encompasses three major functions:

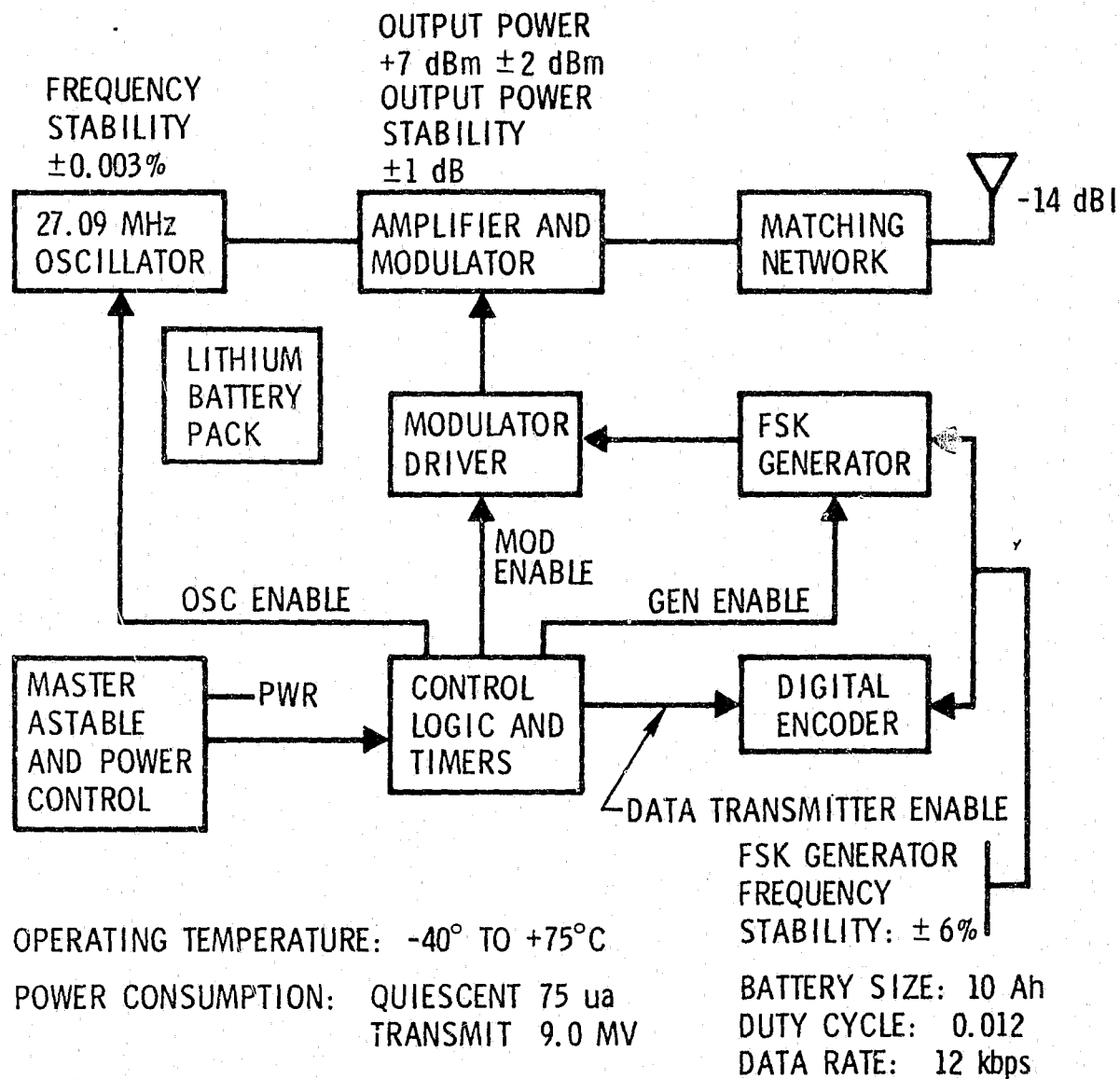


FIG. 2-7 SIGNPOST ELECTRICAL DESIGN

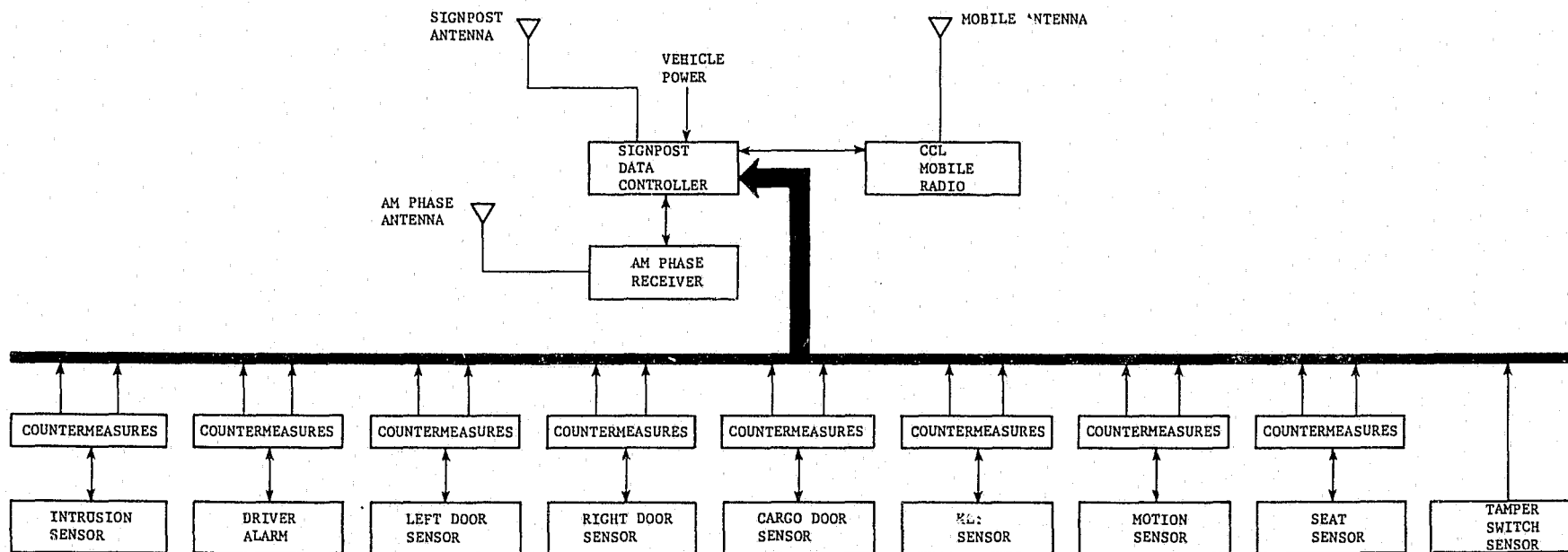


FIG. 2-8 VEHICLE EQUIPMENT BLOCK DIAGRAM

- o filtering and combinatorial processing of sensor data
- o detection of proximity unit transmissions
- o data management and communications control

(iv) Mobile Radio

A commercial land-mobile communications unit (Motorola MOCOM 70) operating in the mid UHF band provides bi-directional communications with the base station in a simplex mode of operation.

The technical data in this section is organized into five subsections as follows:

1. Signpost/Control Unit
2. AM Phase Receiver
3. Mobile Communications
4. Sensor Equipment
5. Physical Installation

1. Signpost/Control Unit. The Signpost/Control Unit is shown in Figure 2-9 in the form of a block diagram. The block diagram illustrates the separable functions performed by this unit. The operation of this unit can be described in terms of seven distinct elements.

- o Signpost Receiver
- o Radio Interface Module
- o Executive Control Module (Controller)
- o Digital Filter
- o Output Control Module
- o Sensor Control Module
- o Sensor Interface Module

More detailed information is provided in the accompanying engineering drawing as part of Vol. III. It should be noted that the seven functional elements are also physically separable and that they are contained in or on seven separate printed circuit boards.

In simplified terms, the Signpost/Control Unit functions as a data collection, processing, formatting, and transmitting unit. This capability is of particular importance for the cases of rapidly changing location information or a complex series of sensor activations.

Referring to Figure 2-10, the Signpost Control Unit performs the function of radio frequency (RF) and audio processing of the received signpost transmissions. This functional block is uniquely represented by two printed circuit cards, one of which performs the RF processing of the incoming 27 MHz signpost data; the other performs the audio bandpass filtering and demodulation of the detected FSK frequencies. The circuitry and philosophy of operation involved in this function is one of considerable maturity having first been employed in field

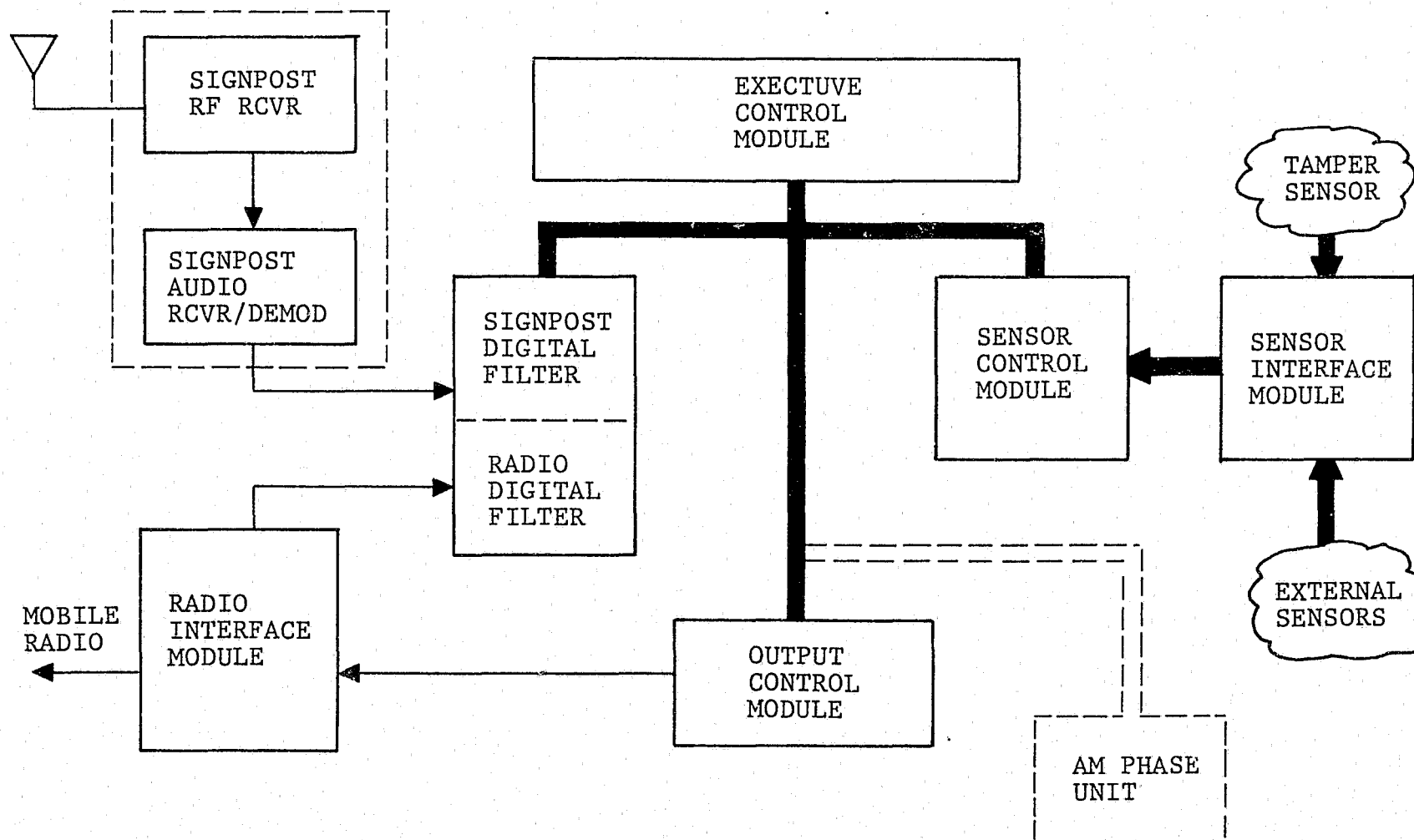


FIGURE 2-9 SIGNPOST/CONTROL UNIT

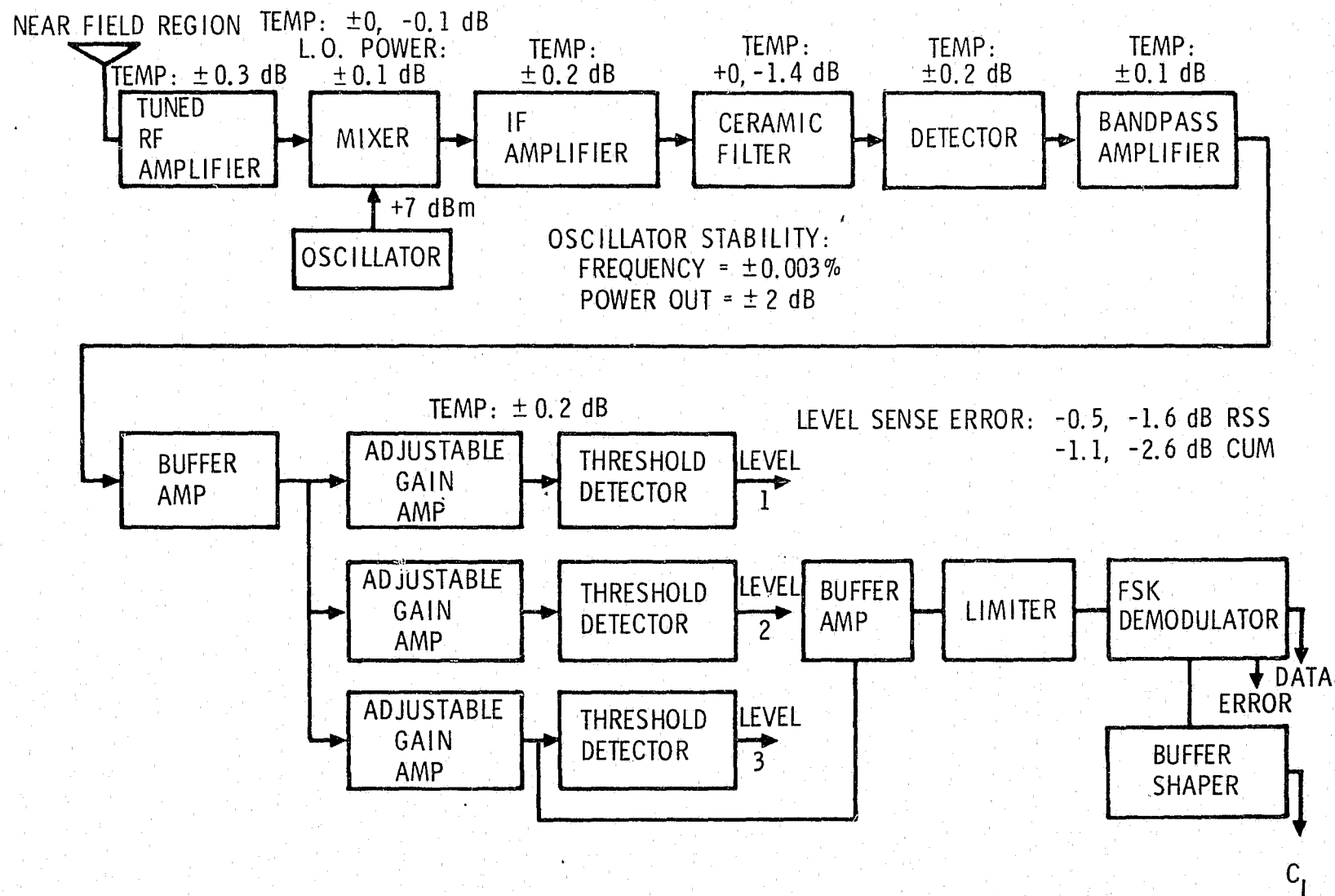


FIG. 2-10 BASIC VEHICLE SIGNPOST RECEIVER

units as early as 1973. Comparable hardware has also been employed in two other major systems prior to this deployment. Interface of this function to the supervisory hardware consists of the buffered audio, the demodulated signpost code, a measure of proximity in terms of a quantized level indicator, and an error flag which identifies the integrity of the demodulated response. A low level output is also sent to the digital filter network to suppress processing when the received signal strength falls below a preset minimum receiver threshold. This last input is simply a safeguard against errors which might escape detection when attempting to process signal of such a level as to be known not to contain any data of interest.

The radio interface module interfaces the vehicle system elements with the UHF radio communication equipment. The receiving section of this module functions similar to that of the audio section of the signpost receiver in that it audio bandpass filters the FSK modulated data, performs the function of digital demodulation, and presents both the buffered audio and a measure of data integrity to a companion digital filter. The receiver section of the radio interface differs from the signpost audio receiver when detecting the low level cutout i.e., the associated digital filter is required to process incoming data from receiver levels spanning the dynamic range from saturation to receiver noise.

The operations of the radio interface module are performed in accordance with a predetermined protocol between the radio interface module, the mobile radio, and the output control module. The protocol, which is standard in all Gould I³ radio interface designs, functions similar to any conventional modem interface. In particular, it

incorporates the logic equivalent of a ready-to-send and clear-to-send as well as transmit preamble and transmit data.

Error filtering of a received audio signal from both the signpost receiver and the radio interface module is performed on a single printed circuit assembly, the digital filter board. Preliminary processing for both inputs are basically identical in that each requires the incoming modulation to conform to a bit-bit complement protocol with prescribed prefix and suffix data. The signpost data filter performs the additional process of comparing the current received word with the previously decoded word prior to interrupting downstream processors. This exception is simply to insure single arrival declaration of a newly encountered location cell for resetting the AM Phase unit.

The sensor interface module performs the function of integrating and buffering the separate inputs from nine remote sensors and eight associated countermeasure inputs. One sensor, which signifies unit tamper, does not have a companion countermeasure input since its source of activation is internal to the vehicle electronics chassis. All other sensors are remote to electronic chassis and require a means of detecting whether or not the interconnect has been intentionally or unintentionally short-circuited or open-circuited. The specific sensors conditioned by this module are the ignition, right seat, right door, left seat, left door, vehicle motion, cargo area activity, and driver alarm. Conditioning of each sensor type is uniquely considered in the sensor interface module design. Sensor conditioning was limited to including single state variable time constant detection to insure that the sensor state had in fact changed. Countermeasures sensing accommodates both the short and

open circuit condition but does not discriminate between which activity compromised the sensor.

Monitoring sensor activity is performed by the sensor control module which is, in the majority of cases, a digital processing unit. This functional unit responds to any change in the state of any of the nine distinct sensors or eight distinct countermeasure inputs. Sampling of both the sensor and countermeasure inputs is performed at a rate of approximately once every millisecond. This sampling rate is tempered, however, by consideration of prior buffering and integration afforded by the sensor interface module. Response to sensor activity can be programmed from the base computer to the extent that unique pairs of sensors must be noted to be activated at a particular sampling time to cause an event transfer to be made to the base computer. If required, each change in activation level of any single sensor can be presented to the base computer. All countermeasures cause an unconditional event and subsequent transfer to the base station. Certain sensor activations such as the driver alarm are also unconditional events and cannot be influenced by the base station by any means other than complete masking of the sensor.

The output control module performs the function of data organization for subsequent UHF radio transmission. This includes recovery of the type of data to be transmitted from other modules in which the data is stored, injecting the vehicle identification code number, injecting the proper mode field designating the type of data being sent, and interfacing with the UHF radio under the prescribed communication protocol. The output control module synchronizes with the output FSK audio, allows injection of a preamble of predetermined length, encodes the data to be transmitted in bit-bit complement

form, and terminates the UHF transmission after completion of the output function. A review of the engineering drawings in Volume III will reveal that AM phase data is recovered directly from the AM phase unit, the sensor and countermeasure status is recovered from the sensor control module, odometer data is jamset from a holding accumulator which is resident on the output control module, and signpost location data is recovered serially from the digital filter module upon detecting that a new reset location cell has been entered.

Functions performed by the executive control module are analogous to a software executive monitor. All requests for servicing are queued and processed on a sequential basis with equal priority in the sense that once the processing of an event is initiated, it is allowed to go to completion without interruption. Activities which may be queued can be identified with one of six categories; namely, sensor data, location data, odometer data, a required uplink acknowledged, Remote Alarm Armed Request transmission, and the Mode Change Acknowledgement transmission. In general, the executive control module responds both to downlink requests for specific data from the base station computer and also supervises the output of events which are declared spontaneously in the mobile unit. Each type of response activity is suitably tagged prior to transmission in order that the base computer can distinguish between a request response and an un-requested spontaneous event.

All communication of critical data between the central base station and the signpost control unit is governed by a handshake protocol which is supervised by the executive control module. This

protocol requires that all requests for on-board status data be responded to with appropriate flags accompanying the response, thus identifying it as having been requested. The receipt of any message which alters either the contents of the RAM sensor mask or the individual sensor enabling/disabling masks requires an acknowledge. In the broad sense, any transmission from the vehicle unit resulting from an event declared by the vehicle unit requires an acknowledge to remove this event from queue. Enforcement of this acknowledgement was recognized as being impractical because, in areas of poor radio coverage, the vehicle unit became essentially insensitive to any subsequent activity until the acknowledgement was received. As a compromise, the executive control module was configured to attempt to communicate to the base station only eight times when a priority event is declared. Failure to receive an acknowledge caused the event to be discarded and allowed processing to continue normally.

Three modes of operation of the vehicle electronics are under control of the executive control module. This may be generally described as Normal, Remote Alarm Armed Request, and Remote Alarm Armed. Each mode is characterized not only by the processing performed while in that mode, but also by the power drain on the vehicle power system. In both the Normal and Remote Alarm Armed Request modes, all on-board electronics are fully powered including the AM Phase unit and the UHF radio. In the Remote Alarm Armed mode, the signpost control unit is powered continuously, the AM Phase unit is switched off, and the UHF radio receives power for 500 milliseconds once every three minutes.

The Normal mode of operation is, as would be expected, the state of the vehicle electronics during delivery hours when both sensor

activity and location tracking is being monitored. The Remote Alarm Armed Request mode is not so much a change in the status of the vehicle electronics as it is a means of notifying the base station computer for either of two special situations.

The first such situation arises as a result of the failure to complete the sequence of data transfers required to load the sensor RAM mask. Once this sequence is initiated, an exacting protocol is necessary to insure that the remote vehicle unit properly receives and store correctly the sensor event matrix. Failure at any point in this sequence causes the RAM to be disregarded by the vehicle electronics and a unique code transmitted to the central computer. This code is transmitted immediately upon failure of the RAM load sequence and repetitively thereafter at three minute intervals until acknowledged by the base station computer.

The second situation invoking the Remote Alarm Armed Request mode is entry of the vehicle into the physical perimeter of the truck company facility. Sensing of this condition is accomplished by sequentially detecting an all one's signpost code followed by an all zero's signpost code. These unique signposts are strategically placed at the yard entry of the trucking facilities to allow automatic detection of vehicle entry and yard exit activity.

The Remote Alarm Armed mode of operation can be initiated only by the base computer and is the preferred mode for non-delivery hours. This period normally includes overnight and weekend time spans when the location of the vehicle is known to be stationary or when sensor activity is still of interest from the standpoint of security. Upon being placed in the Remote Alarm Armed mode, all sensors on the

vehicle are automatically enabled and power is removed from both the AM Phase unit and the UHF radio. Excluding the situation in which a sensor is activated, communication is possible between the base station computer and the vehicle unit only once each three minutes. At these time intervals the executive control module causes power to be applied to the UHF radio and a transmission is made to the base station. Once this transmission is completed, the radio receiver is allowed to remain on for 500 milliseconds for downlink reception. If a request for location is not received during this time slot (this is the message required to place the vehicle in its normal mode) the radio will be powered down for another three minute period.

Activation of any enabled sensor while in the Remote Alarm Armed mode causes the event to be repetitively reported once every two seconds until an acknowledge message is returned by the base station computer. While armed, the sensor RAM matrix is disregarded, thus allowing any single sensor activity to be transmitted.

Removing the vehicle from its Remote Alarm Armed state is allowed by two means. As previously mentioned, the base station computer may in its available time slot, issue a Request for Location. Receipt of this message places the vehicle in its normal mode with sensors enabled as they were while the unit was armed. The second means is automatically invoked if the vehicle unit electronics detects passage of the uniquely coded all one's and all zero's signpost in a yard exit sequence.

2. AM Phase Receiver. The AM Phase receiver simultaneously accepts signals from three predetermined commercial AM broadcast stations through a standard automobile antenna and provides a digital

output signal which is a measurement of the accumulated phase difference between two input signal pairs. The phase difference of the third pair is not independent of the measurement of the first two pairs, and therefore is not measured. The three received signal frequencies are 1540 KHz, 1070 KHz, and 640 KHz (corresponding to radio stations KPOL, KNX, and KFI, respectively). As described elsewhere in this report, and 640 KHz station, KFI, is frequency controlled by a rubidium frequency standard and the other two stations received the KFI signal and utilized a phase lock multiplier/divider technique to control their frequency to exactly share a 10 KHz common factor with the KFI frequency.

In order to avoid the pitfalls of oversimplification of the requirements of the AM Phase receiver, it must be noted that in this application, the three broadcast stations do not produce an unambiguous electromagnetic field because the only modulation information is the frequency of the stations. There is no epochal time measurement inherent in the system and as a result, it can only be used as a differential navigation system. The signpost system provides a signal to the AM Phase receiver for initialization of differential navigation measurement and accumulation. To aid the reader in understanding the reason for inclusion of circuitry that may seem superfluous at initial inspection, the following paragraphs outline the pertinent parameters of the received signal which were considered in the design of the AM Phase receiver.

First, consider the concept of phase measurement of a signal with respect to the phase of a different frequency signal. The measured phase difference is, of course, time variant at the "beat"

frequency, the difference between the reference signal and the signal being measured. If the frequency of the signal to be measured is an integer fraction ($M \div N$, where M and N are integers) of the reference signal frequency, then the "beat" frequency is also an integer fraction of the reference frequency. The integer fraction of the "beat" frequency will be the absolute value of $(N-M) \div N$. The integer fraction characteristic of the received signals was achieved by the described frequency synchronization of KPOL and KNX to the signal received from KFI. Considering the actual signal frequencies involved, KPOL exhibited a frequency exactly $154 \div 64$ times the frequency of KFI and KNX exhibited a frequency exactly $107 \div 64$ times the frequency of KFI. Therefore, KPOL had a frequency exactly $154 \div 107$ times the frequency of KNX. It is easily proven that the highest common factor of the three broadcast station frequencies is 10,000 Hz. Therefore, the complex values of the three signals cycle in a 100 microsecond interval. That is, if the amplitude of three signals, 1540 KHz, 1070 KHz, and 640 KHz, were measured at arbitrary time, T_0 , and found to be $X_1 + iY_1$, $X_2 + iY_2$, and $X_3 + iY_3$, respectively, the same values would also be measured at T_0 plus 100 microseconds. At no time between T_0 and T_0 plus 100 microseconds would the exact same set of amplitudes be measured simultaneously, even though $X_1 + iY_1$ will occur 153 times $X_2 + iY_2$ will occur 106 times, and $X_3 + iY_3$ will occur 63 times in the interval $T_0 < T < T_0$ plus 100 microseconds. Without benefit of intelligent modulation, the longest unambiguous time period present in the three signals is the period of KFI, $100 \div 64$ microseconds. That is, it is assured that an arbitrary value of the amplitude of the KFI signal, usually

considered $0 + i0$, will occur once every frequency cycle of KFI; however, there is no assurance that at a single point in space the signal from either of the other two broadcast stations will be $0 + i0$ at the exact same time as any occurrence of $0 + i0$ in the signal from KFI. This tedious explanation has been presented to enlighten the concept of a time invariant electromagnetic "grid" which is often used in AM phase discussions to avoid repetition of the above explanation. In particular, the section describing hyperbolic mapping should be read considering the AM Phase system as a differential navigation system and noting that the location of the lanes are arbitrary because the AM Phase system utilizes the accumulation of lane crossings from a known starting point

As previously stated, the longest unambiguous period present in the received signals is the 640 KHz cycle from KFI, and that signal was initially used for all time references in the AM Phase receiver. Actually, this choice was arbitrary, and the system would perform equally well if one of the other stations were selected as the reference.

During prototype field test, it was found that the 640 KHz station, KFI, was subject to frequent overmodulation especially when electric guitar music was broadcast. The negative portion of overmodulation has the effect of blanking out the RF carrier for a significant length of time. Because of the importance of the quality of the signal used to lock the Synthesizer Subassembly, the 640 KHz signal was discarded and the 1070 KHz signal was substituted. Because the hardware was already constructed, this modification resulted in a different variance in unit of distance for the two measured phase channels.

a. Basic Theory of Operation. The AM Phase receiver utilizes parallel triple coherent frequency conversion of the 1540 KHz and 640 KHz received signals to a 5 KHz intermediate frequency where they are phase compared to a 5 KHz reference signal derived by frequency division from the 1070 KHz received signal. All heterodyning signals used for the frequency conversions are provided by the synthesizer unit and are derived from only the received 1070 KHz signal.

If a 1070 KHz input signal, $A \sin (1070K \cdot 2\pi t + \phi)$, is applied to the AM Phase receiver, the synthesizer will produce all the signals necessary to convert both a received 1540 KHz and a 640 KHz received signal to a 5 KHz intermediate frequency. To illustrate this operation on the 1540 KHz received signal, consider the following notation. For a common arbitrary reference time, t_0 , the phase at the antenna terminal of the 1070 KHz received signal may be noted as $\sin Rt + \phi_R$ and the phase of the 1540 KHz received signal may be noted as $\sin Ht + \phi_H$, where R is 2 times 1,070,000, H is 2π times 1,540,000, ϕ_R is the phase of the 1070 KHz received signal at the reference time, and ϕ_H is the phase of the 1540 KHz received signal at the reference time. The AM Phase receiver synthesizer provides a signal, F_{1H} (1995 Hz) for conversion of the 1540 KHz received signal to a 455 KHz intermediate frequency. This signal is derived within the synthesizer to be $\sin (1995 \div 1040) R + (1995 \div 1040) \phi_R + \phi_e$. The new term in this expression, ϕ_e , is a time invariant term to account for the phase shift in the physical circuitry. No attempt will be made in this discussion to separate by notation the various equipment phase shifts, and they will be collectively noted

as θ_e . However, to understand the AM Phase receiver, the reader must resolve that there are 107 equally probable values of θ_e for any arbitrary reference time, t_o . The term "time invariant" is used herein to describe the relation of the equipment to any constantly received signal. If the 1070 KHz received signal were removed from the receiver input and reapplied at an arbitrary time, $t_o + t_a$, the value of θ_e would assume any one of the 107 possible values with equal probability.

To illustrate the inevitability of this parametric phenomenon, consider a hypothetical ideal frequency synthesizer scenario for the generation of 1995 KHz from a 1070 KHz reference signal. When the 1070 KHz signal is initiated at an arbitrary time, t_o , the phase of both the reference and the output signal are zero degrees. For each 360 degree rotation of the reference phase, the output will rotate 518.1308411 degrees ($360^\circ + 158.1308411$). The two signals will not be simultaneously 0 degrees until the reference signal has rotated through 107 cycles (38,520 degrees) and the output has rotated through 154 cycles (55,440 degrees). If an observer could only have access to the 1070 KHz reference signal to determine a new reference time when the 1070 KHz reference signal phase was zero degrees, he would be equally likely to select any one of the 107 possible output to reference phase sets. In a differential system such as the AM Phase receiver, any one of the 107 possible sets is perfectly useable as long as there is no discontinuity in the input signal which caused a jump from one set to another set. A large part of the AM Phase receiver circuitry is concerned with this occurrence of discontinuity.

Disregarding the possible discontinuity, the heterodyning action in the first mixer for the 1540 KHz received signal produces a 455 KHz intermediate frequency that has a phase transfer function of negative unity referenced to the 1540 KHz received signal and positive $1.864486 (1995 \div 1070)$ referenced to the 1070 KHz received signal.

The second mixer is provided a signal from the synthesizer that is exactly $49 \div 107$ times the 1070 KHz received signal, 490 KHz. The heterodyned mixer output signal is a 35 KHz intermediate frequency signal exhibiting a phase transfer function of positive unity referenced to the 1540 KHz input received signal and negative $1.40654 (490 \div 1070) - (1995 \div 1070)$ referenced to the 1070 KHz input received signal.

The third mixer is provided a signal from the synthesizer that is exactly $1 \div 26.75$ times the 1070 KHz received signal, 40 KHz. The heterodyned third mixer output signal is a 5 KHz intermediate frequency signal exhibiting a phase transfer function of negative unity referenced to the 1540 KHz input received signal and positive $1.443925 [(40 \div 1070) - (490 \div 1070) + (1995 \div 1070)]$ referenced to the 1070 KHz input received signal.

The third intermediate frequency, 5 KHz, signal is applied to a digital phase detector. The reference signal for the phase detector is supplied by the synthesizer and is exactly the frequency of the received 1070 KHz signal divided in frequency by 214. The Output of this phase detector is a parallel digital signal with a reference measurement unit of 1 cycle, 360 degrees. The phase detector exhibits a positive unity phase transfer function referenced to the

received 1540 KHz signal and negative $1.43925 [(5 \div 1070) - (40 \div 1070) + (490 \div 1070) - (1995 \div 1070)]$ referenced to the 1070 KHz received signal. Note that the transfer function of the phase detector is mathematically identical to that of a mixer, since both are multipliers.

The final phase detector output provides an increase of 360 degrees for each cycle of increase in phase of the 1540 KHz received signal and a decrease of 360 degrees for each cycle divided by 1.43925 of increase in phase of the 1070 KHz received signal. Since 1.43925 is $1540 \div 1070$, and the two received signal are so harmonically related, the phase detector output is in a static state (constant output) when the receiver is at a point in space. Since the unit of measurement of this phase detector is one cycle of the received 1540 KHz received signal, the change of location of the receiver in space can be related in wave lengths of 1540 KHz to the output of the phase detector. For example, if the receiver travels a path along a circle centered at the 1070 KHz station, KNX, toward the 1540 KHz station, KPOL, the phase detector will indicate a unity increase in measured phase when the radial position of the receiver has decreased 194.8 meters relative to KPOL. In a similar example concerning movement relative to KFI, the phase detector will produce the same unity output when the receiver travels along the path of a circle centered at KPOL and away from KNX until the distance from the receiver to KPOL has increased 194.8 meters. Movement of the receiver along a line between KPOL and KNX will produce a unity positive output when the receiver travels 97.4 meters toward the 1540 KHz station, KPOL.

b. 640 Receiver Channel. By similar presentation it can be illustrated that the output of the phase detector in the portion of the AM Phase receiver relating to the 640 KHz received signal has a unit of measurement of the wavelength of 640 KHz, 468.75 meters. Except for the first mixer heterodyning frequency, 1095 KHz, the 640 KHz received signal is operated upon in a manner identical to that described for the 1540 KHz received signal.

c. AM Phase Receiver Hardware. A simplified physical block diagram of the AM Phase receiver is presented in Figure 2-11. As illustrated, it comprises an Antenna RF Coupler, a Master IF Subassembly, a Synthesizer Subassembly, an AM Tracking Filter Subassembly, and a Digital Phase Detector Subassembly. Each subassembly is described in the following paragraphs.

d. Antenna RF Coupler. A block diagram of the antenna RF coupler is shown in Figure 2-12. The antenna RF coupler multiplexes and amplifies the three received signals present at the antenna input BNC connector to provide amplified and separated parallel output signals to each of the three input mixers in the Master IF Subassembly operating at 1540, 1070, and 640 KHz. Multiplexing is achieved in the Antenna RF Coupler by connecting the primary windings of three separate transformers in series across the antenna terminals and resonating the tightly coupled transformer secondary windings at the appropriate receiving signal frequency.

Each of the three separated received signals are amplified by separate two stage cascade amplifiers to provide separate output signals to the Master IF Subassembly. All amplifier stages are dual insulated gate field effect transistors, RCA type 40841, and

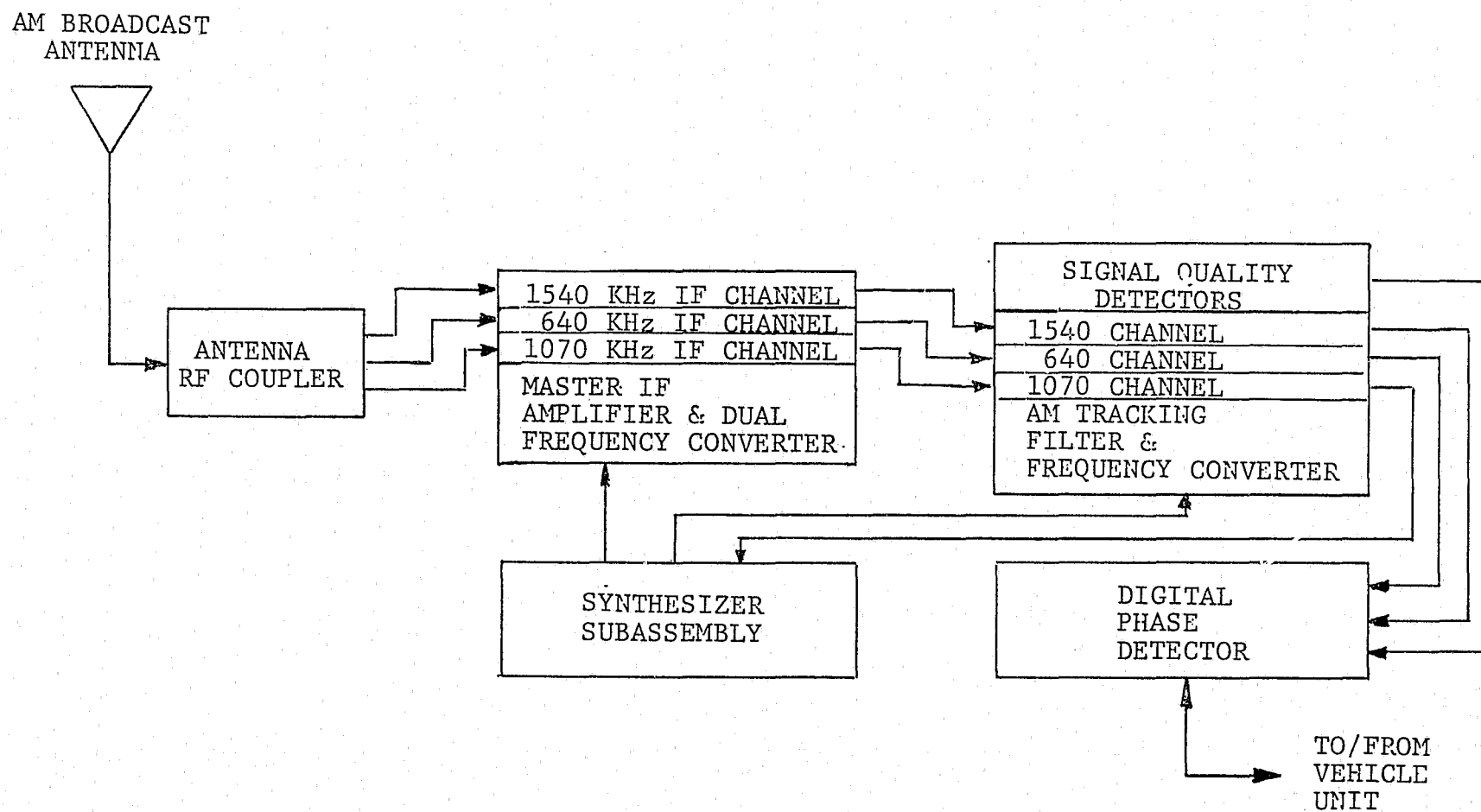


FIG. 2-11 AM PHASE-LOCK RECEIVER BLOCK DIAGRAM

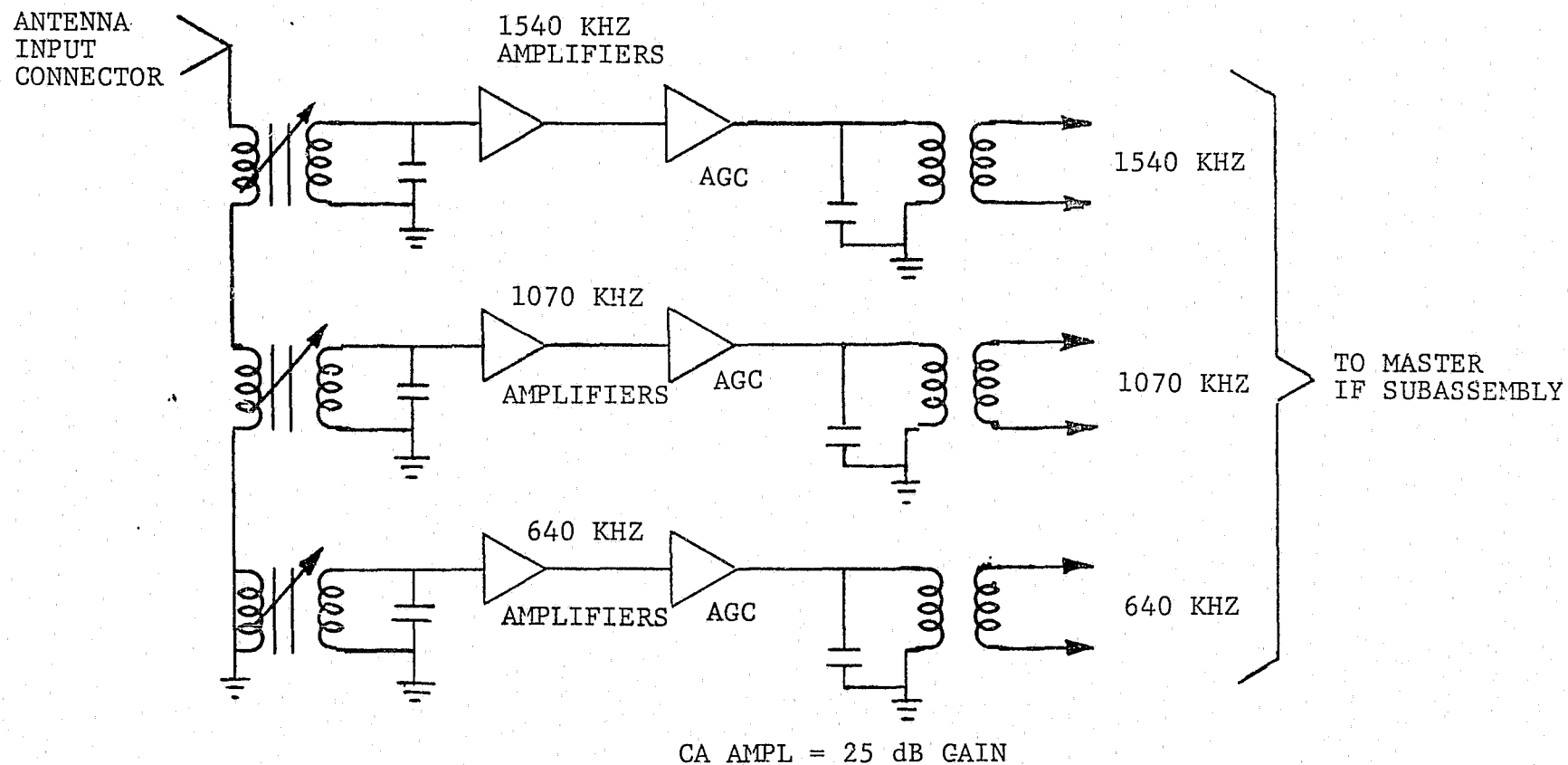


FIG. 2-12 ANTENNA RF COUPLER.

all are coupled by tuned transformers at both input and output. The input stage is a common source type and provides approximately 25 dB voltage gain. To achieve gain stability over the wide temperature range and input battery voltage range inherent to the AM Phase receiver environment, the second gate was supplied an 8.7 volt bias level and the first gate was provided negative feedback voltage proportional to the current through the device.

The output stage is very similar to the input stage except that circuitry is provided for automatic gain control. During field test in the Los Angeles area, it was determined that this feature was not required due to the absence of strong interfering signals which could cause intermodulation within the frequency bands of interest. Consequentially, the automatic gain control input ports were supplied a constant 8 volt level and their gain was thereby fixed at approximately 25 dB.

Each of the three separate filtered, amplified signal was applied through twisted pair transmission lines to the Master IF Subassembly.

e. Master IF Subassembly. The Master IF Subassembly comprises a printed wiring board containing automatic gain control circuitry and three separate, identical mixer/IF amplifier assemblies. The gain control circuitry was not utilized in this application and will not be described. A block diagram of one of the three identical mixer-IF amplifier subassemblies is shown in Figure 2-13.

The amplified, filtered received signal (640 KHz, 1070 KHz, or 1540 KHz) from the Antenna RF Coupler Subassembly is applied to the first mixer along with a heterodyning signal from the Synthesizer Subassembly. The signal from the Synthesizer is a 1995 KHz

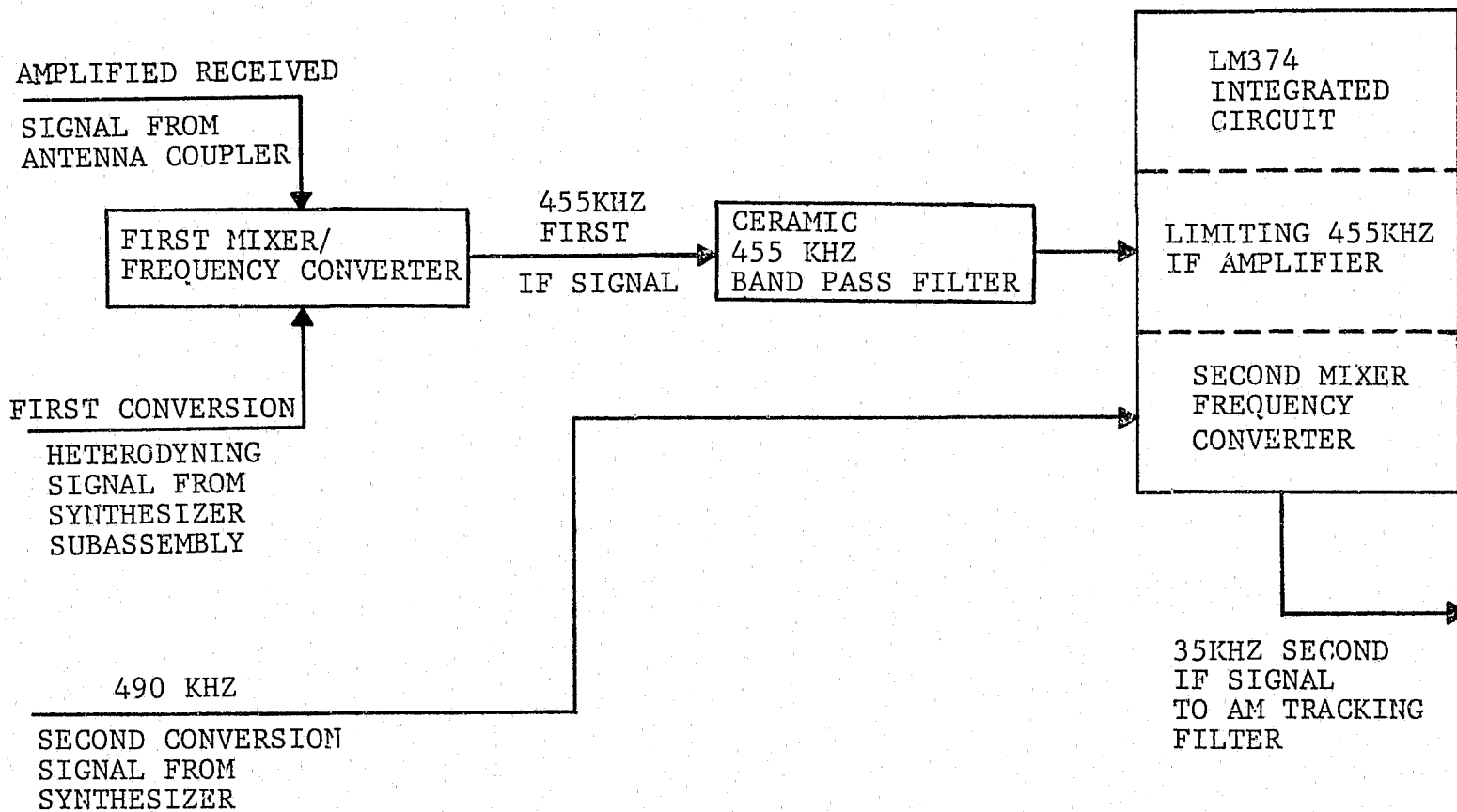


FIG. 2-13 MASTER IF BLOCK DIAGRAM (ONE OF THREE CHANNELS SHOWN)

squarewave for the 1540 KHz channel, a 1525 KHz squarewave for the 1040 KHz channel, and a 1095 KHz squarewave for the 640 KHz channel. The first mixer is a dual insulated gate field effect transistor, RCA type 40841. The Synthesizer signal is applied to the second gate at zero volt DC bias and the amplified, filtered signal from the Antenna RF Coupler Assembly is applied to the first gate also at a zero DC level. The transistor source is capacitively bypassed to ground and provided with negative DC feedback by a source resistor for temperature and input primary power voltage gain stabilization. The mixer heterodyning action results from the instantaneous change in gain of the transistor at the synthesizer frequency rate. The relatively high, one-volt peak to peak, level of the synthesizer signal on the second gate causes the transistor to exhibit a much higher voltage gain from gate one to the transistor drain on the positive state of the synthesizer signal than on the negative state. The resulting signal at the transistor drain is the signal on gate one "chopped" off and on at the synthesizer frequency rate. This signal contains the sum and difference frequency of the signals on the transistor gates. A transformer coupled tuned circuit is connected to the drain which provides a high impedance to only the difference frequency, 455 KHz.

The output of the tuned circuit is applied to a ceramic filter, Mu Rata Type CFR-455H, which provides the major rejection of interfering signals for the AM Phase receiver system. The 6 dB bandwidth of the filter is approximately 5 KHz and it provides 50 dB attenuation at a 20 KHz bandwidth.

The 455 KHz output signal from the filter is applied to a limiting amplifier contained within an integrated circuit, National type LM374. This multistage amplifier provides sufficient gain, over 75 dB. to insure a saturated final stage even if no signal is present at the antenna terminal of the AM Phase receiver. This limiting operation removes the amplitude modulation on the received signal and provides an output signal at a constant amplitude exhibiting the same zero crossing time relationship as the input signal from the ceramic filter. If the limiter action is considered to be perfect, the power at the output is constant and is comprised of the carrier frequency spectral component of the received frequency, translated to 455 KHz, and "noise". In the AM broadcast frequency range in the Los Angeles test area, the primary contributor to "noise" is man made impulse type emissions which exhibit a relatively constant amplitude throughout the received bandwidths. The thermal noise contribution of the first amplifier stage in the RF Antenna Coupler Subassembly was a minor contributor to "noise" because the selected device was of extremely low noise figure. The effect of noise at the limiter output is to advance or retard the zero crossing time of the received signal of interest. Since the bandwidth of the ceramic filter is much wider than that required for the required response of the AM Phase receiver, the 455 KHz intermediate frequency signal was converted to a lower intermediate frequency for further bandwidth reduction.

The second mixer is contained within the LM374 integrated circuit. A 490 KHz signal from the synthesizer is applied to the second mixer and the resulting 35 KHz intermediate frequency is output to the AM Tracking Filter Subassembly.

f. AM Tracking Filter Subassembly. A block diagram of the AM Tracking Filter Subassembly is presented in Figure 2-14. The three 35 KHz IF signals from the Master IF Subassembly are operated upon to produce output signals to the Digital Phase Detector Subassembly when the quality of a received signal is inferior. These output signals are referred to elsewhere in this report as "freeze" signals and "loss of lock" signals. In addition, the AM Tracking Filter Subassembly filters the 1070 channel 35 KHz IF signal and compares its phase with a 35 KHz signal from the Synthesizer Subassembly to provide a feedback phase correction voltage signal to the Synthesizer Subassembly. Also, the 35 KHz IF signals from the 640 and 1540 channels are filtered and heterodyned to 5 KHz TTL voltage level intermediate frequency signals in this subassembly and subsequently, output to the Digital Phase Detector Subassembly.

The 35 KHz intermediate frequency signal from the 640 channel in the Master IF Subassembly is applied to an active two pole low pass filter. The filter exhibits a damping factor of approximately 0.5, a passband of approximately 180 KHz, and provides approximately 30 dB rejection to the 455 KHz first intermediate frequency. The filter cutoff frequency was chosen considering the phase delay at 35 KHz as well as the rejection of 455 KHz. The filter output is amplified to a 12 volt CMOS level and applied to a 35 KHz phase lock loop (PPL) bandpass filter.

The 35 KHz PPL bandpass filter is comprised of a digital mixer, a charge pump amplifier, an integrator, and a 35 KHz voltage controlled amplifier. The phase lock loop type is a second order type 2 to insure nearly zero phase delay under steady state conditions. The

dampening factor of the PPL is approximately 0.7 and the natural frequency is approximately 5 hertz. The basic bandpass filtering operation is obtained by low pass filtering the error signal generated by the mixer when it is excited by the input signal and the output signal from the voltage controlled 35 KHz. The step response of the PPL filter is illustrated in Figure 2-15. This filter is the prime system element to reject the AM to PM conversion that is inherent in a nonlinear limiter such as utilized in the Master IF Subassembly. The rejection to the audio frequency broadcast program spectrum is 6 dB per octave starting at 5 Hz. For example, the filter exhibits approximately 30 dB rejection at 100 Hz. Because of electromagnetic field distortions, at even low speed, the vehicle experiences rapid phase change in the received signals, i.e., the doppler effect. Consequently, the lower limit on the PPL filter bandwidth is the required transient response to this phenomenon. On the other hand, the rejection of station overmodulation is enhanced by a very narrow PPL bandwidth.

The mixer utilized in the PPL filter is a digital phase/frequency detector utilizing CMOS devices. This type phase detector was chosen because of its inherent advantage during acquisition of the signal to be tracked. It is beyond the scope of this report to adequately summarize the available information on PPL filter design, but the following tradeoff considerations were examined in the design phase of the PPL filter. Because the time to acquire phase lock is approximately proportional to the square of the number of filter bandwidths required to equal the initial frequency difference between the input

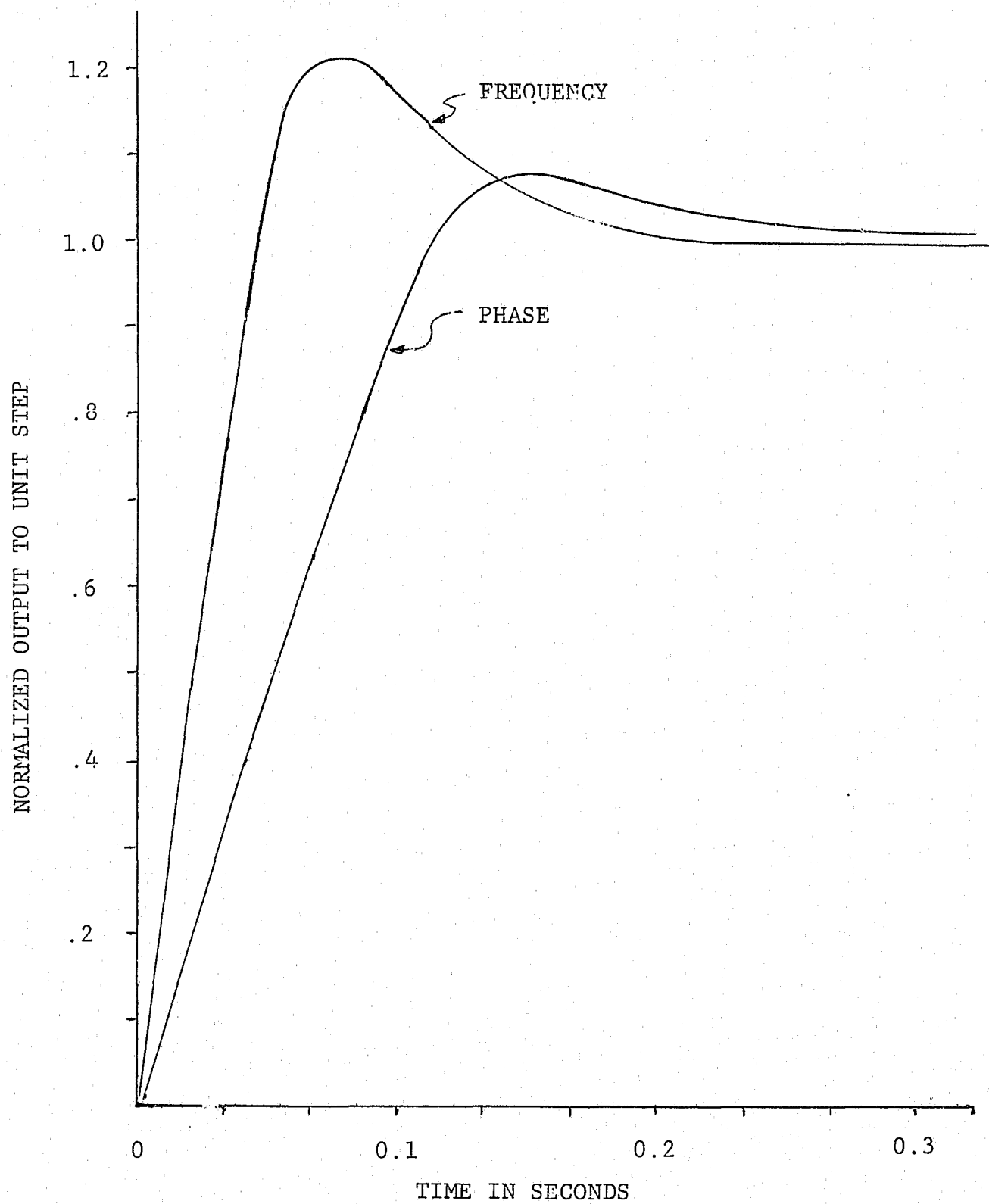


FIG. 2-15 AM PHASE-LOCK LOOP STEP RESPONSE

frequency and the VCO frequency, when a linear phase detector is utilized, additional circuitry is generally employed to widen the filter bandwidth during acquisition when the frequency range of the VCO is much greater than the filter bandwidth. This type circuitry must discern an out of lock condition, switch the bandwidth of the feedback low pass filter, determine if the system is in phase lock, and switch back to the narrow bandwidth state. Many innovative solutions of this problem have been implemented; however, they usually are not universally applicable. The phase/frequency detector utilized as the mixing element in the PPL 35 KHz filter eliminates the need to switch bandwidths during acquisition. The phase/frequency detector utilizes 6 two input NAND gates, a 4 input NAND gate and two 3 input NAND gates. The output of the circuit is two parallel signals that, in combination, produce a pulse width proportional to the phase difference between the two input signals. The range of the output is plus and minus 360 degrees. The primary characteristic of the circuit is that when the 360 degree range is exceeded, the phase detector output does not cycle at the beat frequency, but stays at the maximum output level. In effect, the circuit becomes a saturated frequency discriminator. If the phase detector is utilized in a second order, type 2 PPL filter, the integrator is provided the proper signal for acquisition automatically. The phase detector is schematically identical to a Motorola MC4044 integrated circuit that suffers from internally generated noise and was subsequently discarded for this application because the bulkier CMOS version was virtually noise free. The published Motorola application notes for the MC4044 provide excellent design information for PPL filter circuits such as the 35 KHz PPL filter.

The output of the digital phase detector was applied to a charge pump amplifier to convert the pulse width error information to a direct current error signal. The circuit utilized is not a true classic charge pump amplifier, but approximates it sufficiently for this application. The charge pump amplifier output is applied to an integrator amplifier.

The integrator amplifier is the focal point of the PPL filter characteristics because the transfer function of the VCO, the phase detector, and the charge pump are set by other design criteria. The integrator amplifier components are resistors and capacitors, and henceforth are easily changed. The current restricting input resistor and the feedback capacitor are concerned only with the desired natural bandwidth of the system, W_n , and the gain of the VCO and the phase detector/charge amplifier. The resistor in series with the feedback capacitor determines the dampening factor of the PPL filter. Practical considerations of the actual operational amplifier employed in the integrating amplifier limit the range of practical values of the feedback components. The resulting PPL filter error for the type 2 second order filter is zero at steady state for either a position movement or a step velocity movement of the AM Phase receiver. The error under step acceleration is limited to a finite time so it is of no system consequence. The integrator amplifier is applied to the VCO.

The VCO is an integrated circuit utilizing resistors and capacitors for frequency determining elements. Without the unique acquisition enhancement of the phase/frequency detector utilized

as the mixer in the PPL filter, this VCO would not be useable in this application because of the inherent frequency drift of such a device. The VCO output is applied to one phase detector input and is also utilized as the PPL filter output.

An exclusive OR gate accepts the VCO output signal along with a 40KHz square wave from the Synthesizer Subassembly. Simple graphics will show that an exclusive OR gate is mathematically a double balanced mixer. The resulting 5 KHz intermediate frequency signal has a positive unity phase transfer characteristic referenced to the received 640 KHz signal.

The 5 KHz intermediate frequency signal from the 640 KHz channel is filtered in a two pole low pass active filter and amplified back to a 12 volt CMOS level before being output to the Digital Phase Detector Subassembly. The bandpass of the filter is approximately 30 KHz and is not intended to limit the system noise, but only to restrict sudden "retrigger" in the exclusive OR gate output. The filtering action of the 35 KHz PPL filter has previously eliminated noise from the system.

The circuitry for the 1540 KHz channel is identical to that for the previously described 640 KHz channel.

The circuitry for the 1070 KHz channel is the same for the phase detector and charge pump amplifier, but there is no VCO for this channel. This channel is supplied a 35 KHz square wave signal from the Synthesizer Subassembly to the phase/frequency detector instead of the 35 KHz signal from a VCO as in the other two channels. After the phase detector output has been converted to a direct current voltage in the charge pump amplifier, it is applied to an integrator amplifier

that operates in the same manner as those in the other two received channel signals. The integrator time constants are identical even though the integrator amplifier output is the frequency control feedback signal to the Synthesizer Subassembly. The Synthesizer Subassembly is a part of the PPL filter in the 1070 channel.

A positive unity step input in the phase of the received 1070 KHz AM broadcast signal will pass with a unity transfer function to the input of the 35 KHz phase detector in the 1070 channel. The error signal when applied to the frequency control input of the Synthesizer will cause the first conversion heterodyning frequency, 1525 KHz, to decrease 1.425 ($1525 \div 1070$). Therefore the net phase change in the first intermediate frequency signal is negative 0.425. The second heterodyning signal, 490 KHz, from the Synthesizer Subassembly will decrease .458 ($490 \div 1070$) and the resulting net change in the second intermediate frequency, 35 KHz will be .0327 ($1 - (1525 \div 1070) + (490 \div 1070)$). The 35 KHz reference signal from the Synthesizer Subassembly to the 35 KHz phase detector will decrease .0327 ($35 \div 1070$) and complete the error correction at the 35 KHz phase detector input, which is the null point of the frequency control for the AM Phase Receiver. The system is designed so that any channel can be used for controlling the Synthesizer. After field tests, the 1070 channel was selected because the station exhibited instances of overmodulation than the others.

The AM Tracking Subassembly determines the quality of the received signals by sensing the signals at the phase detector outputs as they are input to the charge pump amplifiers. Large received signal perturbations are manifest by an immediate (sample rate of 35 KHz) abrupt

CONTINUED

1 OF 4

change in the phase detector output pulse width error signal. Pulse width comparison circuitry is provided which can determine the presence of a perturbation long before the integrator amplifier can produce an output response. The detection circuits are straightforward pulse width comparators which provide an output when the quality of the received signal is judged inferior. If an output occurs, the minimum duration is limited to five milliseconds. Because of the frequency control system design, the 1070 channel quality judgement circuitry utilizes different time constants than the other channels. All time constants were derived empirically after field test. A low primary voltage sensor is included and summed with the 1070 channel quality signal to inhibit the system during conditions such as the starter activation of the host vehicle.

The three quality signals and the two 5 KHz intermediate frequency signals are output to the Digital Phase Detector Subassembly.

g. Synthesizer Subassembly. The Synthesizer Subassembly provides all heterodyning signals for the AM Phase Receiver. The frequency of each signal within the Synthesizer is controlled to be an integer fraction of its master oscillator, a 5.12 megahertz voltage controlled crystal oscillator. The control voltage for the master oscillator is provided by the 1070 channel 35 KHz phase detector in the AM Tracking Filter Subassembly. This control signal is the feedback insuring that the Master oscillator frequency is exactly $4.785 (5.12 \div 1.07)$ times the received 1070 KHz signal frequency. The theory of the frequency control phase lock loop is explained in the AM Tracking Filter Subassembly description.

A block diagram of the Synthesizer Subassembly is presented in Figure 2-16. Generically, the circuitry can be divided into direct synthesis and indirect synthesis. The direct synthesis position does not utilize phase lock loops whereas the PPL is characteristic of indirect synthesis. The 5120 KHz crystal stabilized voltage controlled master oscillator is output to a binary counter to generate the 2^{-N} frequencies 2560, 1280, 640, 320, 160, 80, 40, 20, 10, and 5 KHz. The 40 KHz and 10 KHz signals are applied to a double balanced mixer and the resulting 50 KHz component is extracted through a bandpass filter. A times three frequency multiplier is utilized to generate a 150 KHz signal directly from the 50 KHz signal. The phase transfer function of the direct synthesis portion of the Synthesizer Subassembly is much faster than the system requirement and was generally ignored in the calculations involved in stability of the frequency control system in the AM Phase Receiver. A detailed response analysis would be very laborious because the transfer function from a step input on the master oscillator control part to any output is not independent of the instantaneous count in the binary divider. As stated, the system requirement is orders of magnitude below the worst case response of the direct synthesis portion of the Synthesizer Subassembly.

The indirect synthesis portion of the Synthesizer Subassembly circuitry accepts signals from the direct synthesizer and produces the first and second heterodyning signals and the 35 KHz reference signal for the 1070 channel phase detector in the AM Tracking Filter that produces the frequency control signal for feedback to the Synthesizer master oscillator.

FREQUENCY CONTROL
SIGNAL FROM AM
PHASE TRACK FILTER

ALL FREQUENCIES ARE KHZ

→ 320 KHZ
→ 40 KHZ
→ 5 KHZ

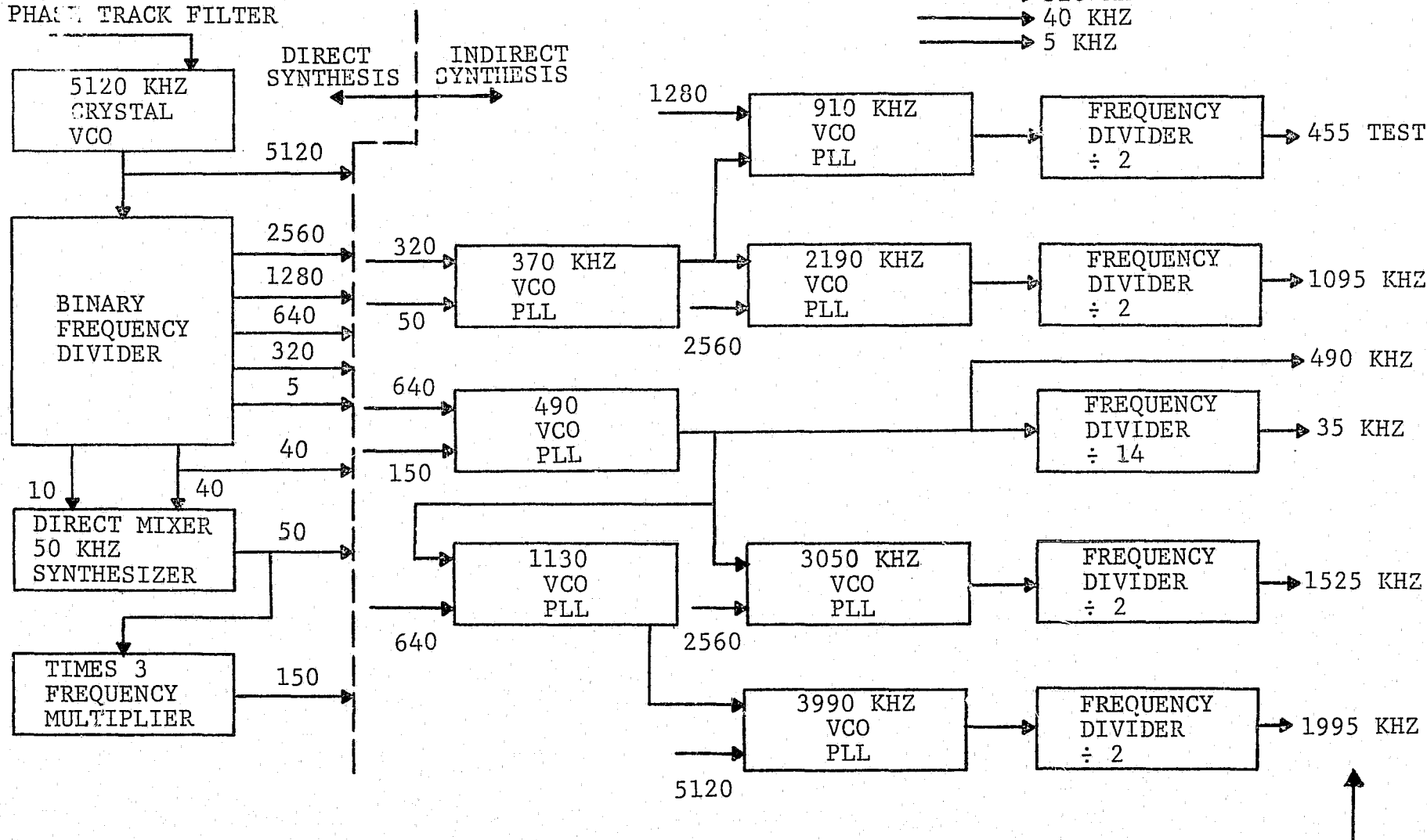


FIG. 2-16 FREQUENCY SYNTHESIZER BLOCK DIAGRAM

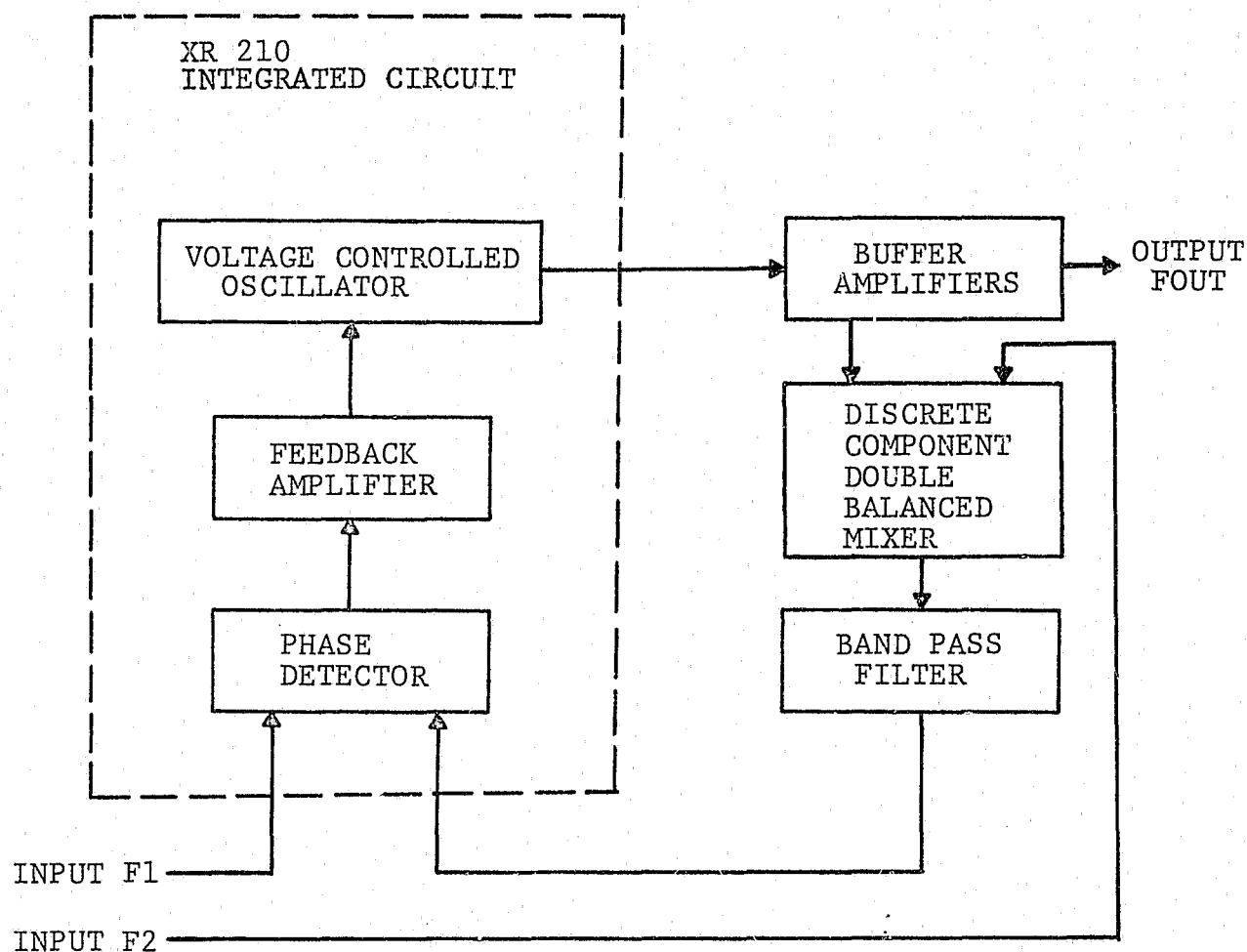
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OUTPUTS

Seven voltage controlled oscillators with phase locked loops are utilized in the indirect synthesis portion of the Synthesizer Subassembly. A block diagram of this circuitry is shown in Figure 2-17. An XRZ10 integrated circuit is utilized to provide a voltage controlled oscillator with an integral phase detector and feedback amplifier. Stabilization and dynamic range of the oscillator is accomplished by external resistors and capacitors. This integrated circuit has a seldom provided feature in devices of this type in that both phase detector input parts are accessible. This feature is necessary because the selected method of the synthesis requires that the phase detector operate at a frequency different from the VCO frequency. The VCO output signal is applied to a discrete component double balanced mixer through a buffer amplifier. The other input to the double balanced mixer is a signal from the direct synthesizer portion of the Synthesizer Subassembly.

The discrete component double balanced mixer comprises CMOS integrated circuit inverters and a pair of dual gate insulated gate field effect transistors whose drains are commonly connected to a parallel resonant LC circuit tuned to the desired output frequency. The VCO signal is applied to gate 1 of transistor A and an inverted VCO signal is applied to gate 1 of transistor B. The signal from the direct synthesizer is applied to gate 2 of transistor A and an inverter provides the same signal inverted to gate 2 of transistor B. This technique greatly reduces the energy from either phase detector input signals present at the common drain node. The signal at the

common drain node is amplified and applied to one input of the integrated circuit phase detector. The other input to the XRZ10 integrated circuit phase detector is provided by either the direct synthesizer or one of the other VCO/PLL circuits. The resulting phase detector output signal is amplified to correct the voltage controlled oscillator signal to be the desired sum or difference of the two input signals as delineated in Figure B. The seven VCO output frequencies generated are 490, 3050, 1130, 3990, 370, 2190, and 910 KHZ.

The 3050 KHZ signal is divided by a flip flop and output as the 1525 KHZ first local oscillator signal for the 1070 channel first converter. The 3990 KHZ and the 2190 KHZ signals are divided by two in frequency also to provide the other two first local oscillator signals needed by the Master IF Amplifier Subassembly. The 490 KHZ signal is also provided to the Master IF Amplifier Subassembly through a buffer amplifier for use as the second converted signal for all three received channels. The 490 KHZ signal is input to a module 14 frequency divider to provide the 35 KHZ reference signal to the 1070 channel 35 KHZ phase detector in the AM Phase Tracking Filter Subassembly. The 910 KHZ signal is divided by two to provide a 455 KHZ signal which was utilized in initial alignment of the AM Phase Receiver but has no function during operation. The 320 KHZ and 5KHZ signals required by the Digital Phase Detector are provided by the direct synthesis portion of the Synthesizer, as well as the 40 KHZ third converter signal utilized by the AM Phase Tracking Filter Subassembly.



CIRCUIT NUMBER	1	2	3	4	5	6	7
VCO Frequency, KHZ	490	3050	1130	3990	370	2190	910
F1 Frequency, KHZ	150	490	490	1130	50	370	370
F2 Frequency, KHZ	640	2560	640	5120	320	2560	1280

FIG. 2-17 INDIRECT SYNTHESIZER VOLTAGE CONTROLLED OSCILLATOR/PHASE-LOCK LOOP

h. Digital Phase Detector Subassembly. The Digital Phase Detector (DPD) Subassembly is contained on a single printed circuit board. The prime function of this unit is to measure the phase of the received 640 KHz and 1540 KHz signals as translated to 5 KHz and presented by the AM Tracking Filter Subassembly against the phase of signals presented by the Synthesizer Subassembly which are phase locked to the received 1070 KHz signal. Upon request from the vehicle unit, the DPD outputs a serial 16 bit word and a parallel clock signal which is the measure accumulate phase difference between the received signals. Because of the empirical selection of the 1070 KHz station as the reference station instead of the originally intended 640 KHz station, the unit of measurement of the two channels are less uniform than originally intended. The modification to the DPD to make the units of phase measurement more uniform was not performed due to time constraints. For the 1540 KHz channel, the unit of measurement is one-eighth of the free space wave length of 1540 KHz, approximately 24.35 meters. For the 640 KHz channel, the unit of measurement is also one-eighth of a wave length, approximately 58.59 meters.

A functional block diagram of the DPD is presented in Figure 2-18. In addition to the basic phase detection function, the unit is required to make decisions based upon the received signal quality signals from the AM Tracking Filter Subassembly, provide an overflow signal when the accumulation registers are filled, and generate the data output format. The DPD also responds to a signal from the vehicle unit when initialization of the accumulation registers is desired. Much of the physical circuitry is concerned with these

SIGNAL QUALITY
FROM AM TRACKING FILTER

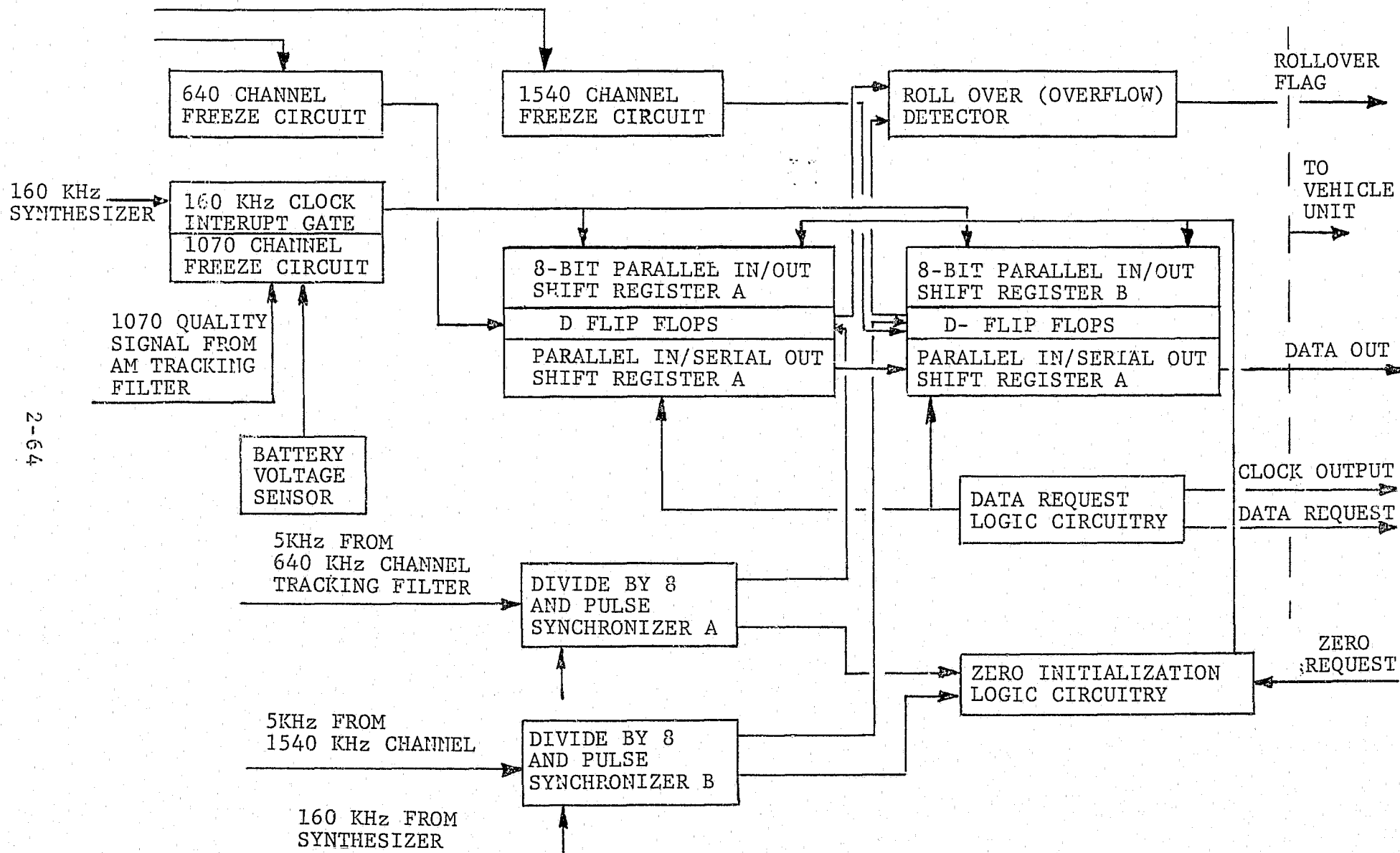


FIG. 2-18 DIGITAL PHASE DETECTOR

auxiliary functions. The bulk of the circuitry of the DPD is accomplished in 54 MSI CMOS integrated circuits. The resulting quantity of interconnections makes detailed description of each signal exhaustive and will not be attempted. Detailed information of the DPD is contained in schematic 506-1716. An overview of the DPD follows.

The 5 KHz translated 1540 signal is differentiated and applied to a 3 bit binary counter to produce a pulse at every eighth zero crossing of the 5 KHz input signal. In another portion of the DPD circuitry an 160 KHz signal from the Synthesizer Subassembly has been generated. A cascaded pair of D flip-flops is utilized to synchronize the divided 5 KHz signal to the 160 KHz signal from the Synthesizer. The resulting signal is a single pulse which is at a 625 Hz rate and is a single cycle of the 160 KHz signal that occurs immediately after the eighth zero crossing of the 5 KHz input signal. This 625 Hz repetition rate signal, Lb, is the prime timing signal in the 1540 KHz channel.

The actual phase measurement of the 1540 KHz channel is achieved in an eight bit parallel in/parallel out shift register comprised of two 74C161 integrated circuits connected in series. The shift register clock is supplied a 160 KHz signal from the Synthesizer Subassembly that has been derived solely from the received 1070 KHz signal. Consequently, the 8 bit binary shift register counts with a cycle of 625 Hz ($160 \text{ KHz} \div 256$). Since the received 1540 KHz and 1070 KHz signals were synthonized at the AM broadcast transmitters, at a non-variant point in space, the two 625 Hz signals have an invariant phase difference. A binary measurement is obtained when the counter is sampled at the positive zero crossing of the 625

Hz signal derived from the 1540 KHz signal, Lb. The sampling is accomplished by applying the parallel output ports of the shift register to the D input of eight flip flops and strobing the clock of the flip flops with Lb, the 625 Hz signal derived from the 1540 KHz received signal.

The resulting static signal is then transferred to a parallel in/serial out shift register for serial output to the vehicle unit. The 640 KHz channel is processed in an identical manner and its serial output register is connected in series with the 1540 KHz channel to provide the 16 bit serial output format. Upon receipt of a request to read signal from the vehicle unit, an 80 KHz clock signal is derived from the Synchronizer input signal. This signal is utilized to clock out the parallel in/serial out shift registers and also provides a parallel clock to the vehicle unit.

The accumulating shift registers are set to a zero state upon request by the vehicle unit. Upon receipt of the zero request unit, gating logic is utilized to generate a clear signal for the counting parallel in/parallel out shift register. The clear signal occurs immediately prior to the next Lb signal so that the counter shift register is at a zero state at the next strobe time.

The freeze logic circuitry interrupts the 160 KHz clocking signal to the counting shift register whenever the signals from the AM Tracking Filter Subassembly indicate the quality of the received 1070 KHz signal is insufficient for proper measurement. After the signal is determined to be acceptable, the 160 KHz signal is reapplied to the counters and the last good data, which is stored at the output of the D flip flops, is loaded into the counting shift registers.

Both the stopping and starting of the clock signal is synchronized to the 625 Hz sampling signal, either La and Lb, for each channel. In this manner, the accumulation resumes at the last known good data point in the event of an interruption of the 1070 KHz received signal.

Upon the receipt of an indication of insufficient signal quality of the received 640 KHz or 1540 KHz signal, the clock to the counting shift registers is not interrupted unless the 1070 KHz signal is also judged to be of insufficient quality. However, during this period, no new measurement sample is allowed. This condition is allowed because of the heterodyning frequency conversion of these two channels is dependent only on the Synthesizer being constantly locked to the received 1070 KHz signal. The divide by eight and synchronization circuitry is interrupted in unit cycles of 625 Hz derived from the Synthesizer signal. This technique results in the 3 least significant bits (LSB) of the phase measurement to undergo no accumulating error in the event of an insufficient signal level in either the 640 KHz channel or the 1540 KHz channel. However, the fourth LSB, which is one unit of wavelength at the transmitted frequency, can be in error. Computer software is utilized to detect this relatively gross error.

Circuitry to detect the overflow of the accumulation registers is included in the DPD. Upon overflow, a signal is presented to the vehicle unit. The physical length of the 640 KHz channel register is approximately 15 kilometers in the shortest possible case, and 6.2 kilometers in the 1540 KHz channel.

When the vehicle starter is engaged, the available battery voltage can decrease to less than 6 volts which is below the minimum level necessary to operate the AM Phase Receiver. Circuitry is provided to detect this condition and to provide the same circuit function as if the 1070 KHz channel signal was detected to be of insufficient quality.

3. Mobile Communications. The vehicle UHF radio and radio interface unit is shown in Figure 2-19 as packaged in the Cargo Security vehicle unit. The radios selected for this program were Motorola MOCOM 70 UHF radios. The mobile radio technical specifications are given in Table 2-2.

Because of the data-between-voice experience gained in the Cargo Security System Pilot Test Program, a common communication link (CCL) concept was used in the Cargo Security Field Test Program. The common communication link requires that each vehicle have its own radio. This approach eliminates the need for the individual radio interface modules which must detect voice and data using shared voice equipment similar to that implemented and tested during the Pilot Test Program. The CCL approach allows additions and deletions of the vehicle units without interfering with the existing volts network.

a. Implementation. The 25 watt mobile Motorola MOCOM 70 unit used in this program was interfaced with the vehicle unit and put in a common box with the signpost receiver and AM Phase unit as shown in Figure 2-19. This design not only allowed the vehicle unit to be designed separately from the radio unit but also provided

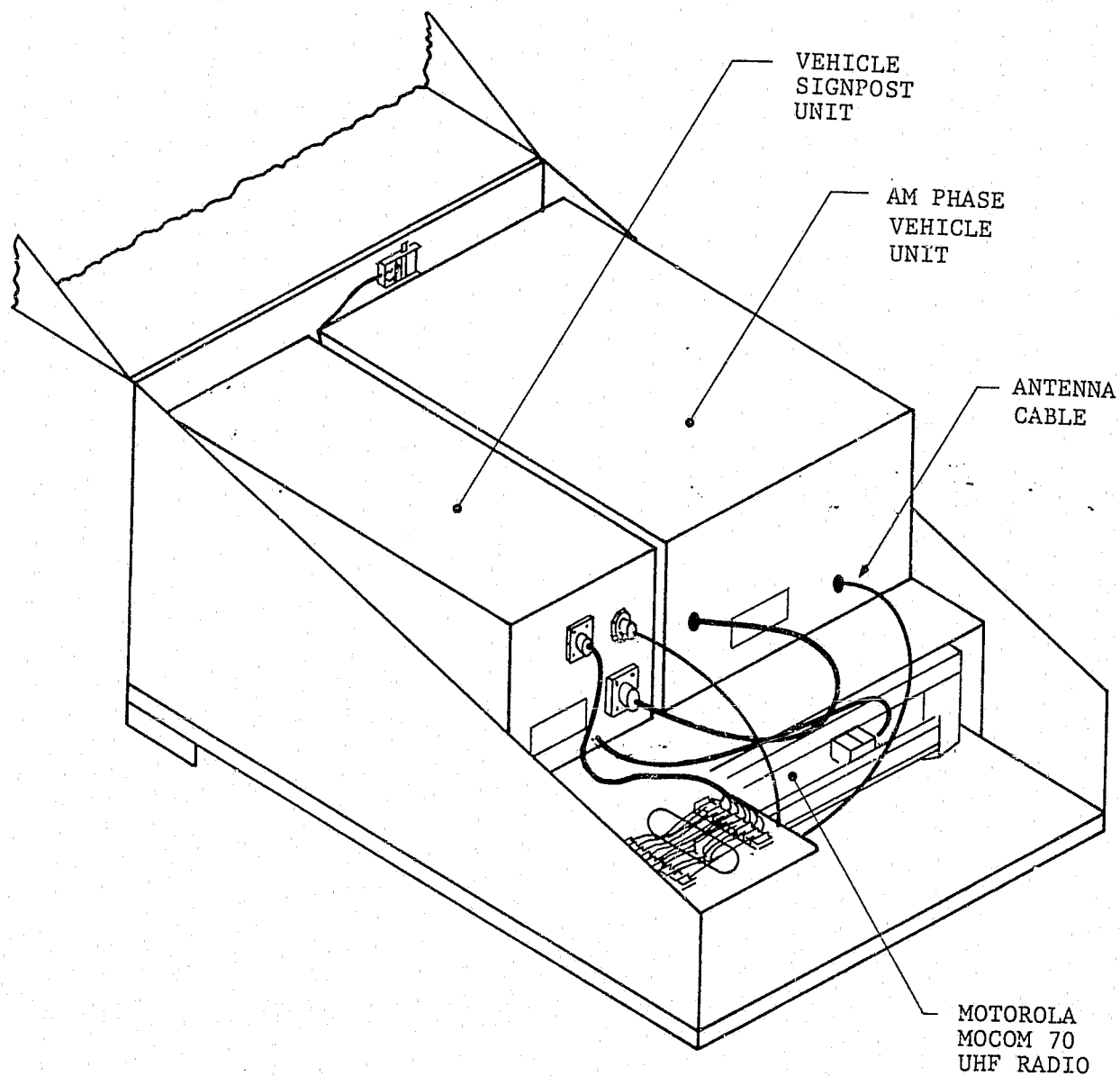


FIGURE 2-19 VEHICLE RADIO INTERFACE

TABLE 2-2 MOCOM 70 MOBILE RADIO SPECIFICATIONS

MOCOM•70 FM Two-Way Radio

Guaranteed Performance Specifications

General

No. of Frequencies:	One- and up-to-four frequency models are available.
Squelch Options:	Carrier Squelch Type—1000 Series Models; "Private-Line" tone coded squelch—3000 Series Models.
Primary Power:	12V dc, negative ground (optional positive ground adapter available)
Dimensions:	
30 & 45 Watt Models:	4" high x 10 1/4" wide x 16 1/2" long. (102 mm high x 273 mm wide x 420 mm long)
60 & 100 Watt Models:	4" high x 10 1/4" wide x 18" long. (102 mm high x 273 mm wide x 457 mm long)
Weight:	Approx. 25 lbs. (11340 g.) (Shipping wt. incl. accessories: Approx. 50 lbs.) (22680 g.)
Metering:	A single-scale, 0-50 microampere meter or Motorola Portable Test set can be used to measure all circuits essential to tuning and checking.

Transmitter

Output Impedance:	50 ohms
Spurious and Harmonics:	spurious and harmonics more than 85 dB below carrier
Oscillator Frequency Stability:	±.0005% from -30°C to +60°C ambient (+25°C reference)
Frequency Separation:	up to 1.2 MHz total separation with no degradation
Modulation:	16F3: ±5 kHz for 100% at 1000 Hz
Audio Sensitivity:	0.100 volts ±3 dB for 3.0 kHz deviation at 1000 Hz
Audio Response:	+1, -3 dB of 6 dB/octave pre-emphasis characteristics from 300-3000 Hz
FM Noise:	80 dB below ±3.0 kHz deviation at 1000 Hz
Audio Distortion:	less than 3% at 1000 Hz; ±3.0 kHz deviation
FCC Designation:	
	One Freq. 4 Freq.
30 Watt:	CC3114 CC3114-4
45 Watt:	CC3110 CC3110-4
60 Watt:	CC3210 CC3211
100 Watt:	CC3206 CC3207
	All models are licensable under FCC Rules Parts 21, 89, 91 and 93

* @ 13.4 V

Receiver

Sensitivity:	Standard	With B135 Option
20 dB Quieting	0.5 μv	0.35 μv
EIA Sinad	0.35 μv	0.25 μv
EIA Sinad Intermodulation:	More than -80 dB down at ± 25/30 kHz	More than -70 dB down at ± 25/30 kHz
Spurious & Image Rejection:	more than -90 dB (With B138 Option)	more than -90 dB (Not Available)
Frequency Separation:	Up to 1.2 MHz total separation with no degradation (With B138 option—up to 500 kHz total separation with no degradation)	Up to 1.2 MHz total separation with no degradation
Squelch Sensitivity:		
(at the threshold setting)		
Carrier Squelch	0.25 μv	0.18 μv
Tone-Coded Squelch	0.25 μv	0.18 μv
EIA Sinad Selectivity:	More than -90 dB down at ± 25/30 kHz	
EIA Modulation Acceptance:	± 7.0 kHz	
Oscillator Frequency Stability:	± .001% from -30°C to +60°C ambient (+25° reference) Optional .0005%	
Audio Output:	5 watts at less than 5% distortion (into a 3.2 ohm load @ 1000 Hz)	
Channel Spacing:	25/30 kHz	
Input Impedance:	50 ohms	

flexibility to change the type of radio units in the future, if needed. The radio is connected to the antenna through a coaxial cable which was routed thorough the floor of the vehicle unit underneath the cab and up the side of the vehicle truck body. The original antennas were not capable of withstanding the vehicle environment and were subsequently changed to more ruggedized quarter length flexible antennas.

The radio interface card was located in the vehicle signpost unit. The interface card matched the impedance levels of the selected radio with the vehicle unit and housed the control logic for the radio and the vehicle unit communication channels. The radio interface board detected when the vehicle radio channel was available for use. It also detected any message directed at any of the vehicles on that channel and sent this information to the vehicle unit message decoder logic board which contained the error filters.

b. Coverage. The radio coverage afforded by the MOCOM 70 system using the 0 dB gain quarter wave monopole antenna was adequate with the antenna mounted on top of the UCB building as the input to the base station. In fact, the radio coverage was more than adequate and subsequently, required the test program to be halted.

The results of the radio test was so outstanding it even suggested that one or two watt mobile units might well cover the LA area if the base station were located on top of the UCB building. However, additional clear channels will have to be made available in this area, and probably many other metroplexes, before such a CCL system can be extensively deployed at UHF frequencies. Consequently,

future systems will probably be required to use the high frequency band in the 800 KHz to 900 KHz frequency range.

c. Communication Encoding and Decoding. The basic radio encoding and decoding techniques used in the program were virtually identical to those previously tested. These techniques are illustrated in Figure 2-20 and are described in the subsequent paragraphs showing the error detecting capabilities of the implemented scheme.

In the process of transmitting CSS data, the communications interface unit in the vehicle performs three primary functions: (1) it takes digital data from the vehicle unit and encodes it into the error filter format, (2) it modulates the data using FSK techniques, and (3) it monitors the radio receiver and waits for the channel to become clear before transmitting.

During the reception of a digital transmission, the interface first demodulates the FSK data. The demodulated received data is then passed through the specialized error filter which ensures that only error-free digital data are presented to the vehicle unit.

The cargo security system design objectives placed a number of requirements upon the selected communication technique. These requirements are related to (1) message error control, (2) the modulation technique, and (3) the associated achievable data rate. Message error control is extremely important in a Cargo Security System in order to keep the number of false alarms to a minimum. The selected modulation technique and associated data rate determines the number of vehicles and/or the amount of information which can be reliably associated with a single narrow band voice radio channel.

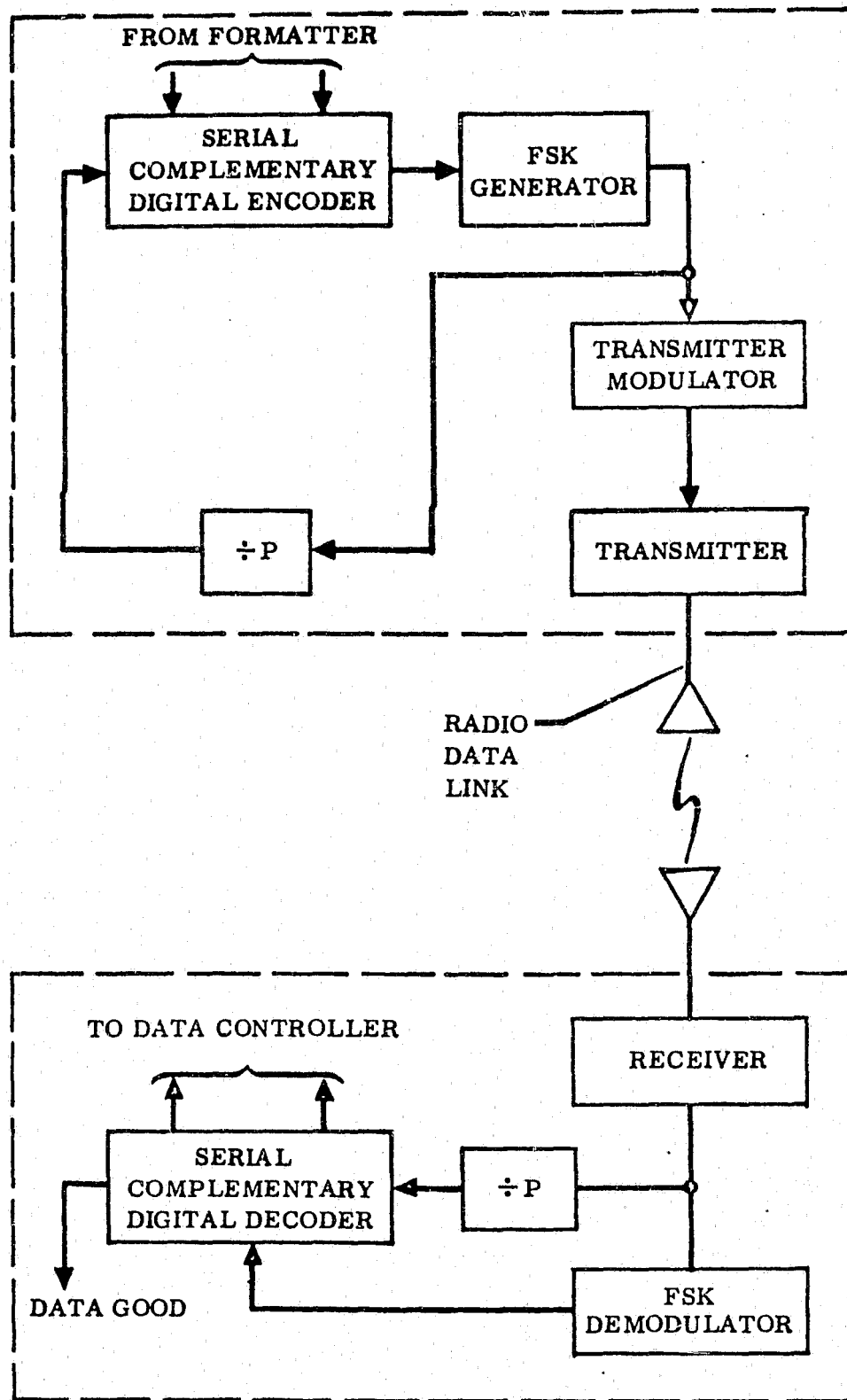


FIG. 2-20 BASIC COHERENT LOW ERROR RATE ENCODER/DECODER DIAGRAM

In order to achieve reliable digital communication, Gould I³ developed and has extensively used a very efficient encoding/decoding technique. The technique is referred to as the Coherent Frequency Shift Key (CFSK) bit-bit complement ($B - \bar{B}$) technique. The technique allows data to be transmitted one data bit per FSK cycle and also allows the encode/decode clock, as illustrated in Figure 2-20 to always come from the transmitter modulator or received audio. The technique provides that each information bit is automatically followed by the bit complement. The process can be repeated (e.g., $B - \bar{B}$ or $B - \bar{B} - B - \bar{B}$) in order to set the probability of undetected message error consistent with the communication requirements. The technique is much more efficient than schemes such as repeated data transmission since the beginning of the word can be established with very few data bits and only one information bit by deliberately injecting an error (i.e., the beginning of a message is always initiated in the decoder through the sensing of an error).

However, even when using error detection only and using 64 bits to transmit 32 bits of information, the probability of an undetected message error is still very dependent upon the coding/decoding technique. To meet the performance objectives, it is necessary to achieve a 10^{-9} undetected error rate in all Signal/Noise conditions. Consider for example the case of signpost location data transmission. If simple redundancy (i.e., repeat message once) was used, the probability of no undetected message error, $P_m(E)$, would be:

$$P_m(E) = \frac{1}{N} \times P_v(S/N)$$

where

$P_v(S/N)$ = probability of a vehicle being in a location region
when the S/N ratio allowable error rate is $1/N$

N = Number of information bits in the message.

If $N = 32$, then $P_m(E)$ would be $1/32$ of the probability that the vehicle was in an area where signal-to-noise would give 1-bit error every 32 bits. This signal-to-noise condition is approximately 3 dB. Therefore, simple redundancy alone in a good mobile radio environment would give one undetected message error every 32,000 messages.

The above example emphasizes the need for using a more powerful encoding/decoding technique than used for fixed signal-to-noise (wire, microwave, etc.) data links. Also, it explains why many of the digital data systems currently being used in the mobile radio field do not operate reliably or still must use the slow data rate frequency coding techniques (tone coding). To design reliable, efficient (high data rate) digital data links in a variable S/N environment such as that in which the CSS must operate, a different approach was used. The mobile radio digital data link error detector design was based on the following probability of error equation. The equations allow the encoder/decoder design to be evaluated in the mobile radio S/N region when presents the problem.

$$P_m(E) = \text{Sup} \left[P_E(S/N) \times P_V(S/N) \right]$$

where

$\text{Sup} \left[P_E(S/N) \right]$ = Error Filter Probability Function Evaluated at the value of S/N which gives the maximum probability of undetected error.

$P_V(S/N)$ = Probability of a vehicle being in location region such that the S/N maximizes the probability of undetected error.

To again illustrate the significance of the above equation another example will be used. $P_v(S/N)$ is typically 10^{-2} (no signal, 1% of radio coverage area) for a simple parity check (odd or even) error filter in which $\text{Sup } P_E(S/N)$ is clearly $1/2$ in a random noise environment. Thus, the probability of an undetected message error using simple parity in a mobile radio environment is greater than one in every two hundred messages independent of the message length. To reduce the $P_m(E)$ to levels considered acceptable, the encoder/decoder described earlier and illustrated in Figure 3 will be used. It follows then that the basic $P_m(E)$ equation for a 32-bit message is as follows:

$$P_m^E \left(\frac{32}{64} \right) = \left(1 - \frac{1}{32} \right)^{62} \left(\frac{1}{32} \right)^2 \times P_v(S/N)$$

where the error filter equation is, in general,

$$\left(\frac{N_I}{KN_I} \right)^K = \left(1 - \frac{1}{N_I} \right)^{(K \cdot N_I - 1)} \left(\frac{1}{N_I} \right)^K$$

N_I = Number of Message Information Bits

K = Number of Times $B, \bar{B}$ is used (e.g., for $B, \bar{B}$, $K = 2$; and for $B, \bar{B}, B, \bar{B}$, $K = 4$, etc.)

A conservative value for $P_v(S/N)$ is $1/2$ (i.e., good radio coverage only 50% of the time) which gives an undetected message error rate of approximately one every million messages. Use of this method satisfied the cargo security error control requirement.

In addition, the coherent FSK portion of the design allows reliable decoding since the clock is always transmitted with the

data and the normal variations in the FSK generator frequency with temperature and other environmental factors do not influence the decoder reliability. Very reliable operation has been achieved operating at 1600 bps which will allow 800 baud for 32-bit messages and 400 baud for 16-bit messages (where $B \cdot \bar{B} \cdot B \cdot \bar{B}$ must be used to maintain the 10^{-9} undetected error rate).

The described digital encoder/decoder method is simple in terms of equipment complexity. In fact, the digital circuits required to accomplish the powerful encoder/decoder error control technique described above are less than those required for implementing simple parity encoding and decoding techniques.

4. Sensor Equipment. Sensors used on the cargo security system consisted of eight discrete sensors, each was accompanied by a sensor countermeasure detection circuit plus a separate countermeasures sensor in the vehicle enclosure unit (a tamper sensor which sensed lid closure). The eight sensors were installed on each truck to detect a potential theft or hijack situation. Sensors were installed to detect (1) left door open or closed, (2) right door open or closed, (3) cargo door open or closed, (4) seat occupied or unoccupied, (5) truck in motion or stopped, (6) cargo compartment intrusion, (7) vehicle ignition switch on or off, and (8) a foot switch used for the driver alarm.

Sensors may be generally classified by protection type. For this application, four types were assumed to be sufficient; i.e., spot, volume, motion, and operator actuated. Spot sensors were used to detect operation of the cab doors, cab seats, ignition switch, and doors to the cargo compartment. A volume sensor was positioned to detect intrusion into the cargo compartment.

The spot sensors were selected from a large number of candidates. The magnetic switch was found to be the most favorable for detecting opening and closing of the cab doors based on criteria of reliability, durability, immunity to noise, and adaption to the rugged trucking environment. The cab seat application was found to require the use of a pressure switch based on the same criteria. The most reliable sensor for the door to the cargo compartment was an impact resistant, magnetic switch because of its relative immunity to local disturbance and tamper-proof characteristics. The volume sensor used for detecting movement within the cargo compartment was an ultrasonic detector. The other sensor type used was the motion detector. Detecting movement of the vehicle was accomplished by direct sensing of wheel motions which required a magnetic detector attached to the fixed axle as a pick-up for small magnets attached to the inside rim of the wheel. These units were selected because of their rugged structure and their ability to adapt to various installation applications.

All sensor data was routed to the signpost/control unit for further processing. Figure 2-21 depicts a typical sensor interface with this unit. The sensors installed in the system consisted of the following units.

Motion Sensor - The 200-100 (Numetric) magnetic sensor assembly consists of a transducer which operates with the aid of eight small magnets which are equally spaced and epoxied on the selected tires rim. The transducer is mounted on the steering arm and adjusted to a fixed location approximately $\frac{1}{4}$ " from a magnet located on the tire rim. Movement of the vehicle causes the magnet to pass by the

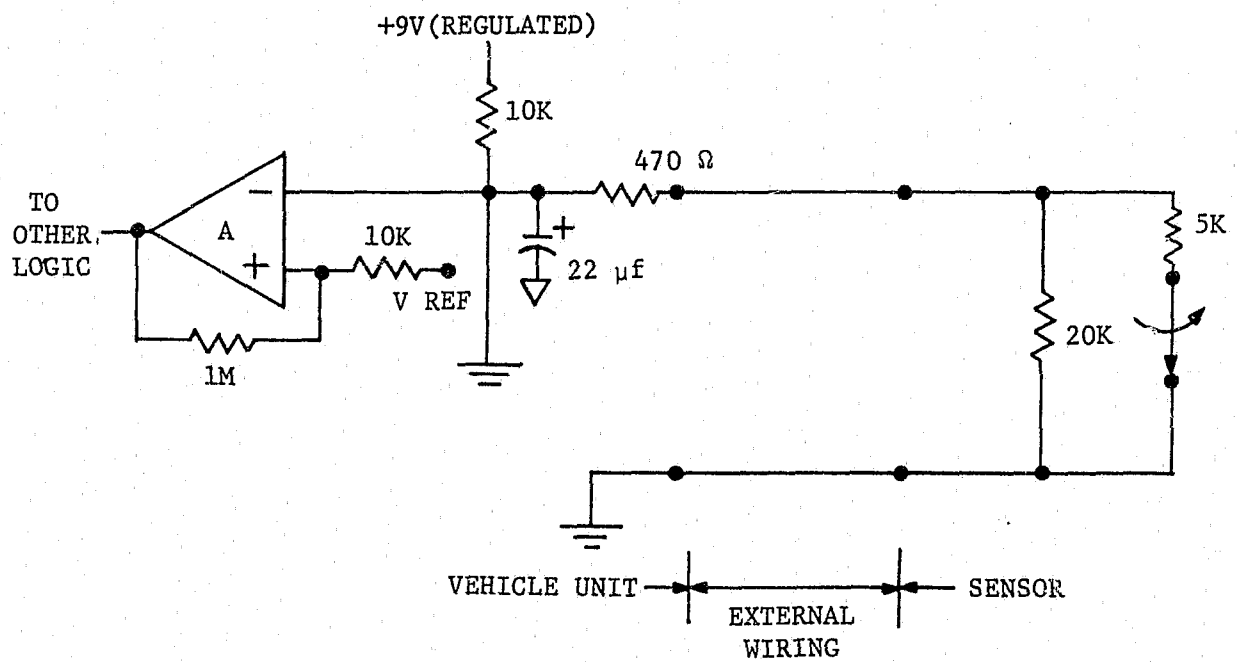


FIG. 2-21 TYPICAL SENSOR INPUT CIRCUIT INCLUDING COUNTERMEASURES

Transducer which creates a detectable disturbance of the magnetic field. Detection of this disturbance results in generation of a signal which is transmitted to the master control interface for processing.

Cargo Door - The (ADEMCO) #57 overhead door contacts were chosen to detect opening and closing of the cargo door. This low profile reed switch is protected inside a rugged aluminum case by shock absorbing material. The switch is further protected by a waterproof compound. The magnet portion is also enclosed in a rugged aluminum housing. Included with the switch is an 18 inch length of steel armored cable to protect the switch wires. This switch is a single-pole-single-throw type and operates off 12 VDC.

Seat Sensor - The (GENERAL MOTORS) FN-9730851 pressure switch was selected and used on all forty trucks. This switch operates when 40 pounds of pressure is applied. The device contains an adhesive backing on one side for securing the switch in position.

Key Sensor - This sensing device consisted of tapping directly onto the ignition switch. The selected ignition switch contact provided 12 VDC when the key was turned to the on position. This signal was transferred to the master control interface unit.

Door Sensor - The HR301 (CODE) Hide-A-Reed Switch was used on the cab doors. This switch is a single pole, single throw - SPST-NO closed circuit operation.

Volume Sensor - The ultrasonic detector #351-12 (ADEMCO) was chosen for the cargo area. This detector transmits inaudible sound waves in a pattern 25 ft. long by 12 ft. wide. These waves bounce

back from detected objects to the unit's receiver which constantly analyzes them. When an intruder causes a change in the wave pattern a built-in alarm relay is triggered. This shown signal is transmitted to the signpost control unit for processing. This unit operates from 12 VDC.

Driver Alarm - This momentary switch #993 (SMITH) was installed in the (GENERAL MOTORS) #8411K12 dimmer switch housing to provide an inconspicuous and rugged driver activated alarm switch.

Tamper Switch - This push-type switch #12TL6-4 SW was attached inside the master control box to determine if the master control box was open.

5. Physical Installation. The vehicle unit installation (Figure 2-22) is comprised of three major groups.

a. Vehicle Electronics. The AM Phase receiver/processor, the signpost/controller, and the mobile radio equipment are housed in a single electronic enclosure designed to resist access by unauthorized personnel. For this program, the enclosures were mounted in the driver compartment of each vehicle (Figure 2-23).

b. Antennas. Two antenna systems are installed in each vehicle. The first, a MR264 unit, is utilized for both the AM Phase and 27 MHz proximity signals transmitted by the location support elements of the system, and for this program was installed on the centerline of the cab roof. This antenna also includes a signal splitter to isolate the two receivers. The second antenna, Nocom 201, serves the UHF communications unit, and was mounted on the leading edge of the top of the cargo compartment.

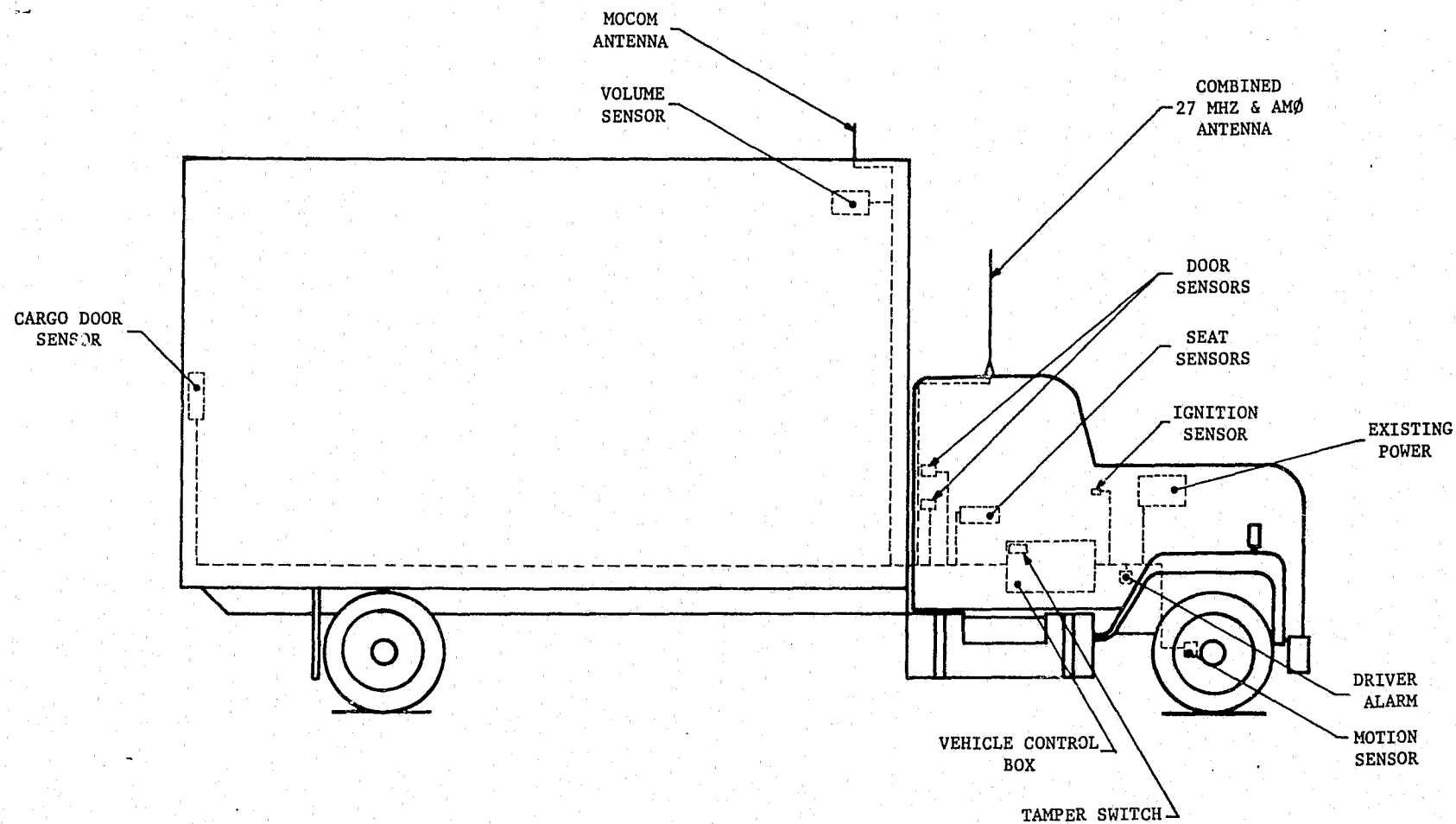
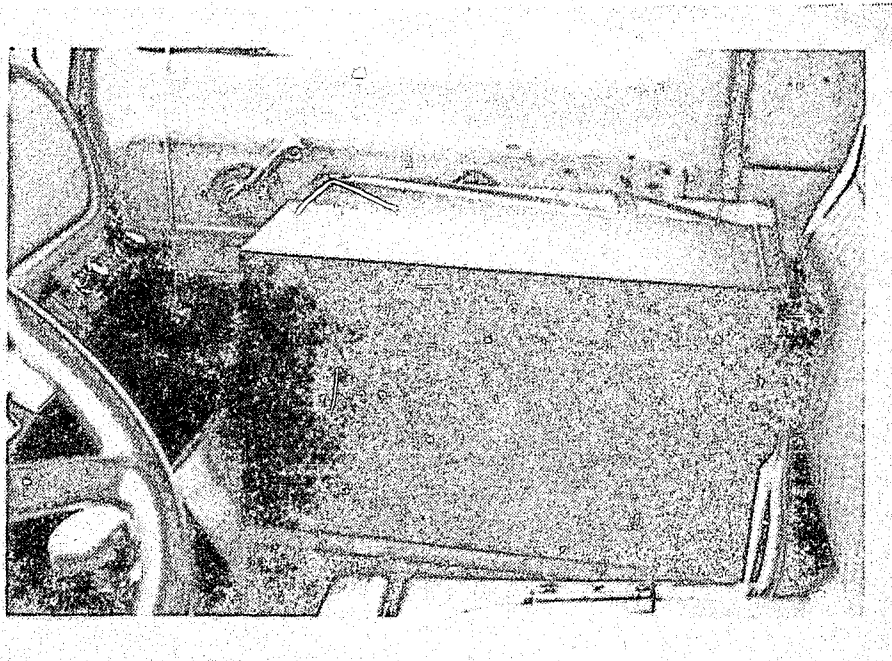
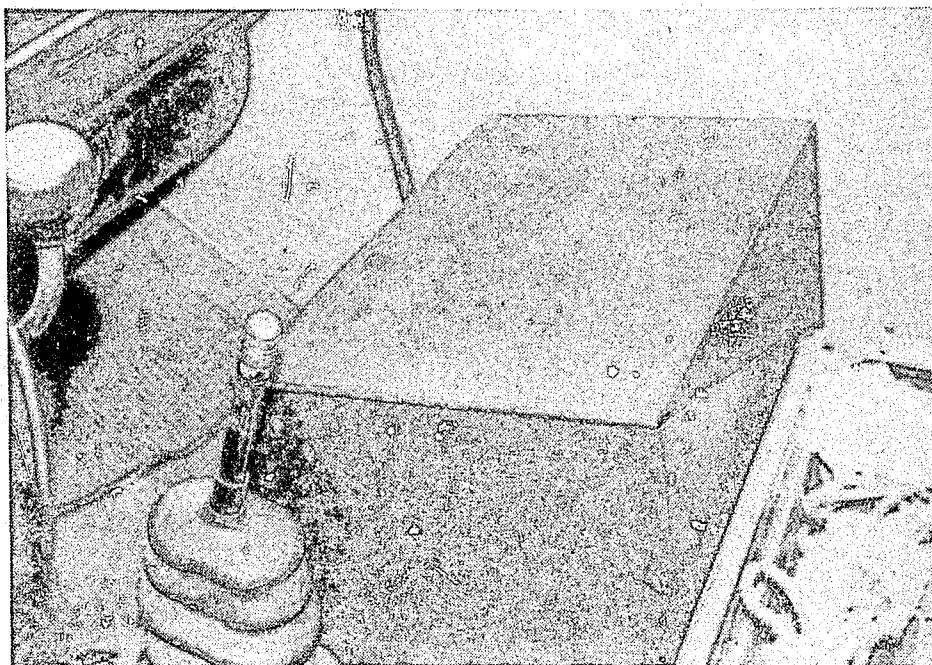


FIG. 2-22. VEHICLE EQUIPMENT INSTALLATION



(a) GI TRUCKING



(b) TRANSCON

FIG. 2-23 VEHICLE INTERFACE CONTROL UNIT INSTALLATION

c. Sensors. The motion sensor was installed on the front left wheel of the vehicles. The nut on the steering arm was removed and the transducer and bracket were positioned over the threaded stud. The nut and cotter key were then replaced to the original state. The nut and cotter key were then replaced to the original state. Eight magnets were equally spaced and epoxied on the tire rim after thoroughly cleaning to ensure adhesion throughout the program. The cable was secured with cable ties and routed along the frame and up into the cab through the harness hole directly into the master control interface box.

The cargo door sensor switch was attached to the inside of the cargo area next to the overhead door runners. The design was attached to the wooden side panels with three 1-1/2 inch wood screws. The magnet was attached to the inside of the door with three 1-inch wood screws so that when the door was in the closed position, the magnet would line up with the reed switch housing. The switch cable was routed inside the protected channel of the cargo compartment along the side and up to the roof. The cable was routed from the back end of the cargo area to the front end along the protected inside roof edge. The cables were routed down along the corner edge and out through the double wall portion of the cargo area to the underside of the truck. From there, the cable was routed along the frame with existing cables to the harness hole and directly into the cab and master control box. The seat sensor was slipped under the seat and positioned because the seat springs and the cushion portion of the vehicle seat. The adhesive side of the switch was pressed against the cushion to secure it.

The door sensor switches required a 3/4 inch hole to be drilled in the cab and in the door itself. These two holes were lined up when the door was in the closed position. The reed half of the switch mounts in the cab portion with two retaining clips that securely held the switch in place. The wires were routed between the cab walls to the floor and out through existing holes along behind the seat and under the master control interface box to the harness entering the box.

The volume sensor was installed in the front end of the cargo area approximately 2 feet from the roof and approximately 10 inches from the right inside wall. This unit was mounted on a #353 ADEMCO bracket and installed with four 1 inch wood screws into the wooden portion of the wall. With the unit mounted in this position, it was possible to cover the entire cargo area. The routing of the cable went directly from the unit to the protected corner and down through to the bottom side of the cargo area. The routing followed the frame with existing cables and up through the harness into cab and master control interface box.

F. Base Station Equipment

The base station provides the central communications, central processing functions and overall control for the cargo security systems and is comprised of three major functional elements (Figure 2-24):

- o Radio communications - provides for bidirectional radio communications with each vehicle
- o Central Computer - provides for system control and data processing

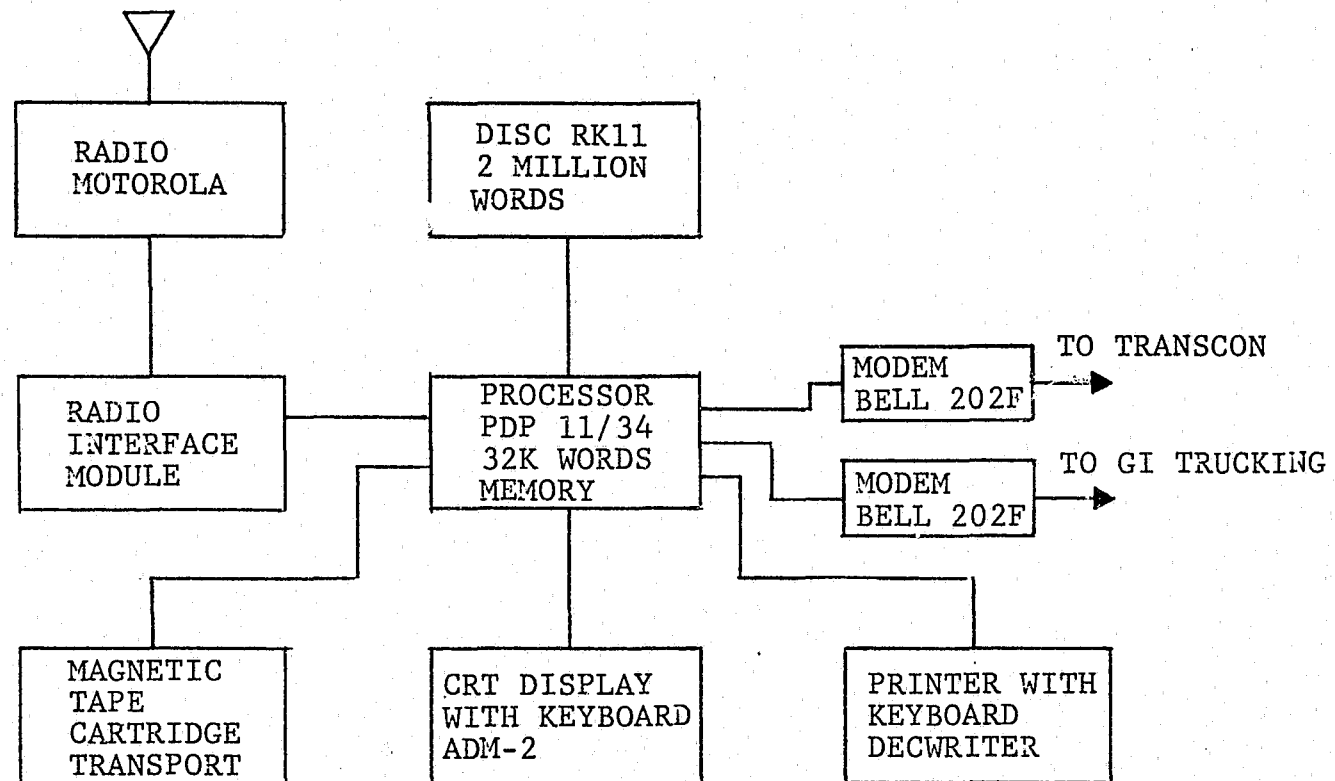


FIG. 2-24 BASE STATION EQUIPMENT BLOCK DIAGRAM

- o Communications Interfaces - Interface the central computer to the radio communications equipment and to the landlines connecting the base station to the two dispatch stations.
- 1. Base Station Hardware. The base station consists of the following hardware elements.
 - o Radio Communication - A commercial land mobile communications base station (Motorola B/C44PCB, 300 watts ERP) is operating in a simplex mode, provides bidirectional communications with all vehicles
 - o Central Computer - A Digital Equipment Corporation PDP 11-34 computer with a total of 32K words of memory is employed as the central computer. An external cartridge disk system (Digital Equipment Corporation RK 11) is used on-line storage of programs and data. System control and data display/printout capabilities are provided by an on-line terminal (ADM-2) and keyboard/printer (DECWriter II), and a DIGIDATA magnetic tape unit is employed for transaction history data.
 - o Communications Interfaces - A special purpose radio interface unit is used between the control computer and the Motorola base station. Commercial modems (Bell 202) are utilized to interface the central computers to the land line circuits.
- 2. System Software. The cargo security software is comprised of two individual real-time programs. The principal program provides for the real-time monitoring of vehicle location and status and the routing of these data to the appropriate dispatch stations. A

special purpose program is employed for communications and system integration testing and provides interactive control with a single vehicle for the purposes of testing data throughput, data compatibility, format verification, location accuracy, etc. The software is structured to execute system application programs under the control of a real-time operating/executive program.

This section is organized as follows:

- (a) Communications - describes the formats and protocols employed for the transmission of data between the various system elements and the base station and radio interface
- (b) Software - describes the function and implementation of the following software elements
 - o architecture
 - o memory layout
 - o data exchange
 - o data bases
 - o subroutines
 - o global variables
 - o flags
 - o operation
 - o application modules
- (c) System Control - describes the control functions available at the base station.

These descriptions are intended to provide a summary of the base station functions: detailed flow charts, listings and other pertinent data is contained in Volume III of this report.

a. Communication Formats. The communication subsystem, which was developed to satisfy the data interchange requirements of the system, includes a dedicated mobile radio link and three land line links. The mobile radio link provides a means whereby the individual trucking company vehicles are able to provide information to and receive commands from the host computer system. This is a digital data exchange system using rigidly structured, compacted, data formats. The land line links are also digital exchange links and use ASCII encoded formats. In the following paragraphs, the format, structure, and protocol of the data interchanges between these devices is reviewed.

(1) Vehicle/Host Computer. The vehicle-to-host computer and host computer-to-vehicle data transfer system operates over a simplex mobile radio data link. Uplink (vehicle-to-host computer) and downlink (host computer-to-vehicle) data is encoded at the source and decoded at the receiver to provide the first level of error detection/rejection. The data links were established to service up to 64 separate devices, although the overall communication system design is not limited to that number of vehicles. The uplink data interchange consists of both vehicle declared events and responses to requests from the host computer. The downlink messages are primarily commands to the vehicle. Section B of Volume III contains a detailed description of each message, its function, and the data use.

(a) Vehicle-to-Host Computer Data Structure. The vehicle-to-host computer data is formatted and output in 32 bit message lengths. There are 6 fundamental message structures which are used to provide the information. Figure 2-25 denotes the bit pattern formats for the 6 basic message types.

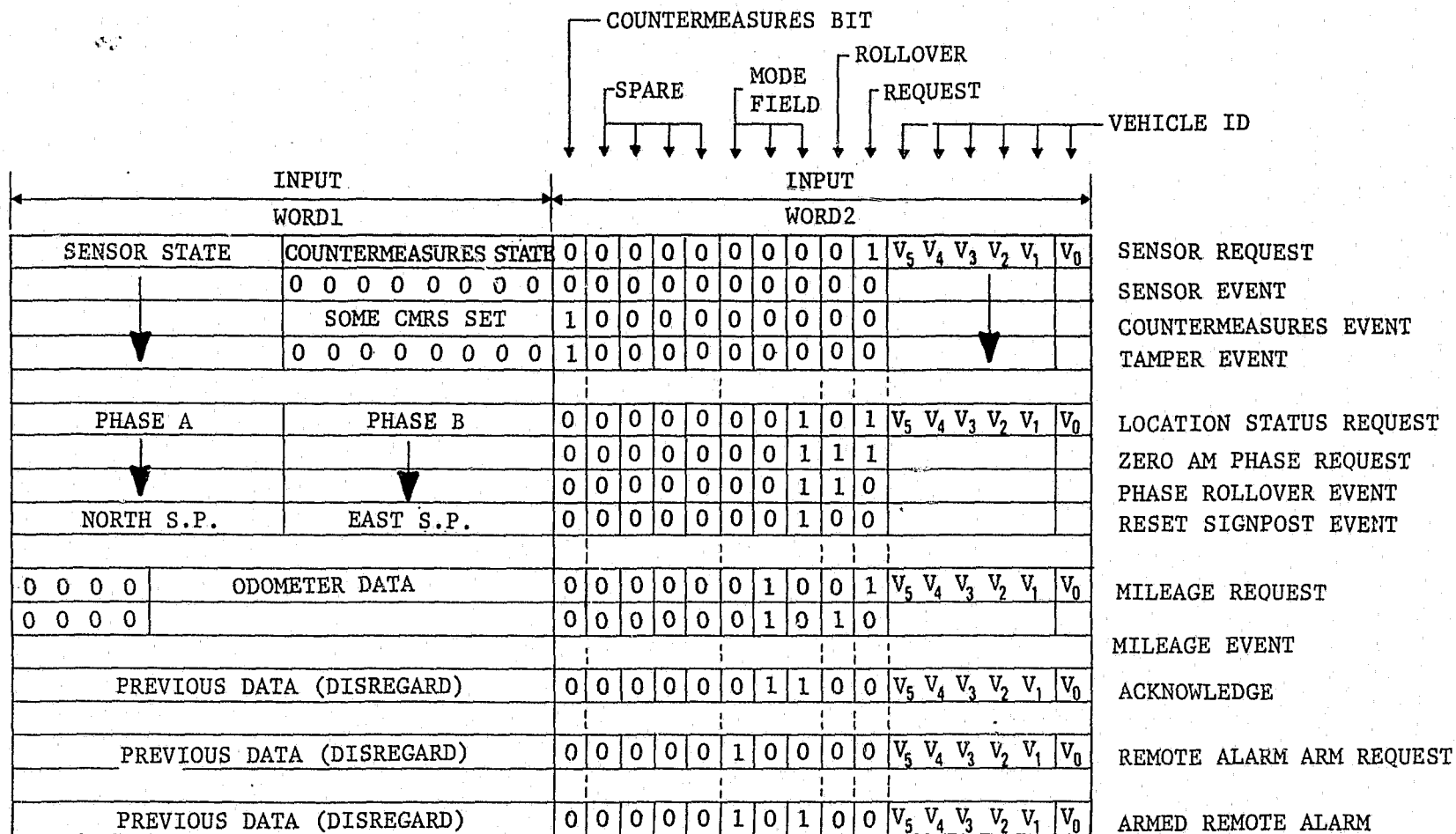


FIG. 2-25 CARGO SECURITY VEHICLE-TO-BASE STATION DATA FORMAT

Referring to Figure 2-25 and the Sensor Status type messages, there are four types of data to be transmitted using that format. The four types of data include: requested sensor status, a sensor event declared by the vehicle, a countermeasures event declared by the vehicle, and a tamper event declared by the vehicle. Differentiation between these submessages within the Sensor Status message structure is accomplished through a combination of the roll-over request, countermeasures and status bits of the countermeasures data field.

The Location Status message is similarly divided into four submessage types. The four submessage types include location status requested, a zero AM Phase, location reset, a phase roll-over event, and a reset signpost event. These four message types are differentiated through use of the roll-over and request bits.

The mileage data is provided in two forms. One, a Requested Mileage Report, and two, a Mileage Event Roll-Over.

The remaining three structures include the Acknowledge, the "Remote Alarm Arm" Request, and the "Arm Remote Alarm" command. These three structures are used to support the multi-modal capability of the vehicle unit and to support the I/O protocol.

(b) Host Computer-to-Vehicle Data Structure.

There are eleven discrete commands output by the host computer to the individual vehicles. The command format is described in Table 2-3. Referring to Table 2-3, the zero AM Phase command is provided to zero the AM Phase registers within a specific vehicle. The location request command requests the current AM Phase data stored in the AM Phase registers of a specific vehicle. Similarly, for the mileage request and sensor requests, these requests are used to determine

TABLE 2-3 COMMAND OUTPUT FORMAT

		DATA				VEH.ID						MODE				
0	0	b	b	b	b	V	V	V	V	V	V	M	M	M	M	
		3	2	1	0	5	4	3	2	1	0	3	2	1	0	
0	0											0	0	0	1	Zero AM Phase
0	0											0	1	0	0	Location Request
0	0											1	0	0	1	Mileage Request
0	0											0	0	1	1	Sensor Request
0	0											0	1	1	1	Disable all Sensors
0	0											0	0	1	0	Zero Odometer
0	0											1	0	1	0	Acknowledge
0	0	(1/2 Mask)										0	0	0	0	Load RAM
0	0	(BINARY SELECT 1-8)										0	1	0	1	Sensor Disable
0	0	(BINARY SELECT 1-8)										0	1	1	0	Sensor Enable
0	0											1	0	0	0	Arm Alarm

the status of those specific registers in the vehicle processor. The disable all sensors command is executed to a specific vehicle to disable all sensors excluding the intrusion sensor. The zero odometer command will cause the odometer mileage register to be zeroed in the vehicle unit. The acknowledge command is used in the I/O protocol. The RAM command is a specific command which must be output in sequence. There are 64 different bits to be set in the vehicle RAM. One-half of one 8-bit mask is loaded for each transmission. The load of the RAM is provided in Figure 2-26. The sensor disable and sensor enable commands are output to enable any one of the specific sensors located in the vehicle. The alarm arm command changes the mode of the vehicle from remote alarm arm mode to remote alarm mode.

(c) Vehicle/Host Computer Protocol. Since this system operates on a simplex radio channel and accommodates both polling and events declared by vehicles, a specific acknowledge protocol has been established for operation. The acknowledge protocol, relative to the vehicle declared events, involves the output of an acknowledge command by the host computer to that specific vehicle. The specific messages (uplink) which require an acknowledge include the sensor event, countermeasures event, tamper event, phase roll-over event, reset signpost event, and mileage roll-over event. When any of these events are declared by a specific vehicle, an acknowledge must be output by the host computer in order for that message to be taken out of the queue of the vehicle. In the event that an acknowledge is not received by the sending unit (vehicles), the message will be periodically output by the vehicle until acknowledged. There is an eight transmission limit on the number

15																	0
	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	
	0	0	0	0	1	1	0	0	0	0	0	0	1	0	1	0	
	0	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0	
	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	1	
63																	48

(a) RAM DATA

0	0	0	0	0	1	0	1	= E
0	0	0	0	1	0	0	1	= I
0	0	0	0	1	0	1	0	= J
0	0	0	0	1	1	0	0	= L
0	0	0	1	1	0	0	0	= X
0	0	1	1	0	0	0	0	= O
0	0	0	0	0	0	0	1	= A
0	0	0	1	0	0	0	0	= P

(b) FABRICATED FROM THESE CHARACTERS
WITH BITS 6 AND 7 SET TO ZERO

FIG. 2-26 RAM LOAD STORED IN VREF

of events to be declared by the vehicle. This limit is eight transmissions. If the event is not acknowledged by the host computer, the vehicle unit will discard the particular event to be transmitted to the host computer. Similarly, for commands output by the host computer to the vehicles, certain of them require an acknowledge. Those conditions which do require an acknowledge include the RAM load command, sensor activate command, the sensor deactivate command and the sensor disable command. All other outputs by the host computer do not require an acknowledge by the individual vehicles.

(2) Base Station Peripherals/Host Computer. The base station peripherals which include the LA36 DECwriter, and the ADM-2 CRT display, are interfaced to the host computer via an asynchronous data link. The asynchronous data link supports ASCII data transfer between these devices and the host computer. Special characters such as cursor positioning, carriage return, line feed, etc., are provided to the peripheral device as part of the total format of data sent across the data link. There is no requirement for echoing. These devices can be interconnected with the host computer via a 103F telephone modem. These devices interface to the computer through a DL11 asynchronous interface.

(3) Base Station Radio and Interface. The base station radio and computer interface system is illustrated in Figure 2-27. The base station equipment was a 45 watt Motorola transmitting unit as described in Table 2-4. The transmitting unit and the receiving unit were connected to a 6 dB gain stacked antenna located on the south corner of the roof of the UCB building. The antenna pattern coverage provided by the antenna caused interference with co-channel user in San Diego. In fact, subsequent testing showed

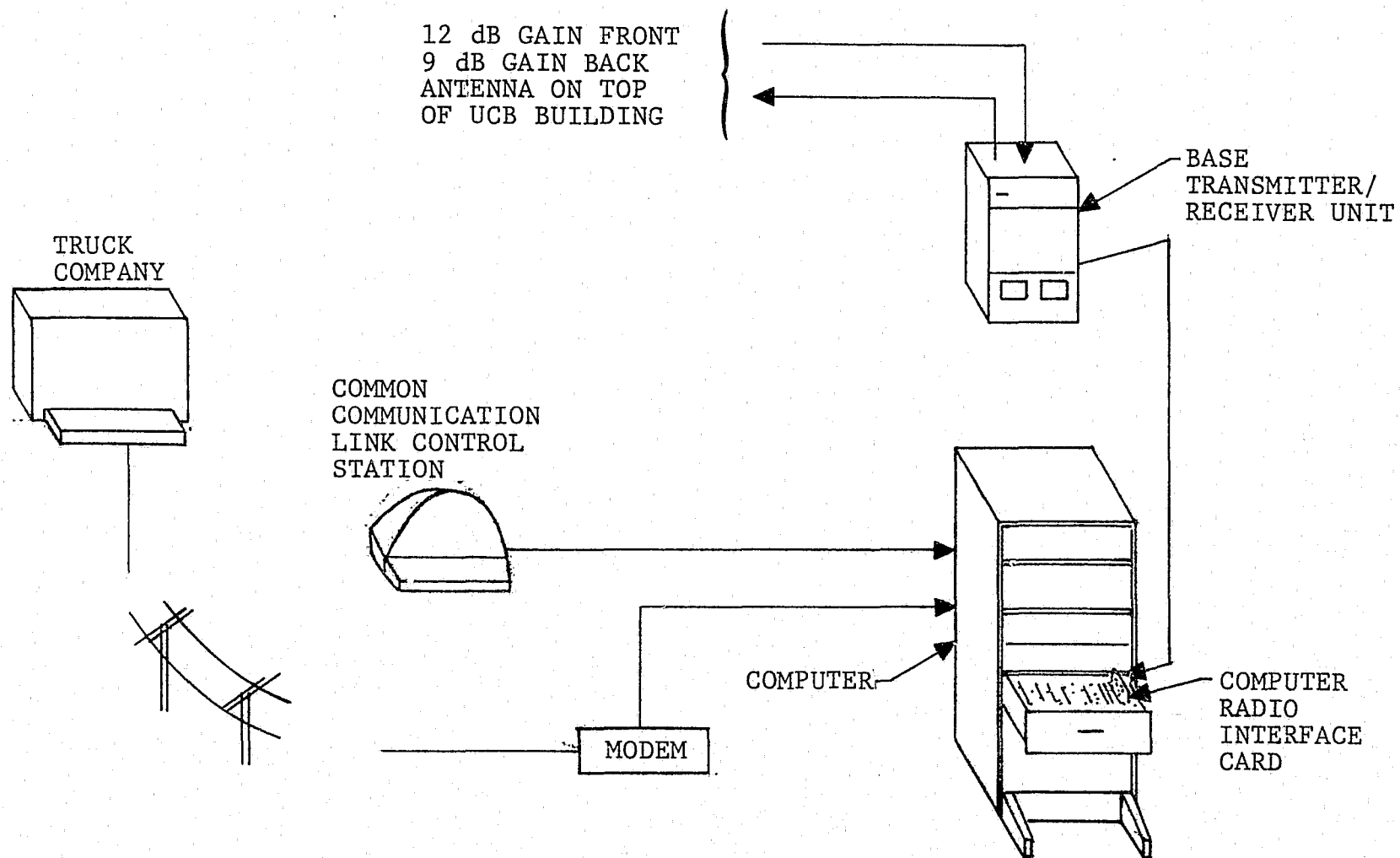


FIG. 2-27 COMMUNICATION SUBSYSTEM ELEMENTS

TABLE 2-4 MOTOROLA UHF BASE STATION EQUIPMENT

UHF MICOR Base Stations and Repeaters

Guaranteed Performance Specifications

General

Model	Frequency (MHz)	Minimum RF Output Power	Maximum Input Power†	Input Voltage	Input Current (Amps)			
					AC		13.6V dc Negative Ground	
B/C34RCB	406-420, 450-512	12W	30W	120V ac $\pm 20\%$, 60 Hz (optional 120/240V 50/60 Hz $\pm 20\%$ - 40%)	Stby.	Xmt.	Stby.	Xmt.
B/C44RCB	450-512	20W	60W		.85	2.1	1.5	10.0
B/C54RCB	406-420, 450-512	45W*	120W		.85	2.6	1.5	11.0
B/C64RCB	406-420, 450-512	75W**	180W		.85	3.8	1.5	17.9
					.85	6.1	1.5	27.0

All Models Continuous Duty † 450-470 MHz * 40W 470-512 MHz ** 60W 470-512 MHz

No. of Frequencies: Single, two-frequency and two-receiver stations (dc and tone remote control)
Four-frequency stations (tone remote control)
Single frequency repeaters (dc or tone remote control)

Squelch options: Carrier squelch, Private-Line coded squelch, and Digital Private-Line squelch.

Metering: Upright unit—2 panel-mounted meters, with associated selector switches, provide resonant indication of all receiver, exciter, and power amplifier circuits essential to tuning and checking.
COMPA-STATION radio unit—Optional internal-mounted meter used to measure all essential circuits for tuning and checking.

Transmitter

Antenna Connector:	Type "N"
Base Station Repeater Station	Xmt.—Type "N" Recr.—Type "BNC"
Optional Duplexer	Type "UHF"
RF Output Power:	75W, 45W, 12W (406-420 MHz) 75W, 45W, 20W, 12W (450-470 MHz) 60W, 40W, 20W, 12W (470-512 MHz)
Output Impedance:	50 Ohms
Oscillator Frequency Stability:	Channel element maintains oscillator frequency within $\pm 0.002\%$ from -30°C to $+60^{\circ}\text{C}$ ambient ($+25^{\circ}\text{C}$ ref.)
Transmitter Sideband Noise:	-85 dB @ ± 25 kHz -100 dB @ ± 1 MHz
Spurious and Harmonics:	More than 85 dB below carrier

Modulation:	15F2 and 16F3: ± 5 kHz for 100% at 1000 Hz
Audio Sensitivity:	0.120 volt ± 3 dB for 60% maximum deviation at 1000 Hz Remote Telephone Line: -20 dBm max. for 60% maximum deviation at 1000 Hz
FM Noise:	55 dB below 60% system deviation at 1000 Hz
Audio Response:	+1, -3 dB from 6 dB/octave pre-emphasis, 300-3000 Hz, referenced to 1000 Hz
Audio Distortion:	Less than 2% at 1000 Hz; 60% system deviation
FCC Designation:	
450-470 MHz	470-494 MHz 494-512 MHz
12W CC4221C	CC4221C-1 CC4221C-2
20W CC4222C	CC4222C-1 CC4222C-2
45W (40W) CC4223C	CC4223C-1 CC4223C-2
75W (60W) CC4224C	CC4224C-1 CC4224C-2

Receiver

Channel Spacing:	25 kHz
EIA Modulation Acceptance:	± 7 kHz minimum
Oscillator Frequency Stability:	Channel element and AFC maintains oscillator frequency within $\pm 0.002\%$ from -30°C to $+60^{\circ}\text{C}$ ambient ($+25^{\circ}\text{C}$ reference)
Sensitivity—20 dB Quieting:	WITHOUT PREAMP: Less than 0.5 μV WITH PREAMP: Less than 0.25 μV
EIA SINAD:	WITHOUT PREAMP: Less than 0.35 μV WITH PREAMP: Less than 0.175 μV
Selectivity EIA SINAD (± 25 kHz):	-90 dB
Intermodulation—EIA SINAD:	-85 dB
Spurious and Image Rejection:	100 dB min.
Squelch Sensitivity—Carrier Squelch (adjustable):	0.25 μV or less at threshold
Tone-Coded Squelch (fixed):	0.125 μV or less at threshold
Audio Characteristics—Remote Control Models:	Telephone Line: Output: +18 dBm at 600 ohms Response: +1, -3 dB Distortion: 3% at 1000 Hz Hum & Noise: -55 dB For Local Speaker: Output Available: 10 watts at 8 ohms Response: +1, -8 dB Distortion: 5% at 1000 Hz Hum & Noise: -50 dB
RF Input Impedance:	Nominal 50 Ohms

Notes:

1. 75W models are licensable under FCC Rules Parts 21, 89 and 91.
2. 60W models are licensable under FCC Rules Parts 21, 89, 91 and 93.
3. 45W models are licensable under FCC Rules Parts 21, 89, 91, 93 and 95 (i).
4. 40W models are licensable under FCC Rules Parts 21, 89, 91 and 93.
5. 20W models are licensable under FCC Rules Parts 21, 89, 91, 93 and 95 (i).
6. 12W models are licensable under FCC Rules Parts 21, 89, 91, 93 and 95 (i).

that even with 13 dB suppression, the radio system would still reach the San Diego basin. However, the very positive program results show that a low power system could possibly cover the LA basin and certainly a clear channel, licensed, station, of the off-shelf commercial variety, is more than adequate to perform the tasks required by the radio network.

The computer radio interface electronics performed essentially the same functions as the vehicle radio interface hardware described in Chapter 2, Section B.3. As configured for base station application, the full-duplex computer/radio interface logic card consists of two separate functional elements. Approximately thirty percent of the logic performs the control functions required to accept a data word from the base station computer, encode the word in bit-bit complement format, and interface with the base station radio. The protocol for transfer of data from the PDP-11 to this interface logic is consistent with specifications for the DR11-C interface module supplied by DEC. Excluding the data signals, only two hand-shake control lines are required to perform the data transfer for downlink interrogation. The remaining seventy percent of the logic on the Gould interface module performs error filtering on the uplink (received) data, serial accumulation of the received data, and transfer the resulting 32 bit word in two 16-bit data blocks to the PDP-11 via the DR11-C. As before, this data transfer requires only two control lines for interface to the DR11-C. Virtually no difficulties were experienced in the radio interface hardware during the program.

Serious consideration should be given to using high band to the 800 to 900 KHz frequenct range. Studies have been conducted and tests run by Goudl personnel on a DOT program in the Los Angeles basin using an 800 to 900 KHz radio system. These tests results indicated that although the fading is different, the coverage is certianly adequate to use high band radio gear although multiple base stations may be required. Consequently, the recommendation is to seriously consider using high band to avoid co-channel interference.

b. Software. The software system developed for the Cargo Security Field Test Program incorporates an operating system, supplied by Digital Equipment Corporation, and an applications software package. The software system makes use of the vendor supplied operating system for file manipulation and support of the overlay structure. Task scheduling, interrupt handlers and controls console operation are removed from the operating system to insure program operational control is maintained by the applications package.

(1) System Architecture. The modes and operational capabilities of the system are provided via a combination of executive programs and supporting callable routines and subroutines which were linked together into a single program. The overall software system architecture is illustrated inFigure 2-28. The system design is based on providing information to the dispatch station as it is detected. To accommodate this goal, the design is formulated around a pseudo multi-tasking approach which used data files existing in

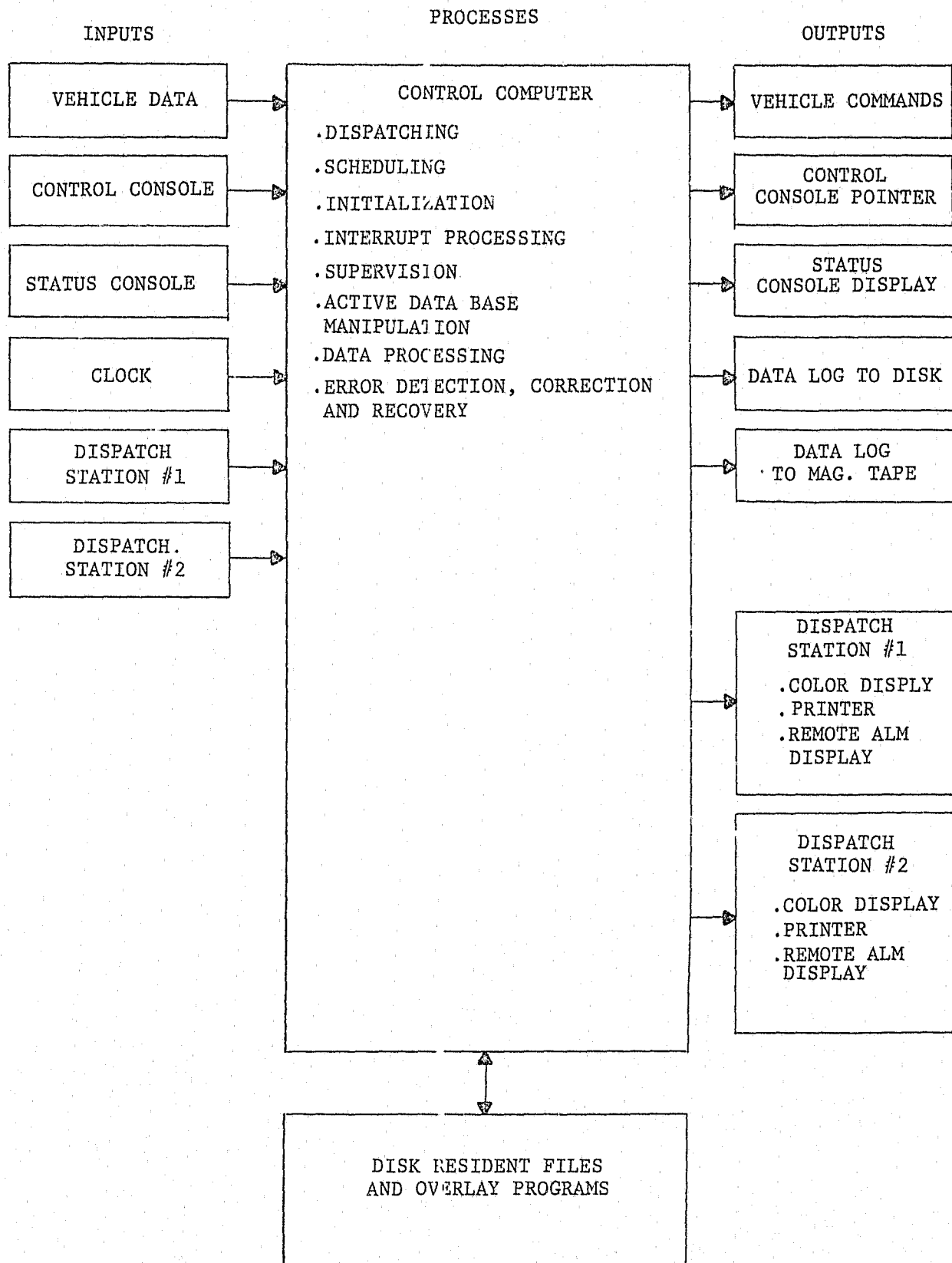


FIG. 2-28 SYSTEM DATA FLOW

memory and on disk. A comprehensive scheduling system is implemented to support this approach. The scheduling system is based on the use of multiple levels of priority and FIFO stacking of commands within priority levels.

Two of the basic processing elements are functionally combined to form the system modules, the real time executive and utilities and the base station display/control processing elements. This combination, along with the other system modules and their relationship to the overall processing operation, is shown in Figures 2-29, 2-30, and 2-31. The RT-11 Operating System was not allowed to control the system at any time since all control was transferred to the base station modules. However, numerous macro calls, file manager functions and the overlay program control was used.

The overlay structure of the system is illustrated in Table 2-5 along with a brief description of each module. The overlay modules are structured to occupy less than 3K of the total 23K area available for program execution in the system.

(2) Memory Layout. The basic program memory layout is pictorially presented in Figure 2-32. The basic program, if all memory resident, would require in excess of 38K words of area. Since the PDP-11/34 computer system can only execute programs within a 32K word area, of which approximately 10K is reserved for fast file manipulation, operating system vectors and status interrupt vectors and system common, it is necessary to specifically organize the program tasks to support the real-time operating requirements. This is accomplished by retaining the DISPATCHER, the SCHEDULER, the interrupt processors and modules with multiple entry points within the dedicated areas of the memory. Any task which can be scheduled on a non-demand

REAL-TIME EXECUTIVE AND UTILITIES	RT-11 OPERATING SYSTEM MACRO CALLS	VEHICLE COMMUNICATION MODULES
INITT INITP INIT SCHLDR EXHELP DSPCR1 DSPCR2 VEHXPT DSPCHR DSVBS2 PRHIST PRNORM	- o V2 - o REGDEF - o WRITW - o LOOKUP - o ENTER - o CLOSE - o SRESET - o NLIST BEX - o READW	LOCUPD LANEXY PFILE SMUPDPD RAMPRC VOLAY1
ALERT/CONTROL DATA PROCESSING MODULE	DISPATCH STATION DISPLAY/CONTROL	DATA LOGGING MODULE
ALERTP	DSPCP RAMLDD DSEDIT DOLAY1	LOGIT

FIG. 2-29 SYSTEM MODULES

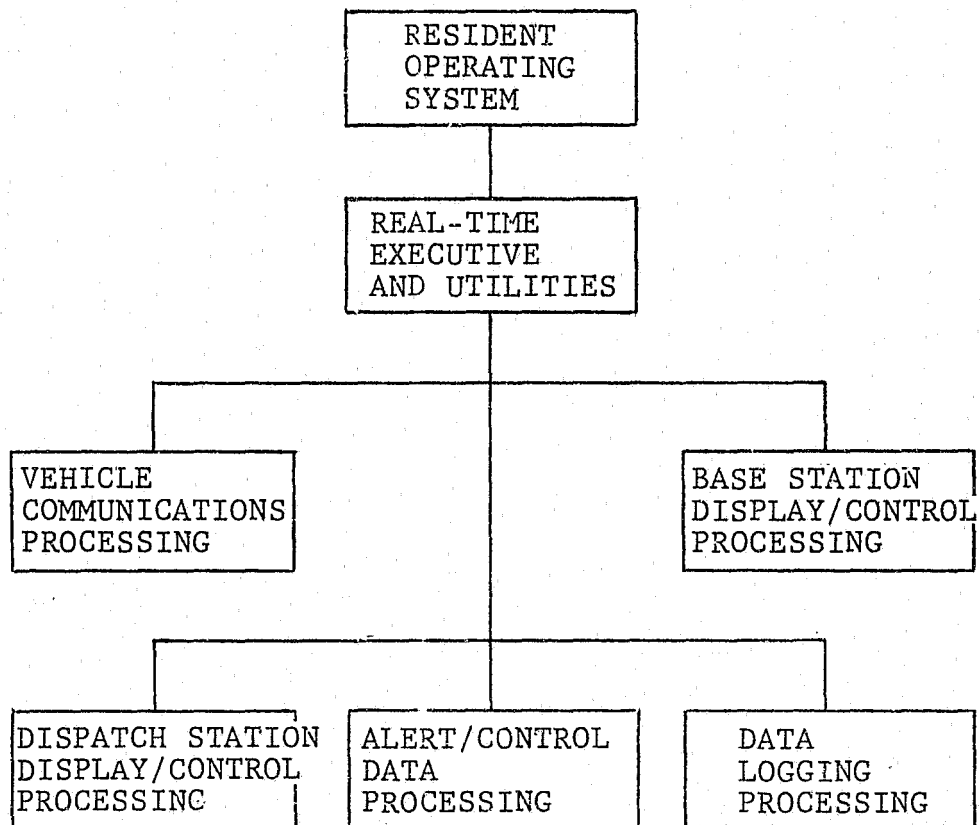


FIG. 2-30 PROCESSING ELEMENTS

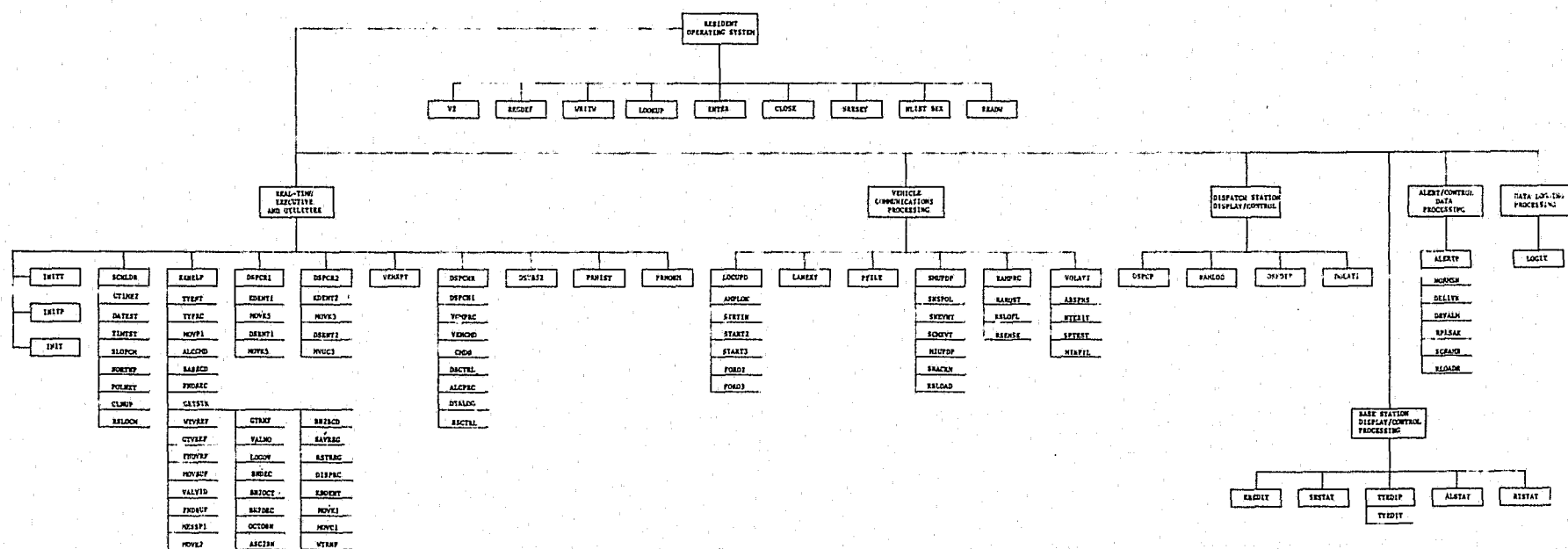


FIG. 2-31 PROGRAM STRUCTURE

TABLE 2-5 SUBROUTINES ARE COMBINED INTO 30 FUNCTIONAL MODULES TO SUPPORT THE RESIDENT AND OVERLAY PROGRAM STRUCTURE

MODULE NAME	FUNCTION
INITT INITP INIT SCHLDR EXHELP DSPCR1 DSPCR2 VEHXPT DSPCHR DSUBS2 PRHIST PRNORM LOCUPD DSPCP LOGIT	INITIALIZATION FOR SYSTEM/VEHICLE CHECKOUT AND TEST PRODUCTION PROGRAM INITIALIZATION FORTRAN COMMON BLOCK INITIALIZATION PROGRAM TIMING AND SCHEDULE CONTROL COMPOSITE OF MULTIPLY USED SUBROUTINES DISPATCH STATION #1 I/O PROCESSOR DISPATCH STATION #2 I/O PROCESSOR VEHICLE RADIO/INTERFACE I/O PROCESSOR SYSTEM DISPATCHER AND SUPERVISOR SUBROUTINES TO SUPPORT OVERLAY MODULES RECENT HISTORY PRINTOUT CONTROL MODULES NORMAL PRINTOUT CONTROL MODULE LOCATION UPDATE PROCESSOR DISPATCH STATION RESIDENT SUBROUTINE MODULE DATA LOGGING CONTROL MODULE
OVERLAY MODULES	
LANEXY PFILE ALERTP TYCDR SMUPDP RAMLDD ALSTAT RTSTAT RAMPRC TYEDIP DSEDIT VOLAY 1 DOLAY 1 KBEDIT SESTAT	AM PHASE LANE COUNT TO X,Y ESTIMATOR X,Y TO STREET INTERSECTION ESTIMATOR ALERT COMMAND/CONTROL MODULE CONTROL CONSOLE OUTPUT DATA PROCESSOR SENSOR, MILEAGE, REMOTE ALARM REQUEST PROCESSOR DISPATCH STATION MEMORY LOAD PROCESSOR REMOTE ALARM DISPLAY (STATUS CONSOLE) PROCESSOR ROUTE STATUS DISPLAY (STATUS CONSOLE) PROCESSOR REMOTE ALARM DATA PROCESSOR CONTROL CONSOLE EDIT PROCESSOR DISPATCH STATION EDIT PROCESSOR VEHICLE DATA PROCESSING OVERLAY MODULE DISPATCH STATION DATA PROCESSING OVERLAY MODULE STATUS CONSOLE EDIT PROCESSOR SECURITY STATUS DISPLAY (STATUS CONSOLE) PROCESSOR

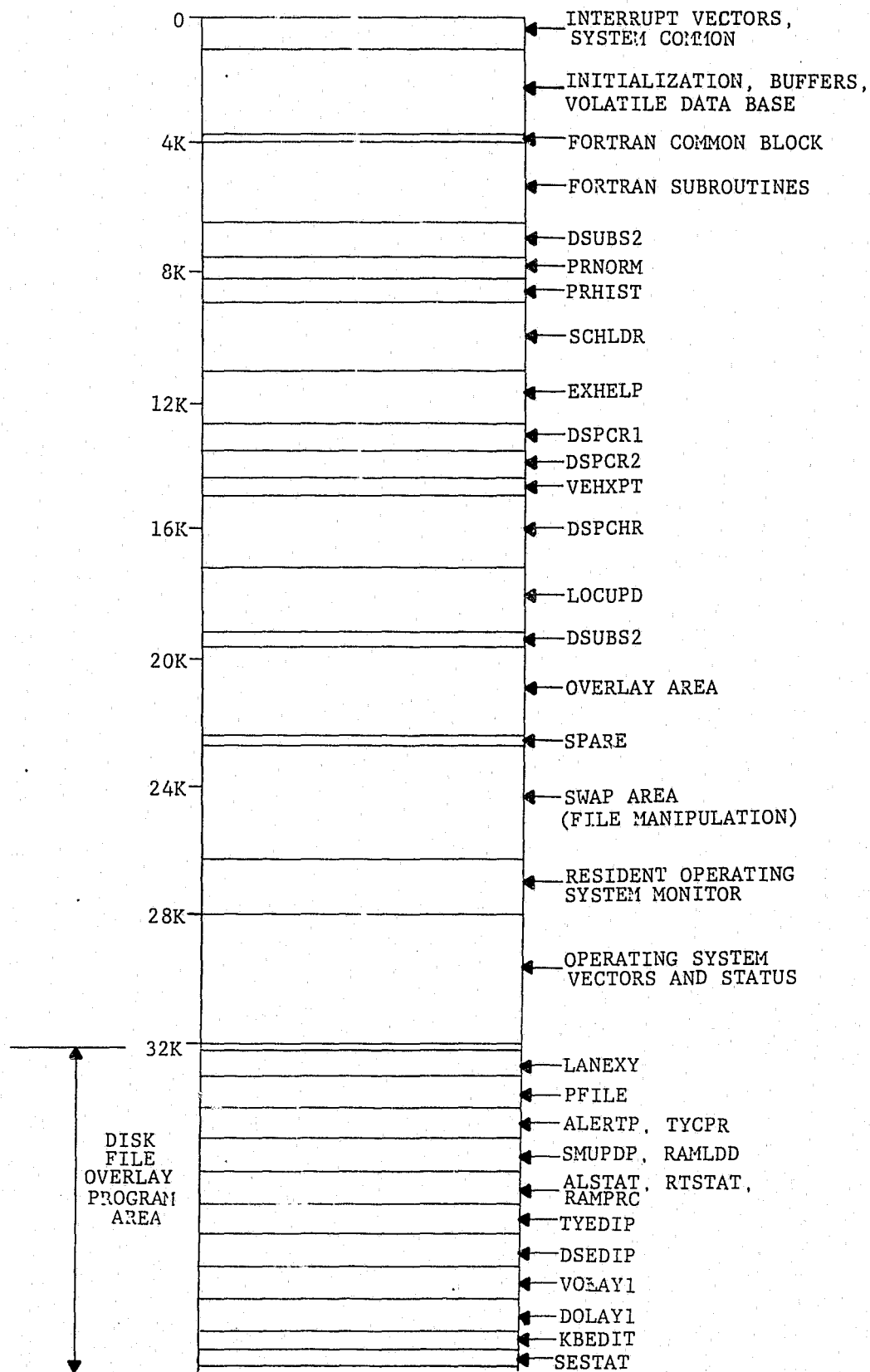


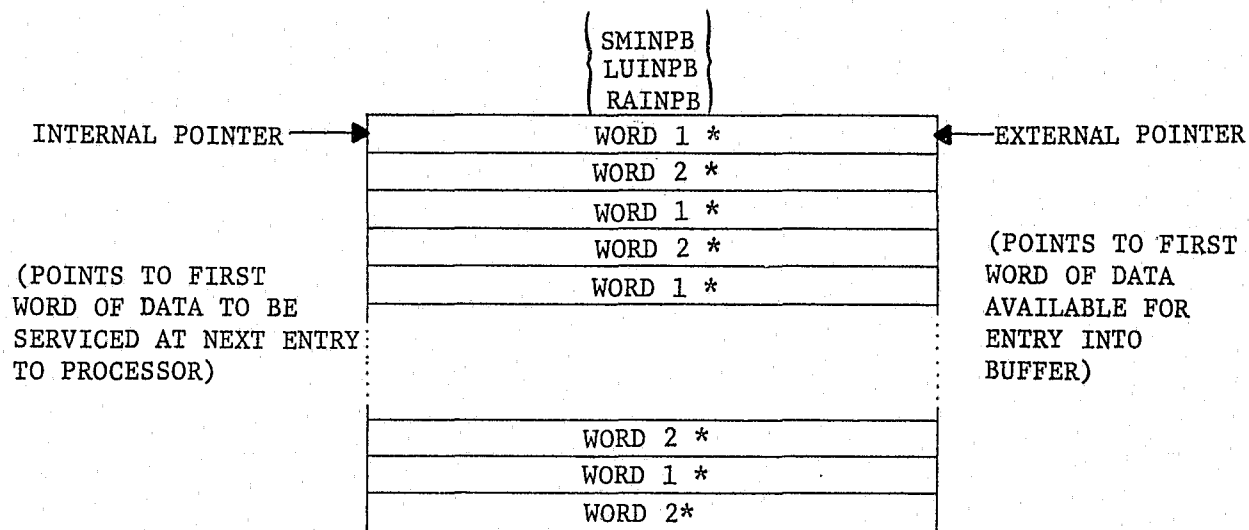
FIG. 2-32 MEMORY MAP OF PRODUCTION PROGRAM

basis is placed in the overlay area and called whenever the priority system indicates that it is the highest priority task. For example, interrupts from vehicles have the highest priority, except for the clock. The associated processing required for this data is immediately accommodated, whereas, any inputs from the dispatch station are temporarily delayed until the vehicle data processing was completed. These delays in processing are on the order of milliseconds to tenths of seconds so that no apparent delay is observed at the dispatch stations.

(3) Data Exchange. Data is exchanged between modules via registers, flags, and buffer areas. As a result of an interrupt, caused by an event, a series of programs is initiated, which sets a combination of flags and command words, to process the event.

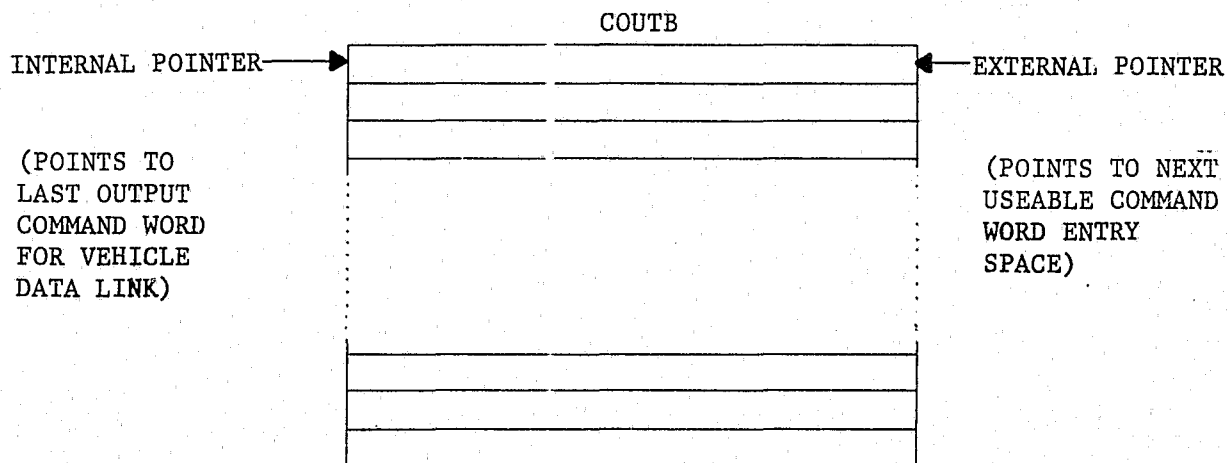
Since the system is real time, the command buffers are not stacks, but are circular. This enables the processing to continue if a buffer is not large enough to handle all the queued commands. That is, (1) pointers to the table are kept to signify the current command word and the entry point for the next command word; (2) the pointers get "bumped" when a command is processed or a new command is input to the buffer; (3) when a pointer is at the "physical end" of the buffer, than the "physical beginning" of the buffer will be the new location of the pointer after it is "bumped"; and (4) if there are no more available entries in the buffer, the oldest entry will be lost to the incoming command. (See Figure 2-33 and 2-34).

The dispatcher subroutine (DSPCHR) prioritizes the operation to service processes in a pre-determined order; however, the dispatcher also analyzes each command buffer and, if necessary, will use another priority to insure the buffer data is not overwritten. Routines are



*WORD 1 AND WORD 2 ARE INPUTS FROM VEHICLE UNIT

(a) SENSOR, REMOTE ALARM AND LOCATION INPUT BUFFER FORMATS



(b) VEHICLE COMMAND BUFFER FORMAT

FIG. 2-33 VEHICLE COMMUNICATION BUFFERS

VEHQUE

EVEN VEHICLE ID		ODD VEHICLE ID	

(a) DURING VEHICLE INITIALIZATION, VEHICLES ARE ENTERED INTO VEHICLE IN QUE BUFFER

{ SSPBUF
 { LOCBUF
 { MILBUF

NULL		VEHICLE ID		MODE	

(b) SUPPORT OF SLOW POLLING COMMAND SEQUENCE PROVIDED BY THREE POLLING BUFFERS

FIG. 2-34 CONTROL BUFFERS

then scheduled which use the command words and the buffer data areas to process information. Buffer areas used for data exchange between modules are listed in Table 2-6.

When a routine is scheduled, the registers may pass data information. These registers could contain command words, flags, parameters, for the routine, addresses of buffer areas, or a combination of the aforementioned. In this way, again, data is readily available to a routine for prompt execution in support of real-time operation.

(4) Data Bases. The Cargo Security System is a data base driven system. In this section, alteration of the data base, location of the files, the recent history data base and access to the data bases are reviewed. In order to promptly handle external events, such as sensor status changes, the data-base structure is configured between memory resident and disk resident files. The criteria utilized to determine memory resident versus disk resident is access frequency and file size. To allow for changes, growth and accommodate addressable memory constraints, non-volatile files such as the street file, line segment file, etc. are stored on disk. Extremely volatile and frequently accessed files, such as the vehicle status file, are memory resident. The mag tape is also a data base file, since all events declared by a vehicle are recorded on mag tape along with the recent history files. These files are output daily to the mag tape.

The data base files are altered by incoming data from various interrupt routines. This data is edited to filter out incorrect inputs before the appropriate data base is updated. Detection errors result in either no activity, a message to the operator or a message

TABLE 2-6 SOFTWARE BUFFERS

NAME	DESCRIPTION
CTFILE	Contains City Names
LOCBUF	Slow Poll Buffer
LOGFIL	Radix Data Containing File Name and Disk For Logging
MILBUF	Mileage Poll Buffer
MTFILE	Radix Information on Mag Tape File
POLBUF	Remote Alarm Polling Buffer
SPSTFL	Radix Information on Signpost File
SPVEHD	Slow Poll Vehicle Delete Buffer
SPVEHE	Slow Poll Vehicle Entry Buffer
SSPBUF	Sensor Slow Poll Vehicle Response Buffer
TELREF	Police Telephone # File for Cities
VEHQUE	List of Vehicle ID's in the System
VOLATL	# Words in Volatile Buffer Followed by Buffer
VSTABL	Radix Information on Temp Volatile Data Base File Name
VSTAT	Vehicle Status Buffer
XYFILE	Information On XY File
BUFC1	Output Storage Buffer For C1
BUFK1	Input Storage Buffer For K1
BUFK2	Input Storage Buffer for K2
BUFP1	Output Storage Buffer for P1
TTYBUF	Buffer Area for Data Conversion
BUFC5	Output Storage Buffer For C5
BUFK5	Input Storage Buffer For K5
TAB	Table of Valid CRT Keyboard Input
BUFC3	Output Storage Buffer For C3
BUFK3	Input Storage Buffer For K3
PDTC1	Physical Device Table For C1
PDTK1	Physical Device Table For K1
PDTK2	Physical Device Table For K2
PDTP1	Physical Device Table For P1
PDTC5	Physical Device Table For C5
PDTK5	Physical Device Table For K5
PDTC3	Physical Device Table For C3
PDTK3	Physical Device Table For K3
ACINPB	Alert Control Process Input Commands
BSINPB	Base Station Input Data Commands
COUTB	Vehicle Output Data Commands
DSINPB	Dispatch Station Process Commands
LUINPB	Location Update Input Data Buffer
RAINPB	Input Data From Vehicle in RALARM, RALARM PENDING, or FIRST ENABLE Response
SMINPB	Input Data From Vehicle In Normal Mode
BSPASS	Base Station Passwords
DEVTAB	Base Station Devices, PDTS and Buffer Addresses
TYETAB	Table of Address of Buffers and Buffer End
POINT	Passed Parameter Buffer for Location Estimator
LUTBUF	Location Update Temporary Buffer
AMBUFF	AM Phase Street Segment Minifile Buffer
LOGBUF	Data Logging Buffer
VEHNUM	Contains Converter Information for a Vehicle #

TABLE 2-6 SOFTWARE BUFFERS (CONT.)

NAME	DESCRIPTION
OUTLOC	Contains Converter Information For A Vehicle Location
TELOUT	Contains Converter Information For a Vehicle Telephone
COLOR	Contains Converter Information For a Vehicle Color
MAKE	Contains Converter Information For a Vehicle Make
MODEL	Contains Converter Information For a Vehicle Model
LICENS	Contains Converter Information For a Vehicle License
ROUTES	Contains Converter Information For a Vehicle Route
MODE	Contains Converter Information For a Vehicle Mode

to the printer. Changes in sensors, detectors or location will update such files as the vehicle status file and the recent history file.

The disk files reside on a formatted disk. Commands used to manage these files are supported by the resident operating system. These commands provide random access to the files which is necessary, in a real-time environment, to meet the response time requirements of the system.

The memory resident files are buffers in the system. The handling of these files is maintained by the applications software. Global variables containing such information as the size of the buffer, the number of entries in the file or the length of each entry, etc., are used in computations for managing the buffer areas.

The recent history data base contains rotating files for each vehicle. Three days of data is kept on every vehicle, and each day the oldest file of data is overwritten with the current day's information. A global variable in the system, "TDFILE", indicates which file contains today's data. This approach saves time, since it is not necessary to transfer data from one file to another on a new day. The recent history file layout is shown in Figure 2-34.

Both the disk files and the memory resident files can be accessed by record number. This allows one file to contain pointers into another file in order to minimize data storage. An example of this is the recent history file which has record numbers of the street and city files instead of the names of the streets or the city.

R H A V V V
 R H B V V V
 R H C V V V

3 ROTATING FILES FOR EACH VEHICLE

BLOCK 1

# BLOCKS THIS FILE	
# RECORDS CONTAINED THIS FILE	
DATE 7 YR 4 MON 5 BITS DAY	
NUMBER	TYPE (A-I)
STREET 1	
STREET 2	
CITY	
TIME HOURS - 4 BITS MIN - 6 BITS SECS - 6 BITS	
DURATION - MILEAGE - OTHER VEHICLE #	

RECORD 1

DATE	
NUMBER	TYPE (A-I)
STREET 1	
STREET 2	
CITY	
TIME HOURS - 4 BITS MIN - 6 BITS SECS - 6 BITS	
DURATION - MILEAGE - OTHER VEHICLE #	
UNUSED WORD 255	
UNUSED WORD 256	

RECORD 36

TD FILE - GLOBAL INDICATING WHICH FILE IS TODAYS DATA

0 - RHAVVV

1 - RHBVVV

2 - RHCVVV

FIG. 2-35 RECENT HISTORY FILE STRUCTURE

(5) Subroutines. The executive routines, supporting routines and subroutines in the system are assembled together in modules, and the modules are linked together into a single program. These subroutines are called with a jump subroutine command, and are re-entrant. Some of the subroutines have multiple entry points in order to be called by different modules. An example of this is "PRHIST", in which the entry points vary when called by the base station or by either dispatch station. Standard "DEC" procedures are used to handle interrupt driven subroutines. The FORTRAN subroutines are called via assembly language subroutines, and they, in turn, call other assembly language routines. The FORTRAN subroutines are structures to perform mathematical functions only. A technique widely used in the system is table-driven subroutines. That is, data is often passed in a table, containing more than one set of parameters of sets of subroutines and a delimiter, for execution by a subroutine.

Table 2-7 contains a list of the subroutines in the Cargo Security System by module.

(6) Global Variables. Global variables are used to define data areas, tables or entry points into subroutines. In this section, data areas and tables rather than entry points are discussed. Global variables are used to pass information between subroutines. They contain counters, pointers, command words and other key data essential to the operation of the system.

As counters, the variables are usually decremented. As pointers they usually contain addresses of buffers of input and output positions for passing data between subroutines. As command words, they

TABLE 2-7 TABLE OF SUBROUTINES

MODULE	SUBROUTINE	DESCRIPTION
INIT	INITT	System Initialization - Test Mode
	INITP	System Initialization - Normal Mode
	INIT	Initialize the Common Block
	SCHLDR	System Program Supervisor
	CTIME2	Clock Interrupt Processor
	DATEST	Data Input Test
	TIMTST	Time Input Test
	SLOPCM	Slow Poll Comm Countermeasures
	NORTNP	Slow Poll No Return Processing and Status Data
	POLNXT	Slow Poll Processing
	CLNUP	Slow Poll Cleanup Routine
	RSLOCM	Remote Alarm Slow Poll Countermeasures
	EXHELP	Composite of Subroutines
	TYENT	Input Interrupt Processor For Base Station DecWriter
EXHELP	TYPRC	Output Interrupt Processor For Base Station Printer
	MOVPI	Move Data to Base Station Printer Output Buffer
	ALCCMD	Load Data Into Alert/Control Command Buffer
	BASECD	Load Data Into Base Station Command Buffer
	DSPCMD	Load Data Into Dispatch Station Command Buffer
	FNDREC	Find Block and Offset of a Street Record
	GETSTR	Read a Record of the Street File
	WTVREF	Write a Record of VREF
	GTVREF	Read a Record of VREF
	FNDVRF	Find Block # of VREF For a Vehicle
	MOVBUF	Move Characters From Source to Destination
	VALVID	Validate Vehicle ID
	FNDBUF	Allocate 256 Word Buffer from "VOLATL" Buffer
	RLSBUF	Release 256 Word Buffer from "VOLATL" Buffer
	MESSP1	Output Error Msg on Base Station Printer
	MOVK2	Move Input Request Data Base Station TTY Keyboard to Buffer
	GTRHF	Read a Block of the Recent History File
	VALNO	Validate Vehicle and Return Entry in VSTAT
	WTRHF	Write Block of Recent History File to Disk
	LOGOV	Log Output Data
	BNDEC	Convert Binary to Decimal ASCII Equivalent
	BN2OCT	Convert Binary to ASCII Octal
	BN2DFC	Convert Binary to Decimal ASCII
	OCTOBN	Convert Octal ASCII to Binary
	ASC2BN	Convert Decimal ASCII to Binary
	BN2BCD	Convert Binary to BCD
	SAVREG	Save Registers
	RSTREG	Restore Registers
	DISPRC	Output Processor for Base Station CRT Display
	KBDENT	Input Processor for Base Station CRT Keyboard
	MOVK1	Move Input Request Base Station CRT to Buffer
	MOVCI	Move Data to Base Station CRT Output Buffer
DSPCR1	DSPCR1	CRT I/O Processor for the #1 Dispatch Station
	KDENT1	CRT Input Processor for the #1 Dispatch Station
	MOVK5	Move Input Request Data From Input Buffer to Output Buffer

TABLE 2-7 TABLE OF SUBROUTINES (CONT.)

MODULE	SUBROUTINE	DESCRIPTION
DSPCR2	DSENT1	Output Processor for #1 Dispatch Station CRT Display
	MOVC5	Move Data to #1 Dispatch Station CRT Output Buffer
	KDENT2	CRT I/O Processor For the #2 Dispatch Station
DSPCR2	MOVK3	CRT Input Processor for the #2 Dispatch Station
		Move Input Request Data from Input Buffer to Output Buffer
VEHXPT	DSENT2	Output Processor for #2 Dispatch Station CRT Display
	MOVC3	Move Data to #2 Dispatch Station CRT Display
VEHXPT		Vehicle Interrupt Processor
DSPCHR		System Dispatcher and Supervisor
	DSPCH1	System Dispatcher and Supervisor
	VCMPRC	Vehicle Command Processor
	VEHCMD	Vehicle Output Command Processor
	CMD0	Load Vehicle Command Buffer
	DSCTRL	Dispatch Station Control Processor
	ALCPRC	Sensor Alert Control Processor
	DTALOG	Data Logging Control Processor
	BSCTRL	Base Station Control Processor
DSUBS2		Composite of Subprocesses
PRHIST		Recent History Print
PRNORM		Vehicle Normal Print
LOCUPD		Initial Location Data Processor
	AMPLOK	AM Phase Data Processing and Control Routine
	STRTIN	X,Y to Intersection Control
	START2	FORTTRAN Input #1
	START3	FORTTRAN Input #2
	FOR02	FORTTRAN Output #1
	FOR03	FORTTRAN Output #2
DSPCP		Dispatch Station CRT Keyboard Edit Subprocesses
	DSFMTR	Dispatch Module Hexadecimal Formatter
LOGIT		Data Logging Control Module
	DTASTR	Data Storage For Vehicle Recent History
	LOGGER	Save Data For Data Logging
	MTOUTP	Mag-Tape Output Processor
LANEXY		Phase to X,Y Conversion
	BNDRYS	Process Route Boundary and Mapped Boundary Data
PFILE		X,Y to Intersection FORTTRAN Processor
ALERTP		Alert Command/Control Processor
	NORMSN	Normal Sensor Data Processor
	DELIVR	Delivery Flag Processor
	DRVALM	Driver Alarm Activated Processor
	RPLSAK	Ramload Acknowledge
	SCRAMB	Scrambled RAM Load Processor
	RLOADR	Vehicle Unit RAM Loader
TYCPR		Base Station Command Print
SMUPD		Sensor/Mileage Update Processor
	SNSPOL	Sensor Polled Response Processor
	SNEVNT	Sensor Event Processor
	SCMEVT	Countermeasures Event Processor
	MIVPDP	Mileage Update Processor

TABLE 2-7 TABLE OF SUBROUTINES (CONT.)

MODULE	SUBROUTINE	DESCRIPTION
	SNACKN	Sensor Acknowledge Processor
	RBLOAD	Sensor RAM Load Acknowledge
RAMLDD		Ram Load Processor for the Dispatch Station
ALSTAT		Alarm Status Display
RTSTAT		Route Status Display
RAMPRC		Remote Alarm Data Processor
	RARQST	Remote Alarm Request Processor
	RSOLPL	Remote Alarm Request Processor
	RSENSE	Remote Alarm Sensor Processor
TYEDIP		Control Console Edit Processor
	TYEDIT	Base Station TTY Keyboard Edit Routine
DSEdit		Dispatch Station Edit Processor
VOLAY1		Vehicle Data Processor
	ABSPHS	Absolute Phase and Stop Data Processor
	NTEXTIT	Yard Entry/Exit Processor
	SPTEST	Signpost Valid Test Processor
	MINFIL	Minifile Processing Routine
DOLAY1		Composite of Subprocesses for the Dispatch Station
KBEDIT		Base Station CRT Keyboard Edit Routine
SESTAT		Security Status Display

are used as temporary storage registers for pertinent command information to enable subsequent efficient processing. As data storage, they are used to hold such things as time and date information. Table 2-8 lists the global variables and their descriptions.

(7) Flags. Flags are used in the Cargo Security System to indicate: (1) processes that are to be executed, (2) sensor status of vehicles, (3) a device is busy, (4) validity of a test, (5) error conditions, or (6) various other conditions such as process complete.

Table 2-9 is a table of flags and their description.

Flags are used in the PDT tables as shown in Figure 2-36 and in VSTAT as illustrated in Figure 2-37. Flags are usually used to indicate processes that are to be expected. An exception to this can be found in flags which indicate a process is complete or a device is busy.

(8) Software System Operation. The software system described herein includes a description of the program structure relative to operation at the dispatch stations and the base station. There are two operational descriptions provided: initialization and normal mode. The normal mode, as treated in the software description, is not to be confused with the normal vs. after-hours mode of operation of the overall system.

(a) Initialization. Initialization of the system involves the start-up of the Cargo Security System operational software package, initialization of the vehicles and initialization of the dispatch stations. A more complete description of the procedures for initialization of the dispatch stations is provided in Section C.2 of this chapter.

TABLE 2-8 TABLE OF GLOBAL VARIABLES

VARIABLE	DESCRIPTION
BSEND	Number of Words in Base Station Command Buffer
VSTEND	Points to End of 'VSTAT'
SPEEND	Points to End of 'SPVEHD'
HOURS	Time-Hours, Binary
MINS	Time-Minutes, Binary
SECS	Time-Seconds, Binary
HALF	Time-AM, PM
MONTHR	Table of RAD50 Months
JCLNDR	Julian Calendar Buffer
DATE	Packed Date-Word
POINTR	Address of Point Buffer
TSTDTR	Passed Parameter Buffer for FORTRAN
TTTEMP	Processor Pointer
PHSROL	AM Phase Rollover Response Buffer
GICTR	GI 60 Sec Counter
TCCTR	TC 60 Sec Counter
POLADR	Normal Slow Poll Address
DSCTR1	TC 434 MSEC Counter
DSCTR2	GI 434 MSEC Counter
DSCTR3	TC 4 SEC Counter
DSCTR4	GI 4 SEC Counter
DSCTR5	TC 32 MSEC Counter
DSCTR6	GI 32 MSEC Counter
DSCTR7	TC 160 MSEC Counter
DSCTR8	GI 160 MSEC Counter
TCMBEL	TC Multiple Bells
GIMBEL	GI Multiple Bells
DSCMD1	CMD Words Dispatch #1
DSCMD2	CMD Words Dispatch #2
GISECT	GI Sensor Enable Counter
TCSECT	TC Sensor Enable Counter
GISETT	GI Times Tried Counter
TCSETT	TC Times Tried Counter
VEHEND	Points to End of 'VEHQUE'
SSPEND	Points to End of 'SSPBUF'
LOCEND	Points to End of 'LOCBUF'
MILEND	Points to End of 'BILBUF'
DYDTC	TC 2 Second Counter for Yard Entry
DYDGI	GI 2 Second Counter for Yard Entry
POLADR	Normal Slow Poll Address
RPTR	Polling Buffer Pointer
LNGUST	Length of Entry in VSTAT Table
MAXTRK	Maximum # of Trucks on System
MCNTC1	Maximum Count for Error Returns from MOVCL
TDFILE	Indicates File that Contains Today's Data for History
TRKTRN	Number Trucks Assigned to TC in VREF
ACEND	End of Buffer ACINPB
AVSTAT	Address VSTAT
BSEND	End of Base Station Command Buffer
BSINPI	Current Process Pointer for BSINPB
BSINPP	Next Process Pointer for BSINPB Process

TABLE 2-8 TABLE OF GLOBAL VARIABLES (CONTINUED)

VARIABLE	DESCRIPTION
ACINPI	Current Process Pointer for ACINPB
ACINPP	Next Process Pointer for ACINPB Process
BSRQST	Request from BS to VC
CMDWDA	Command Word for Dispatch Station
CMDWDB	Command Word for Dispatch Station
CMDWDC	Command Word for Dispatch Station
CMDWDG	Command Word for Dispatch Station
CMDWDT	Command Word for Dispatch Station
COVEND	End of Command Out BUFR COUNTB
COUTP	CMD In Pointer
COUTPI	CMD Out Pointer
DSEND	End of DSINPB
DSINPI	Current Process Pointer for DSINPB
DSINPP	Next Process Pointer for DSINPB Process
LULEND	End of LULNPB Location Input BUFR Ptr
LULNPP	Next Process Ptr for LULNPB Process
RALEND	End of RAINPB Remote Alarm Process BUFR
RAINPI	Process Pointer for RAINPB
RAINPP	Next Pointer for RAINPB Process
SMIEND	End Sensor/Mileage Input Bufr SMINPB
SMINPI	Current Process Pointer for SMINPB
SMINPP	Next Process Pointer for SMINPB
TCCMD	
ADDRES	Table Processing Address
BLK	Block # of VREF Entry
BUFFER	Address of Volatl Block Allocated
CMDWD1	Base Station Command WD 1
CMDWD2	Base Station Command WD 2
DELTA	Recent History Delta
DISADR	Address of Output Routine
ERRPRT	Address of Error Print Routine
GIBELL	CRT Bell Counter For GI
TCBELL	CRT Bell Counter for TC
ICHARS	# of Input Characters
INPUT	Input Data to Edit
INPUT1	Input Data to Edit DS1
INPUT2	Input Data to Edit DS2
MOVER	Address of Move Input Subroutine
PDTADR	Address of PDT Output Device
PDTCLR	Bits to Clear In PDT Status Word
PDTINP	Address of PDT Input Device
DEVICE	Device #
PDTSET	Bits to Set in PDT Status Word
PRTPDT	Address of PDT For Pointer
RETADR	Storage Table of 'ADDRES' For Table Jmp and Returns
SENSOR	Sensor Binary
T	Trucking Company ASCII
TCO	Trucking Company Binary
VID	Vehicle ID Binary
VVV	Vehicle # ASCII
VVVX	Vehicle # Radix
YY	Vehicle ID ASCII

TABLE 2-8 TABLE OF GLOBAL VARIABLES (CONTINUED)

VARIABLE	DESCRIPTION
TEND	End of Table of Sensor Descriptions
PNTR1	Address VSTAT
WORD1	First Data Word
NO1PTR	File Name Ptr #1 Dispatch Station
NO2PTR	File Name Ptr #2 Dispatch Station
LOGBLK	Block # for Data Record
GILRCT	GI Location Counter
GILRTT	GI Location Times Tried Counter
TCLRCT	TC Location Counter
TCLRTT	TC Location Times Tried Counter
PHSROL	AM Phase Rollover Response Word

TABLE 2-9 TABLE OF FLAGS

NAME	DESCRIPTION
DLFLAG	Data Logging Processor Flag
ERAFGP	Remote Alarm Arm Request Flag
RAVCOM	Remote Alarm Mode Processor Flag
POLFLG	Poll Flag
DSFLG5	32 MSEC Flag
DSFLG6	32 MSEC Flag
DSFLG7	160 MSEC Flag
DSFLG8	160 MSEC Flag
GILRCD	GI Location Buffer/Flag
TCLRCD	TC Location Buffer/Flag
GISECD	GI Sensor Enable Buffer/Flag
TCSECD	TC Sensor Enable Buffer/Flag
GI1BEL	GI 1 Bell
TC1BEL	TC 1 Bell
PCMDLT	Polling Complete Flag
SLPHSF	Slow Poll .5 Sec Flag
SLPSTF	Slow Poll Clean-up Flag
SLP3SF	Slow Poll 3 Sec Flag
NOLOG	No Logger Flag
GBFCMD	GBF Command Flag
IFLAGX	In Process Flag for Dispatch Station #1
IFLAG1	In Process Flag for Input Data Blk DS #1
IFLAG2	In Process Flag for Intercolor Input DS #1
PSWDFG	Password Flag
TABEND	# Entries in Tab
IFLAGY	In Process Flag for Dispatch Station #2
IFLAG3	In Process Flag for Input Data Blk DS #2
IFLAG4	In Process Flag for Intercolor Input DS #2
BSFLAG	Base Station Processor Flag
DFLAGG	GI Dispatch Station Processor Flag
DFLAGT	TC Dispatch Station Processor Flag
DSFLAG	Dispatch Station Processor Flag
ALFLAG	Alert Routine Processor Flag
DSFLG1	Cntr Flag DS #1
DSFLG2	Cntr Flag DS #2
GIFLAG	GI Dispatch Station Busy Flag
TCFLAG	TC Dispatch Station Busy Flag
K5FLAG	Busy Flag For PDK5
K3FLAG	Busy Flag For PDK3
LUFLAG	Location Update Processor Flag
RAFLAG	Remote Alarm Processor Flag
SMFLAG	Sensor/Mileage Processor Flag
GICMD	GI Command Word DS
TCCMD	TC Command Word DS
ANSWER	Secondary Test Result Flag
FUNKEY	Function Key Flag
CRFLG1	RAM Load Flag Dispatch Station #1
CRFLG2	RAM Load Flag Dispatch Station #2
RESULT	Test Result Flag
LOCMP5	Location Computer Flag
OBUFFR	Validity Flag
RLD1	RAM Load Dispatch Station #1 Flag

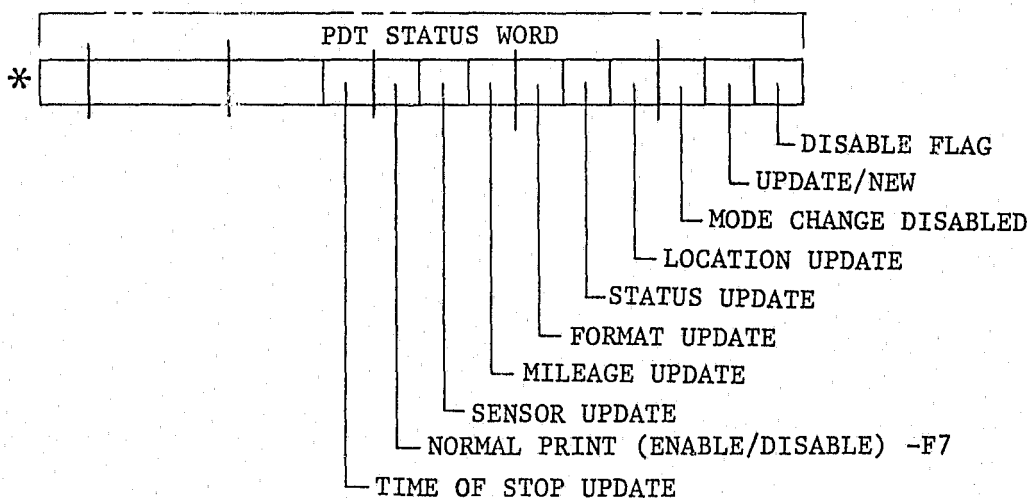
TABLE 2-9 TABLE OF FLAGS (CONT.)

NAME	DESCRIPTION
RLD2	RAM Load Dispatch Station #2 Flag
VCFLAG	Vehicle Communications Processor Flag
SCHED	Scheduling Processing Word
RAVCOM	Flag and Command Word for Veh in RALARM Mode

PHYSICAL DEVICE TABLE (PDT)	
* STATUS WORD	
TIME-OUT COUNTER-MAX	
PREVIOUS FUNCTION FLAG	FUNCTION FLAG(1-FI n-Fn)
TRUCKING CO.	VEHICLE ID (0 FOR ALL)
ADDRESS OF ENTRY IN VSTAT	
EXTRA DATA	POINTER
SUB-BYTE	PRIME BYTE

COMMAND WORDS

FORM PDTC1 - PDT FOR C1 DEVICE
 PDK1 - PDT FOR K1 DEVICE
 PDTP1 - PDT FOR P1 DEVICE
 PDK2 - PDT FOR K2 DEVICE



BUFFER FOR I/O DEVICES	
	# DATA BYTES IN BUFFER (N)
BUFFER 'IN' POINTER	BUFFER 'OUT' POINTER
1	DATA BYTE 0
3	2
...	...
N	N-1

FORM BUFC1 - BUFFER FOR C1
 BUFK1 - BUFFER FOR K1
 BUFP1 - BUFFER FOR P1
 BUFK2 - BUFFER FOR K2

FIG. 2-36 PHYSICAL DEVICE TABLES FOR PERIPHERALS AND I/O BUFFERS

VSTAT (MEMORY RESIDENT)

BLOCK NO. OF VREF	VEHICLE ID (1-63)	0
STATUS WORD #1		2
STATUS WORD #2		4
SENSOR STATUS		6
ODOMETER INPUT		10
STATUS WORD #5		12
(BASE STATION		14
CONTROL)		16
ALERT/DISPATCH CONTROL		20
VEHICLE NO. (RAD 50)		22
	ODOMETER ROLLOVER	24
STATUS WORD #11		26
ST. NO. 1		30
ST. NO. 2		32
TRACKING CHAR.	CITY NO.	34
STREET #1		36
(RAD 50		40
FORMAT)		42
STREET #2		44
(RAD 50		46
FORMAT)		50

FIG. 2-37 VEHICLE STATUS FLAG TABLE - SINGLE VEHICLE LAYOUT

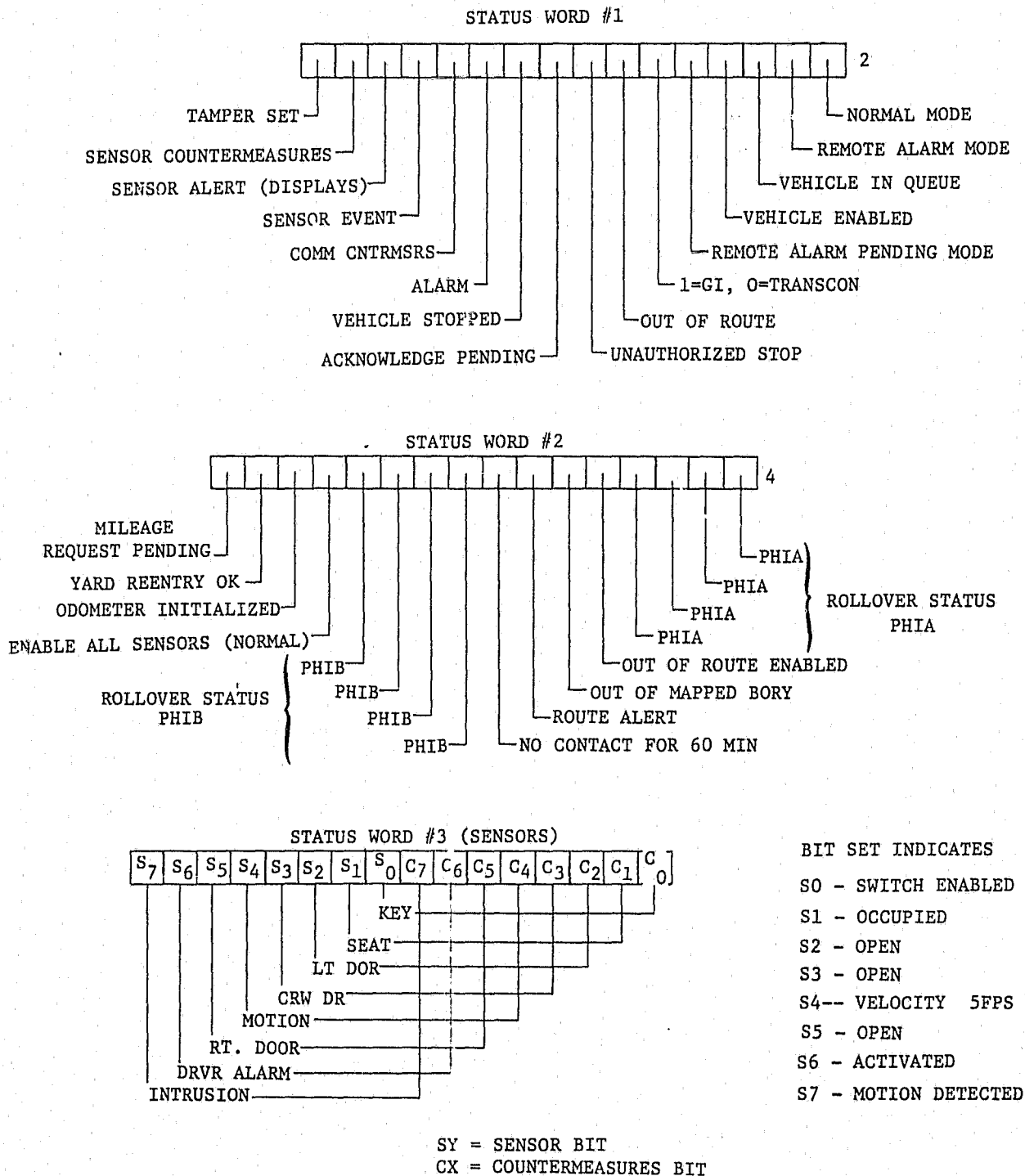


FIG. 2-37 VEHICLE STATUS FLAG DEFINITION (CONT.)

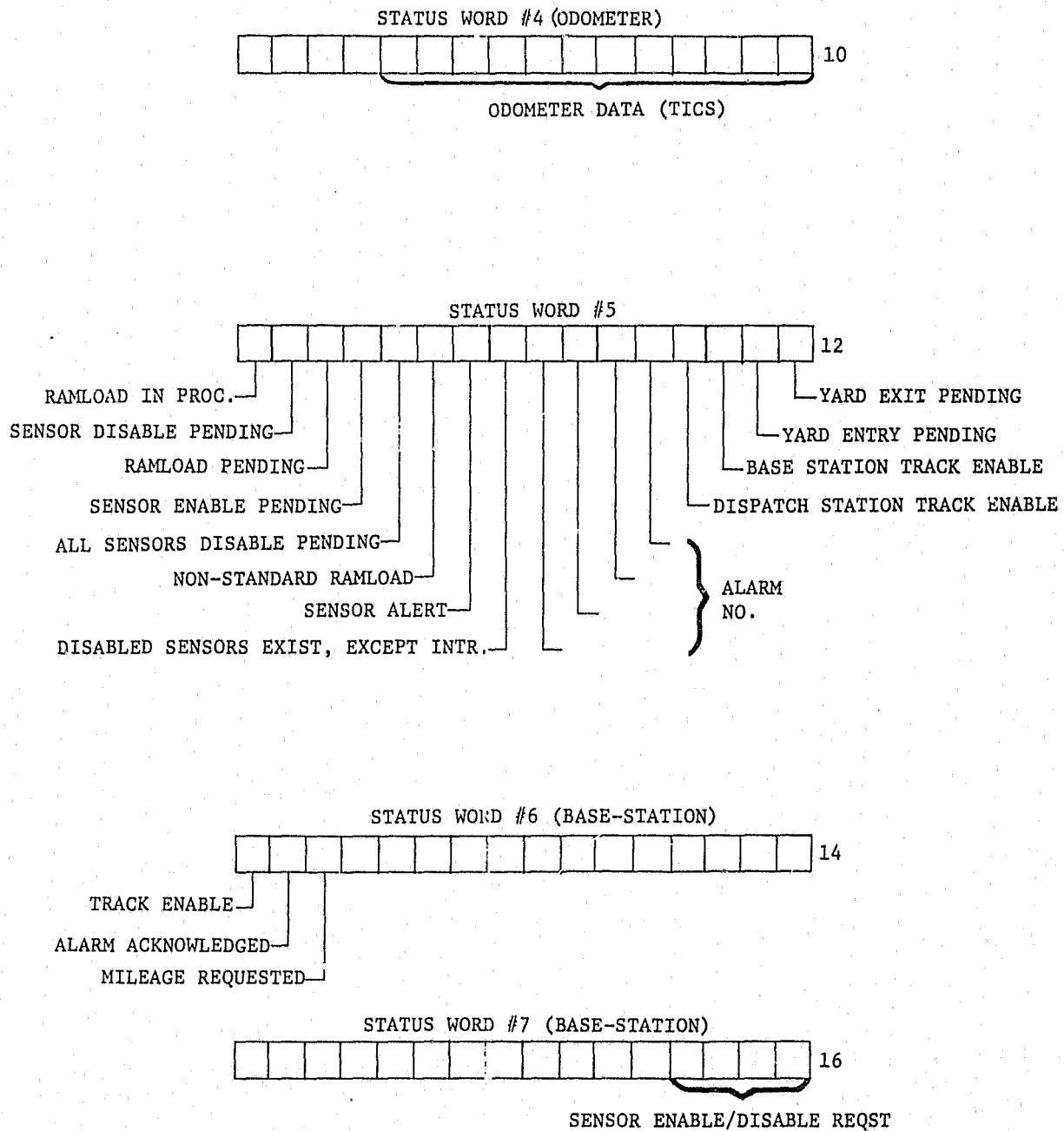


FIG. 2-37 VEHICLE STATUS FLAG DEFINITION (CONTINUED)

o Base Station Initialization

The system initialization processor initializes all variables which are system related. All buffers handling vehicle and display data are initialized and the system time and calendar started. The initialization routine also disables all system traps to insure control is retained in the event of a malfunction.

The system program is loaded and execution initiated following the operating system monitor load by selection R CSPROG. The program will require the operator to insert the date and time from the base station character printer keyboard at which time the key password algorithm is initialized, buffer data initialized, and the normal program sequences made operational. Following enable of all interrupts, the routine exits to the Dispatcher.

o Initialization of a Vehicle

The unit entry command at the base station CRT keyboard initializes a vehicle. This command checks the validity of the request to insure the vehicle is valid for the company, and that it is currently inactive. It then sets the active flag in VEHQUE and initializes an entry in VSTAT. This must be done to activate a vehicle.

The unit delete command at the base station CRT keyboard will deactivate a vehicle. This command checks for valid data on an active vehicle, then deletes the appropriate entries in the VEHQUE and VSTAT tables; thereby making it inactive.

o Dispatch Station Initialization

The Cargo Security System will operate without the dispatch station; however, to initialize the dispatch station, a certain character string must be input at the dispatch station CRT keyboard as

shown in Section D of this chapter. When this character string is input, it will cause: (1) the memory of the dispatch station CRT to be loaded by the host computer, and (2) the route status display to appear on the dispatch station CRT.

(b) Normal Mode. A description of the normal mode of operation of the software system involves: events, data base manipulation, dispatch station operation, display, provide printouts available at the base station and dispatch station. Each of these capabilities is described as follows.

o Events

The Cargo Security System is an event-driven interactive dispatch display and recording system. The CSS has been designed to respond to changes in sensors, detectors or locations.

These changes are then displayed or printed to alert the dispatcher or base station attendant; furthermore, the system will allow the dispatcher to react to an event and/or request specific information concerning a vehicle.

As a result of a sensor status change, an interrupt occurs which initiates a program that determines the vehicle mode and selects the appropriate logic path to process the interrupt. The system has been designed to allow this logic path to be interrupted in order to provide prompt handling of any other event which might occur. To service multiple interrupts the system incorporates the use of tables, modules and priority levels.

o Data Base

In the Cargo Security Software Systems there are volatile and non-volatile data bases. Volatile data bases refer to those areas

which are continuously changing and indicate system or vehicle current status. The non-volatile data bases refer to those elements which are used for references or mapping functions and contain fixed values in general. The volatile data bases are VEHQUE (Vehicle Queue), VSTAT (Vehicle Status), and recent history file. The non-volatile data bases are VREF (Vehicle Reference), Line Segment File, CTFILE (City File), STFILX (Street File), TELREF (Telephone Number File), SPSTFL (Signpost File), ROUTES (Route File).

o Dispatcher

The Dispatcher Processes flag information to call various routines if the processing flag is non-zero and prioritize the operations such that vehicle information is always executed first, then alert processing, base station processing, dispatching and finally data logging. In addition, the dispatcher analyzes each command buffer to insure that the data is not lost or overwritten and uses another level of priority to insure the buffer data is not lost. This routine is part of the Executive processing group. The routine is entered by a jump statement from the initialization routine.

The entry point for the process and return point following a call to one of the tasks is the same. Upon entry, the routine tests the task load for each subtask and selects the task to be performed on a high priority basis. If no high priority task needs to be performed, the routine determines the next task to be performed based on a constant priority. That is, the vehicle communication processing task is analyzed first, then others. All returns are to the high priority task test. If the task has not been completed, say for the vehicle inputs due to disk access delay, the system will continue

examining other tasks to insure that the lower priority tasks are processed until the system becomes available for a higher priority task. Sub-task calling control is maintained through the dispatcher resetting the calling flag and by the processor resetting the calling flag.

- o Displays

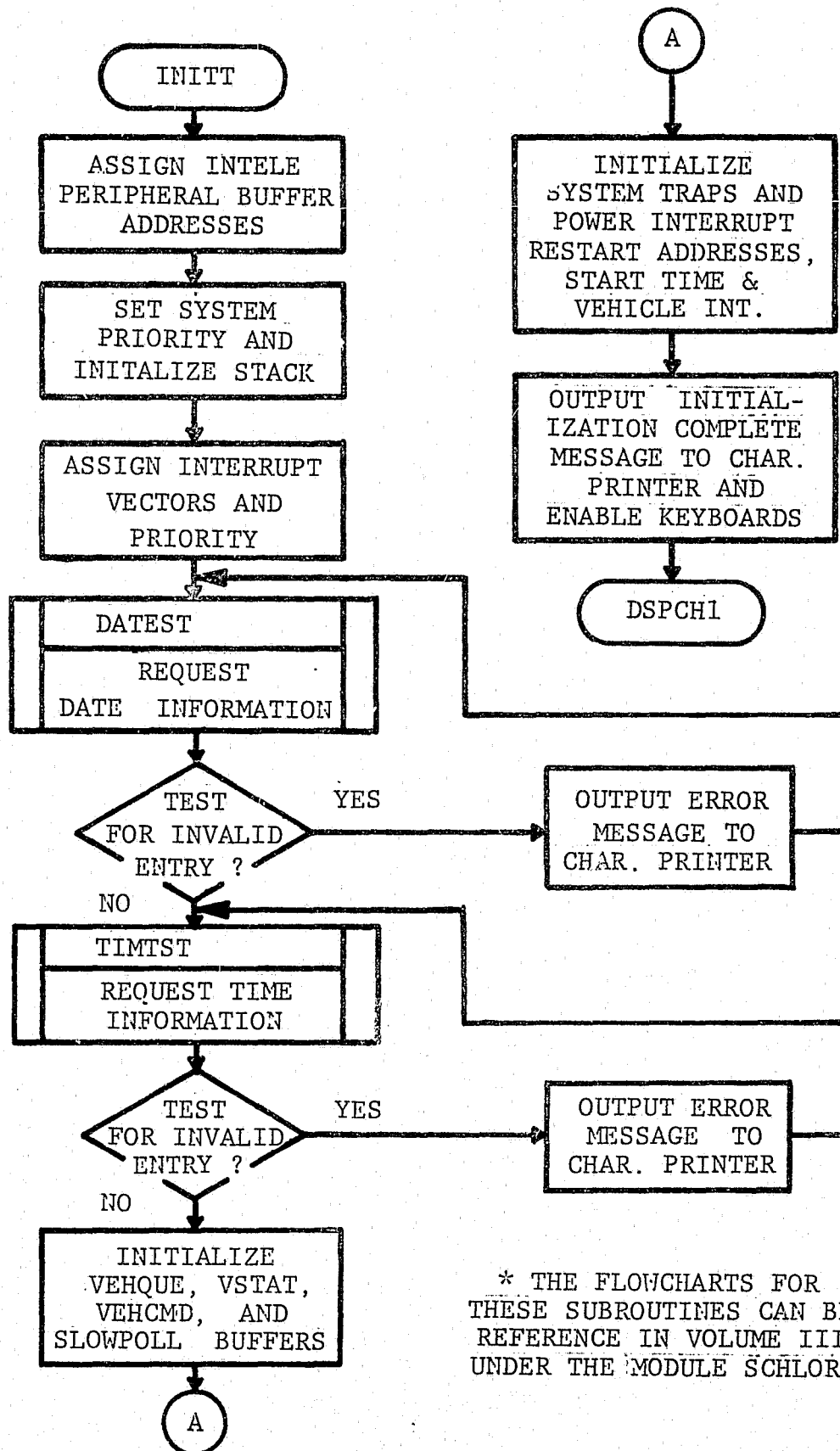
The displays in the Cargo Security System are the Route Status, Security Status, and Alarm Status Displays. A full display can be requested by an operator or if a Unit Entry Command or a Unit Delete Command affects vehicles on an existing display, a full display will be written. Also, an existing line of a display will be rewritten if a change occurs to the status of a vehicle.

- o Printout

The printouts in the Cargo Security System are the Recent History Print and the Normal Print. Whenever an ALARM, R ALERT, or ALERT condition occurs on a truck a Normal Printout occurs. A Recent History Printout is requested by an operator.

(9) Module Description of Application Software. In support of the modular structure, tasks are divided and assigned to various routines. The primary data processing and interrupt processing by routine are as follows:

- (a) INITT. This routine initialized all critical system related variables. All buffers handling vehicle and display data are initialized and the system time and calendar started as illustrated in Figure 2-38. The initialization routine also disables all system traps to insure control is retained in the event of a malfunction. This routine does not include data logging. The routine is



* THE FLOWCHARTS FOR THESE SUBROUTINES CAN BE REFERENCE IN VOLUME III UNDER THE MODULE SCHLOR.

FIG. 2-30 TEST MODULE FOR INITIALIZATION

used for checkout and test and has the feature that the system debugger provided by DEC can be run concurrently.

(b) INITP. This routine initialized all critical system related variables. All buffer handling vehicle and display data are initialized, and the system time and calendar started. The initialization routine also disables all system traps to insure control is retained in the event of a malfunction. This routine differs from "INITT" in that it does include data logging (refer to Figure 2-39). This routine is required for the production program.

(c) INIT. This is a FORTRAN routine which initializes the COMMON block (Figure 2-40).

(d) SCHLDR. This module functions as the system program supervisor. As part of its function it initialized all critical buffer areas for parameter passage and information exchange between modules. It controls the tasking and establishes the priority of servicing each of the modules as shown in Figure 2-41. It provides the interface control with the resident operating system supervision, and maintains the time and date information which is used by the various modules. In addition, this module controls the output commands to the vehicle equipment via a command schedule.

(e) EXHELP. This module is a composite of multiply used subroutines as listed in Figure 2-42. It contains interrupt driven output processors for various devices, as well as subroutines for data conversion, and other special purpose routines for validating data and reading blocks of data from the disk.

INITP

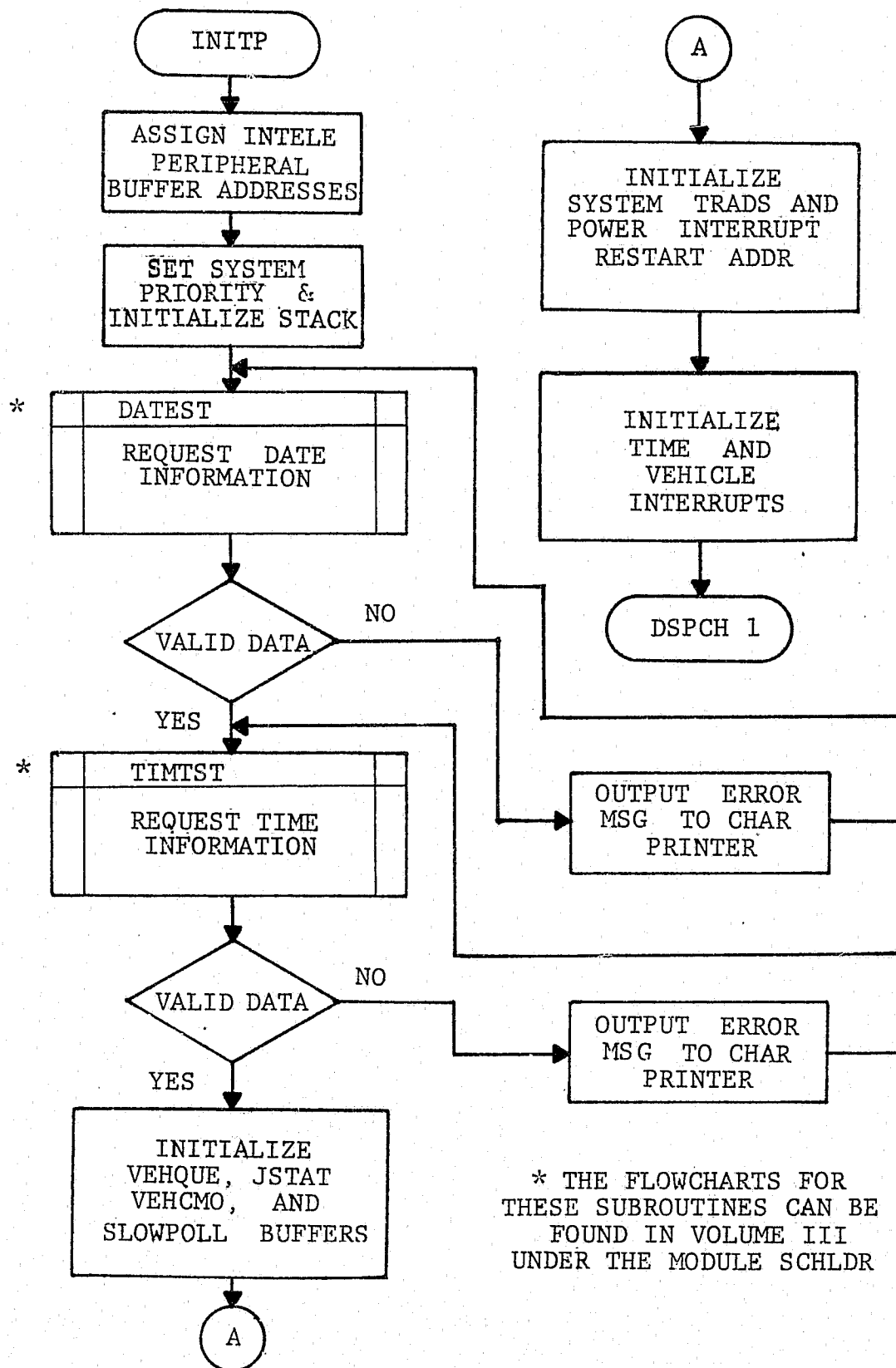
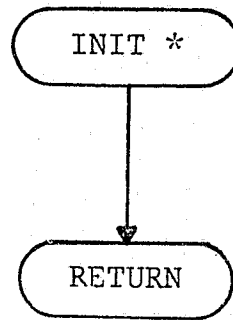


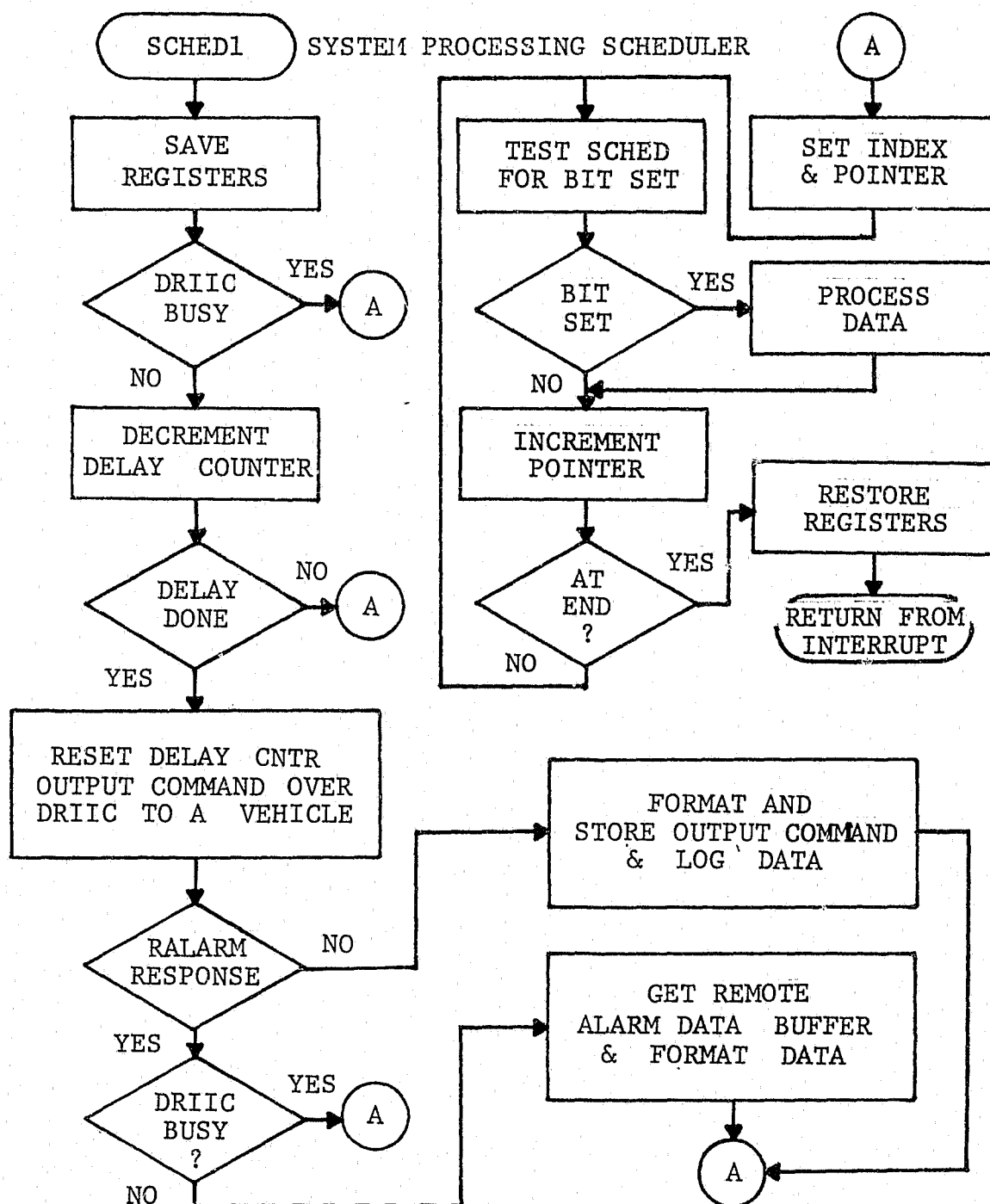
FIG.2-39 PRODUCTION MODULE FOR INITIALIZATION

I N I T



* THIS MODULE DEFINES THE COMMON BLOCK AREAS
FOR FORTRAN DATA PROCESSING.

FIG.2-40 FORTRAN COMMON BLOCK DEFINITION



THIS MODULE ALSO CONTAINS THE FOLLOWING SUBROUTINES

- CTIME2 - CLOCK INTERRUPT PROCESSOR
- DATEST - DATE TEST SUBROUTINE
- TIMTST - TIME TEST SUBROUTINE
- SLOPCM - SLOW POLL COMM COUNTERMEASURES & STATUS DATA PROCESSOR
- NORTNP - NO RETURN PROCESSOR
- POLNXT - POLL NEXT VEHICLE IN SLOW POLL BUFFERS
- CLNUP - CLEANUP & INITIALIZATION ON NORMAL SLOW POLL
- RSLOCM - REMOTE ALARM SLOW POLL COUNTER MEASURES PROCESSORS

THE FLOW CHARTS FOR THESE CAN BE REFERENCED IN VOLUME III.

FIG.2-41 SYSTEM PROCESSING SCHEDULER

E X H E L P

This module is a composite of multiply used subroutines. It contains interrupt driven output processors for various devices, as well as subroutines for data conversion, and other special purpose routines for validating data, and reading blocks of data from the disk. Flow charts for these subroutines can be referenced in volume III. The subroutines are:

- TYENT - Input interrupt processor for ase station Decwriter.
- TYPRC - Output interrupt processor for base station Printer.
- MOVPL - Moves data to base station printer output buffer.
- ALCCMO - Loads data into alert/control command buffer.
- BASECD - Loads data into base station command buffer.
- DSPCMD - Loads data into dispatch station command buffer.
- FNDREC - Finds block # & offset of a street record.
- GETSTR - Read a record of the street file.
- WTVREF - Write a record of VREF
- GRVREF - Read a record of VREF
- FNDVREF - Find block # of VREF for a vehicle.
- MOVBUFF - Move characters from source to destination.
- VALVID - Validate vehicle ID
- FNDBUF - Allocate 256 word block from 'volatl' buffer.
- RLSBUFF - Release 256 word block from 'volatl' buffer.
- MESSP1 - Output error MSG on base station printer
- MOVK2 - Moves input request data base sta. TTY keyboard to buffer
- GTRHF - Read a block of the recent history file.
- VALNO - Validate VEH & return entry in VSTAT
- WTRHF - Write block of recent history file to Disk.
- LOGOV - Log output data.
- BNDEC - Convert binary to decimal ASCII equivalent.
- BN2OCT - Convert binary to ASCII octal.
- BN2DEC - Convert binary to decimal ASCII.
- OCTOBN - Convert octal ASCII to binary.
- ASC2BN - Convert decimal ASCII to binary
- BN2BCD - Convert binary to BCD.

FIG.2-42 MODULE OF MULTI-USED SUBROUTINES

E X H E L P

SAVREC - Save registers.
RSTREG - Restore registers.
DISPRC - Output processor for base station CRT display.
KBDENT - Input processor for base station CRT keyboard.
MOVK1 - Moves input request base station CRT keyboard
to buffer.
MOVCL - Moves data to base station CRT output buffer.

FIG. 2-42 MODULE OF MULTI-USED SUBROUTINES (CONTINUED)

CONTINUED

2 OF 4

(f) DSPCR1. This module is the I/O processor for dispatch station #1. It is an interrupt driven processor for devices K5 and C5 as depicted in Figure 2-43. It sets up #1 dispatch station request to process input data whenever a "." or a "?" is received. It is also the output processor for C5. It moves data to the output buffer for the #1 dispatch station, and it initiates the output driver if the output buffer was empty prior to the call.

(g) DSPCR2. This module is the I/O processor for dispatch station #2. (See Figure 2-44). It is an interrupt driven processor for devices K3 and C3. It sets up #2 dispatch station request to process input data whenever a "." or a "?" is received. It is also the output processor for C3. It moves data to the output buffer for the #2 dispatch station, and it initiates the output driver if the output buffer was empty prior to the call.

(h) VEHXPT. This module is the vehicle interrupt processor. It establishes the communication between the CSS base station and the individual vehicle I/O units as illustrated by Figure 2-45. This routine processes inputs from the vehicles on interrupt. The vehicles are checked against a vehicle queue to determine if the vehicle is enabled and operating. The vehicle inputs are tested for validity, and if valid, the vehicle mode is then determined. There are sections of logic for each vehicle input mode. Upon determining the vehicle mode, the appropriate logic is selected and the respective flags and output commands are set and initiated. The vehicle input data is stored in appropriate buffers for later processing by other routines.

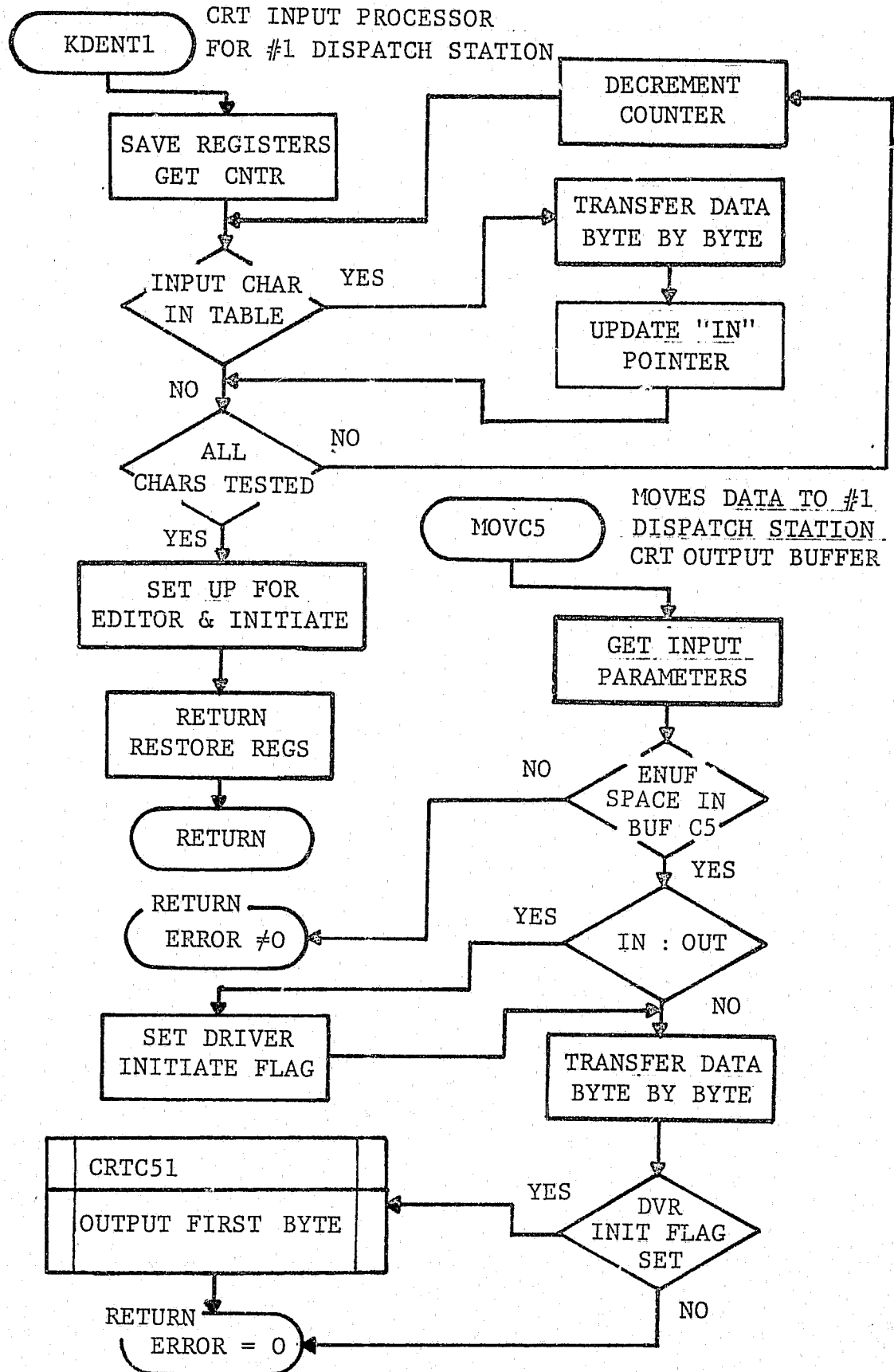


FIG. 2-43 DISPATCH STATION #1 CRT INPUT PROCESSOR

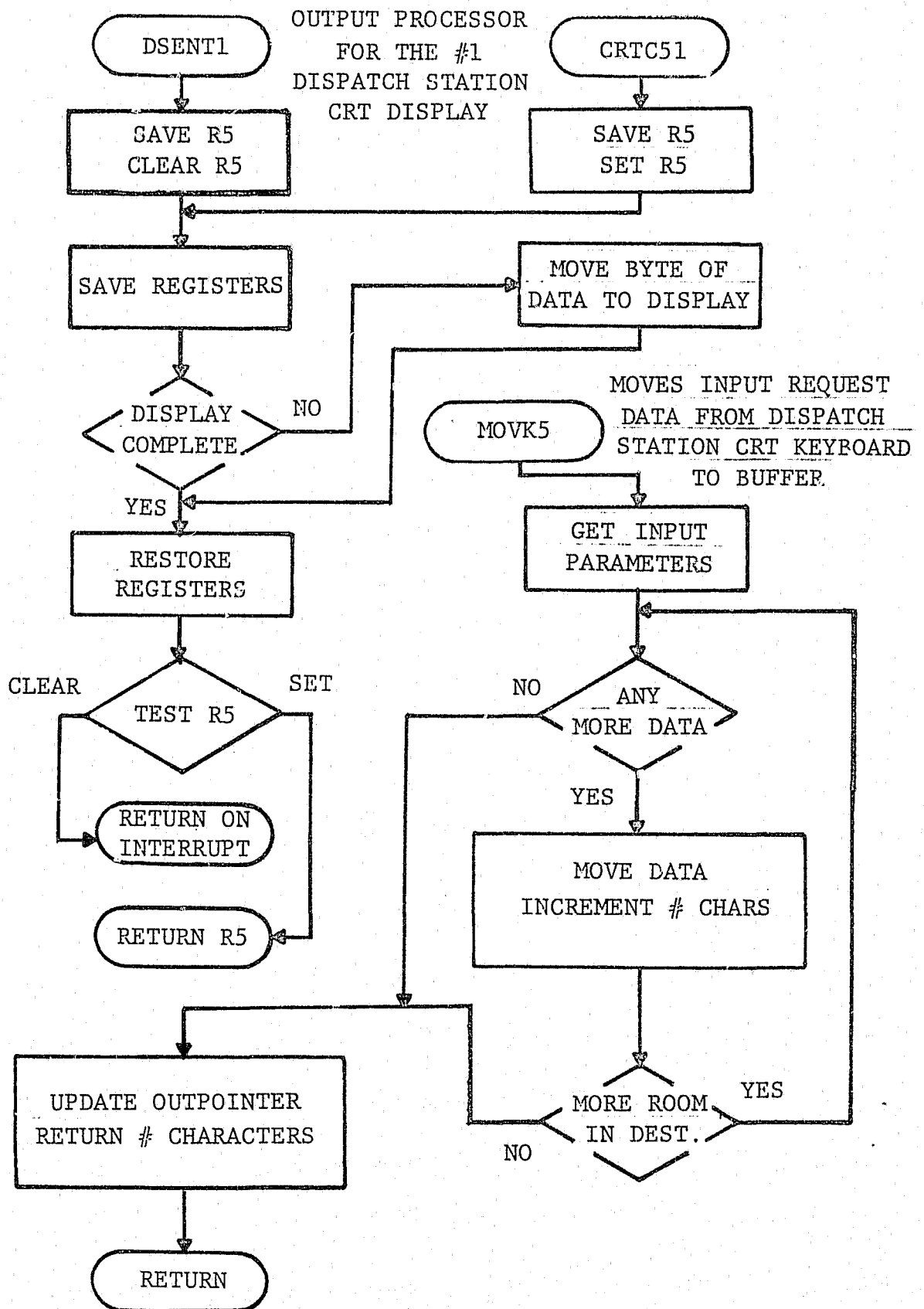


FIG. 2-43 DISPATCH STATION #1 CRT INPUT PROCESSOR (CONTINUED)

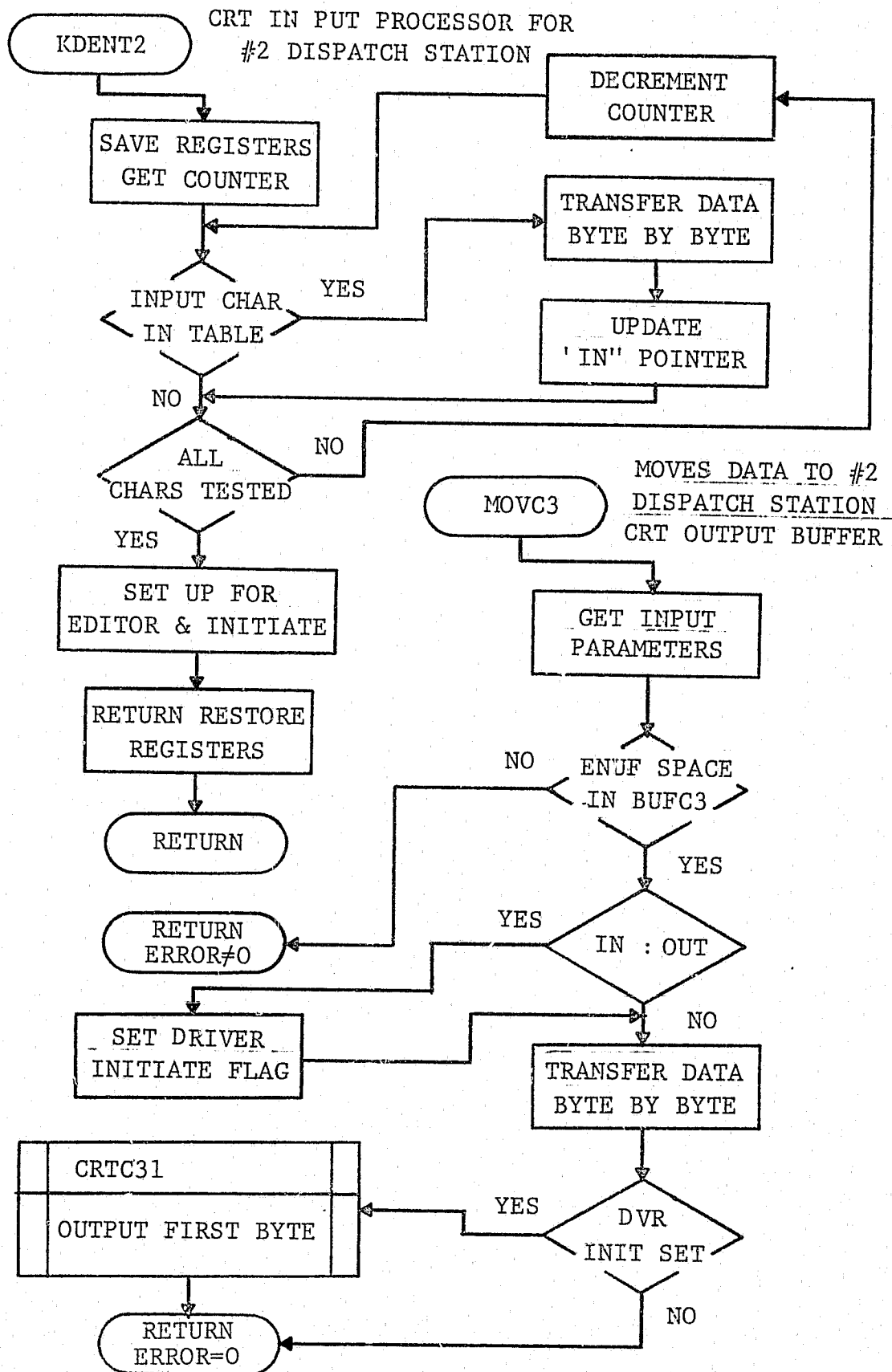


FIG. 2-44 DISPATCH STATION #2 CRT INPUT PROCESSOR.

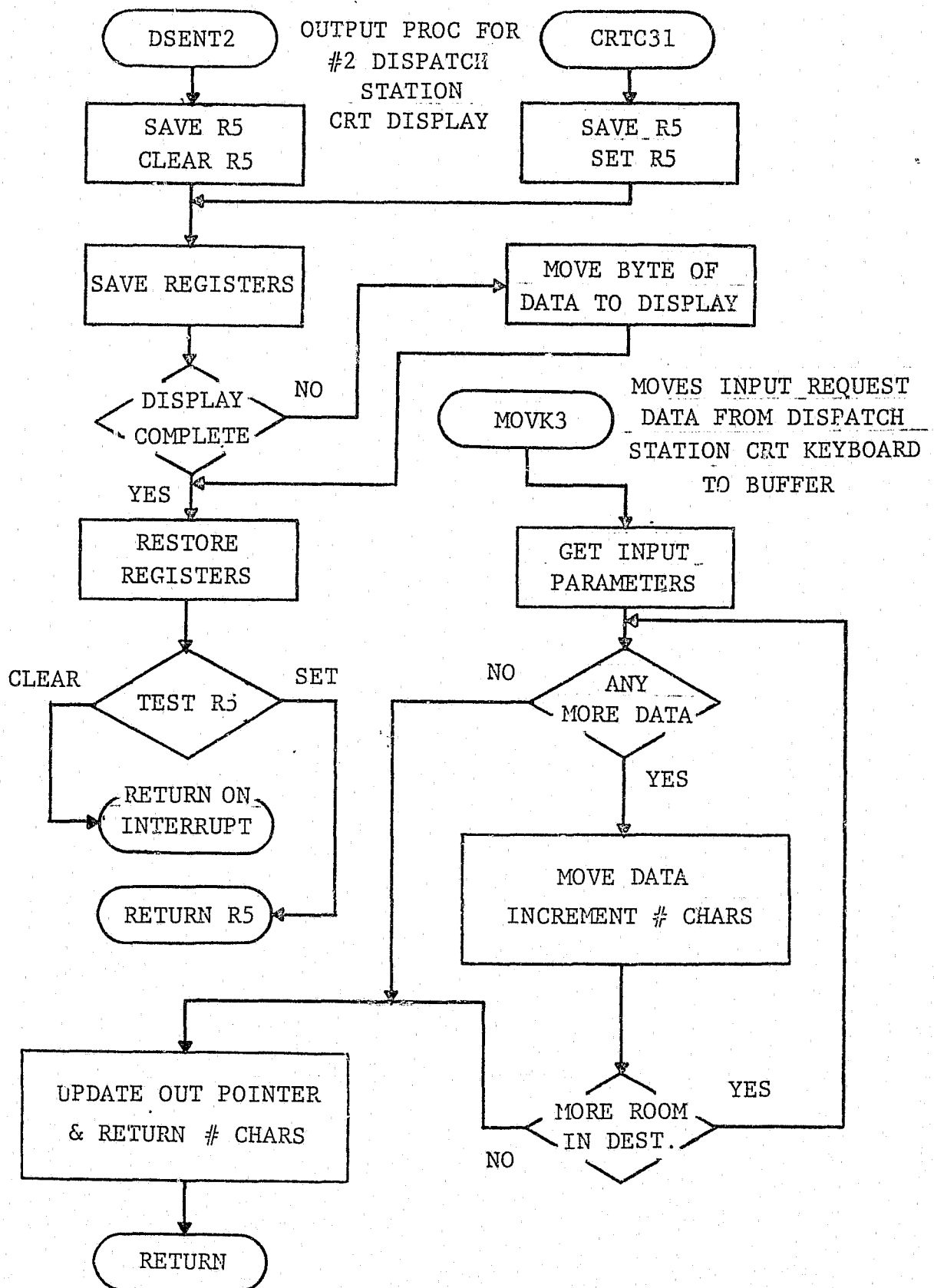


FIG. 2-44 DISPATCH STATION #2 CRT INPUT PROCESSOR (CONTINUED)

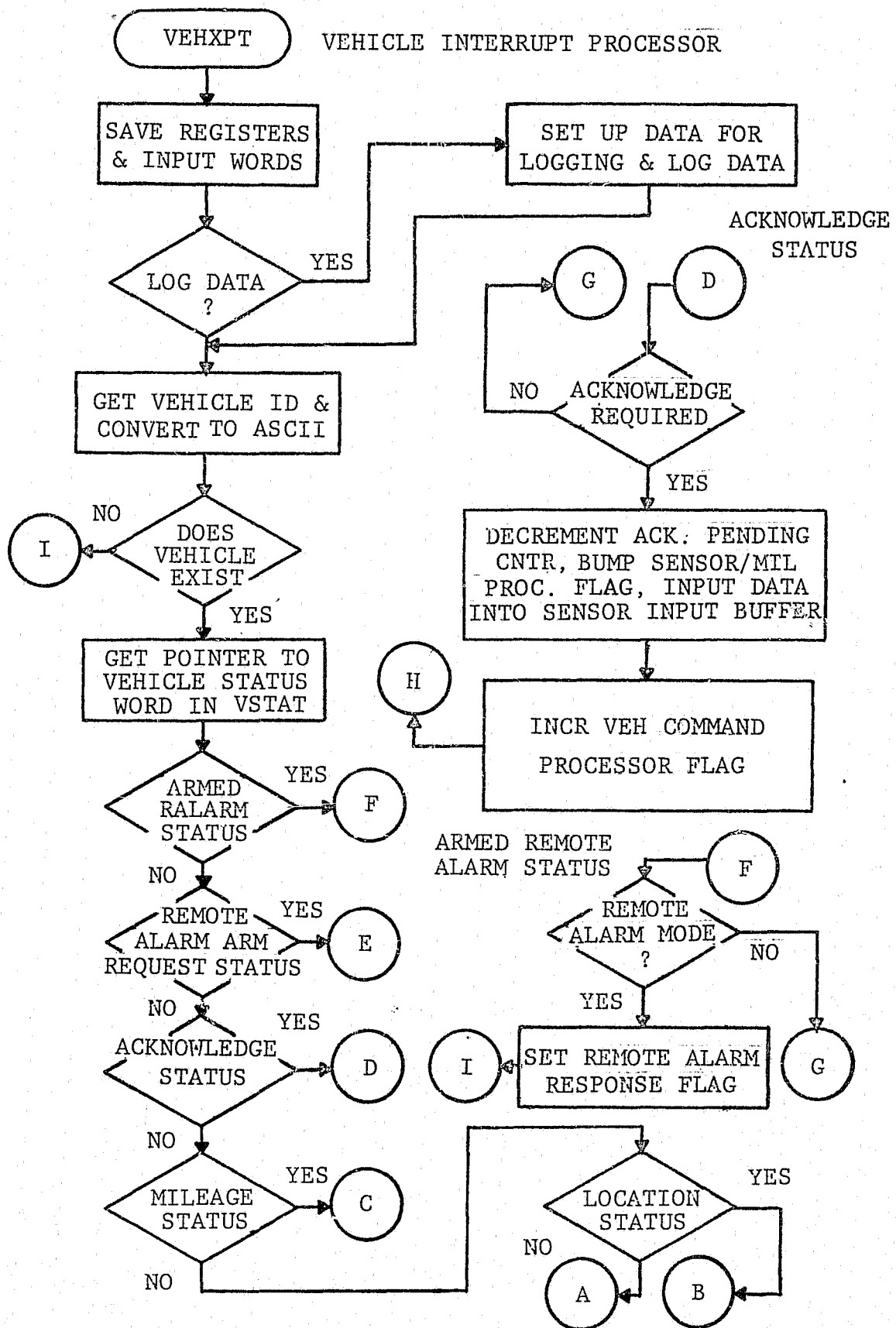


FIG. 2-45 VEHICLE INTERRUPT PROCESSOR

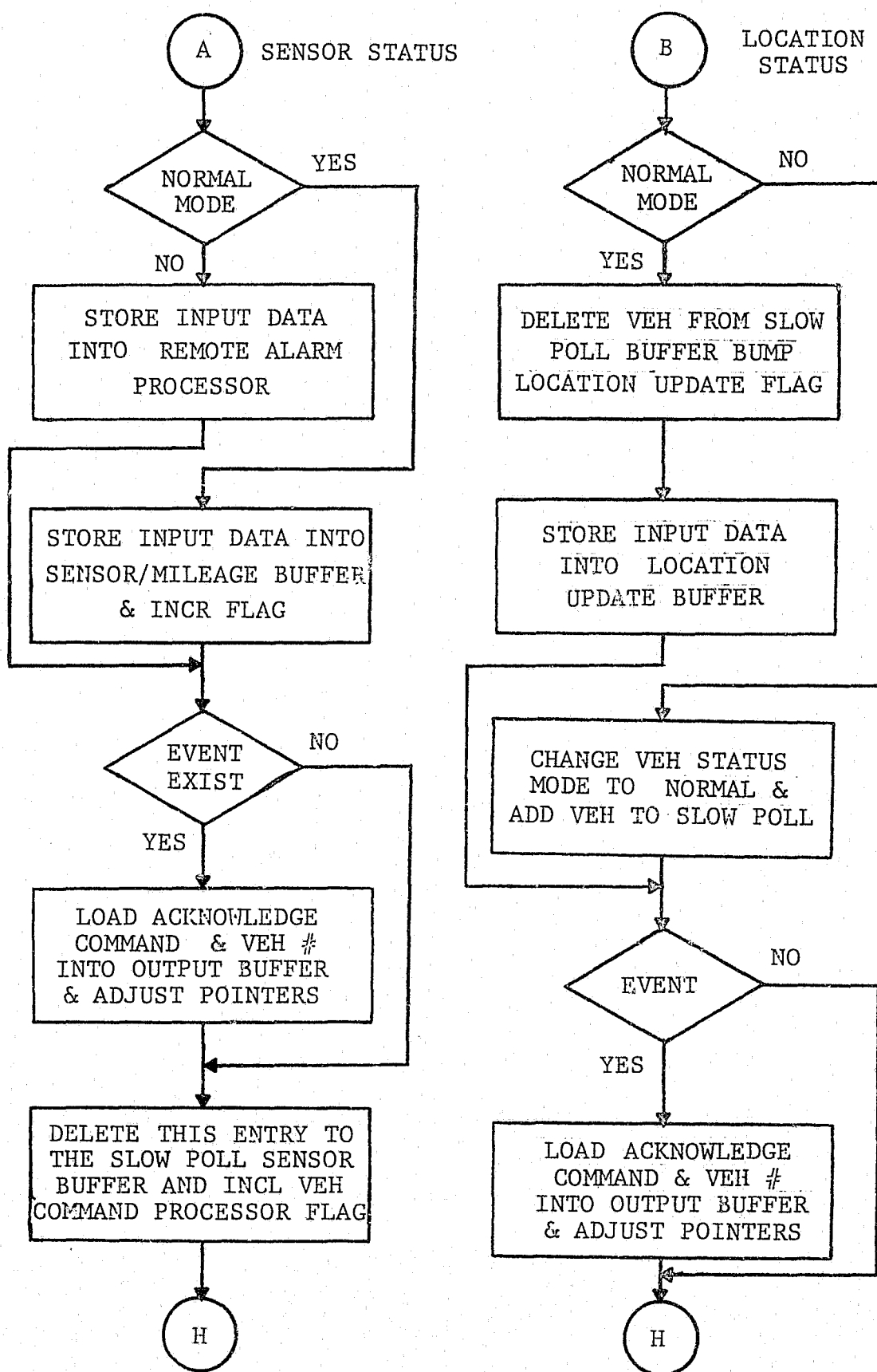


FIG. 2-45 VEHICLE INTERRUPT PROCESSOR (CONTINUED)

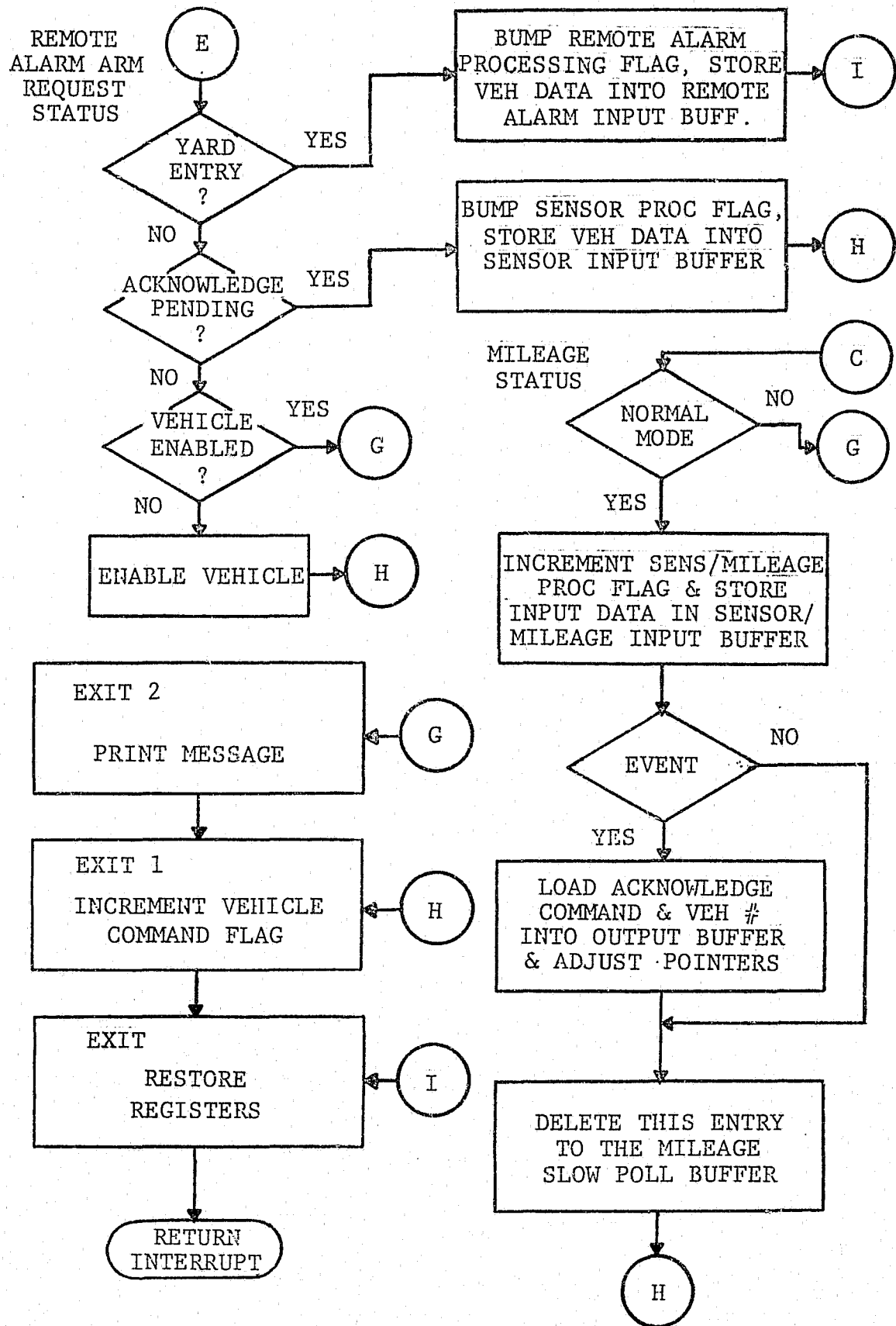


FIG. 2-45 VEHICLE INTERRUPT PROCESSOR (CONTINUED)

(i) DSPCHR. This module is the system dispatcher and supervisor. It processes the flag information to call various routines if the processing flag is non-zero and it prioritizes the processing such that vehicle information is always processed first, then alert processing, then base station processing, then dispatcher and finally data logging (See Figure 2-46). In addition, the dispatcher analyzes each command buffer to insure that the data is not lost or overwritten and uses another level of priority to insure the buffer data is not lost. This routine is part of the executive processing group. The routine is initiated by a jump statement from the initialization routine. The module also contains some subroutines, such as the sensor alert control processor, the base station control processor, and other various subroutines.

(j) DSUBS2. This module is a composite of subroutines and subprocesses which support the overlay modules. It also contains tables of valid routes, passwords and devices (refer to Figure 2-47 and Volume IIIIO).

(k) PRHIST. This module will print the location and status history of a truck. The print can be requested for the current day, the prior day, or two days prior to the current day. The vehicle information is obtained from one of three rotating files for each vehicle (refer to Figure 2-48 for Logic Flow).

(l) PRNORM. This module will print the alarms and alerts for vehicles that enter either status (See Figure 2-49). It will show the vehicle number, the alert or alarm, the location data, the time, and the alert or alarm descriptions.

D S P C H R

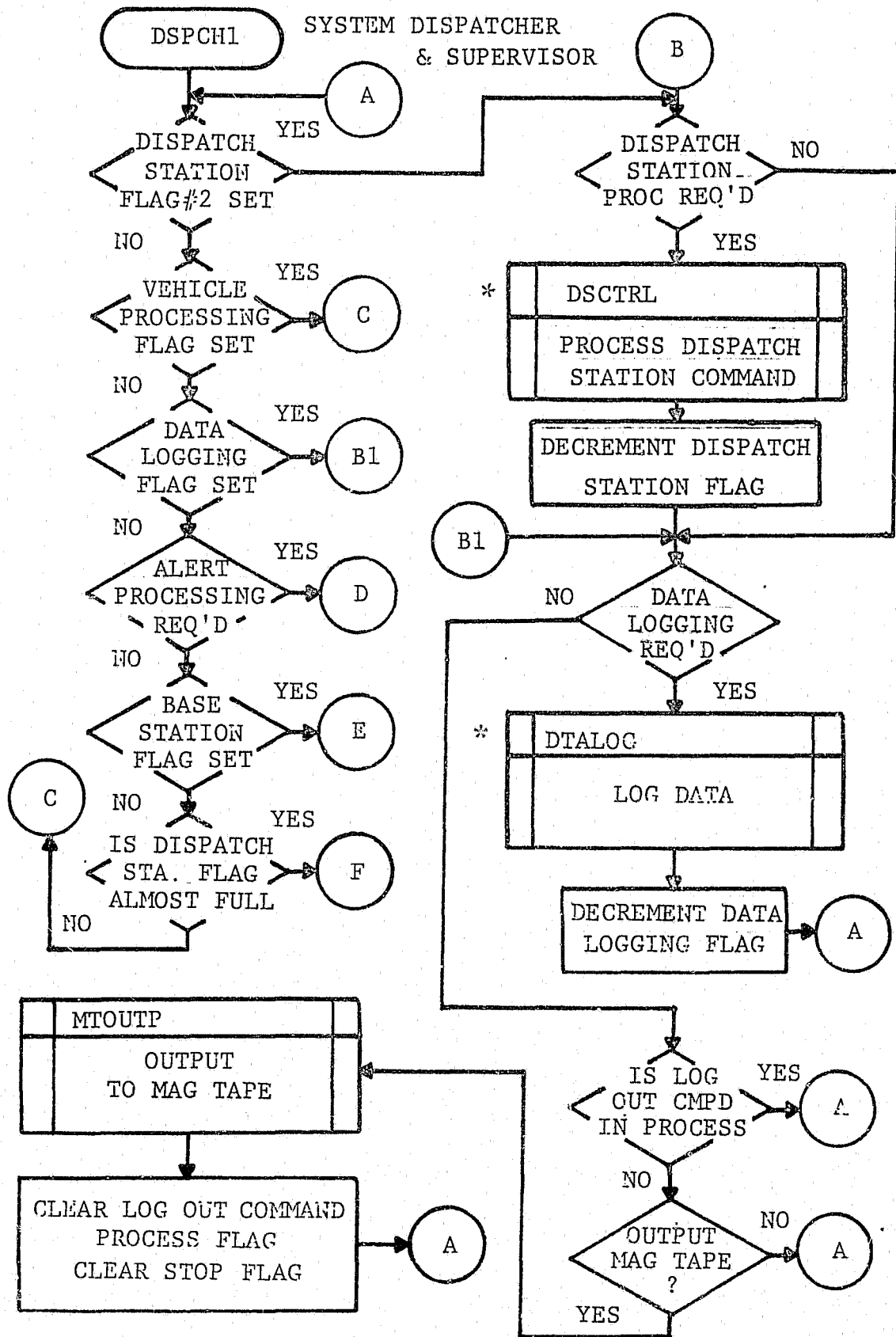


FIG. 2-46 SYSTEM DISPATCHER AND SUPERVISOR

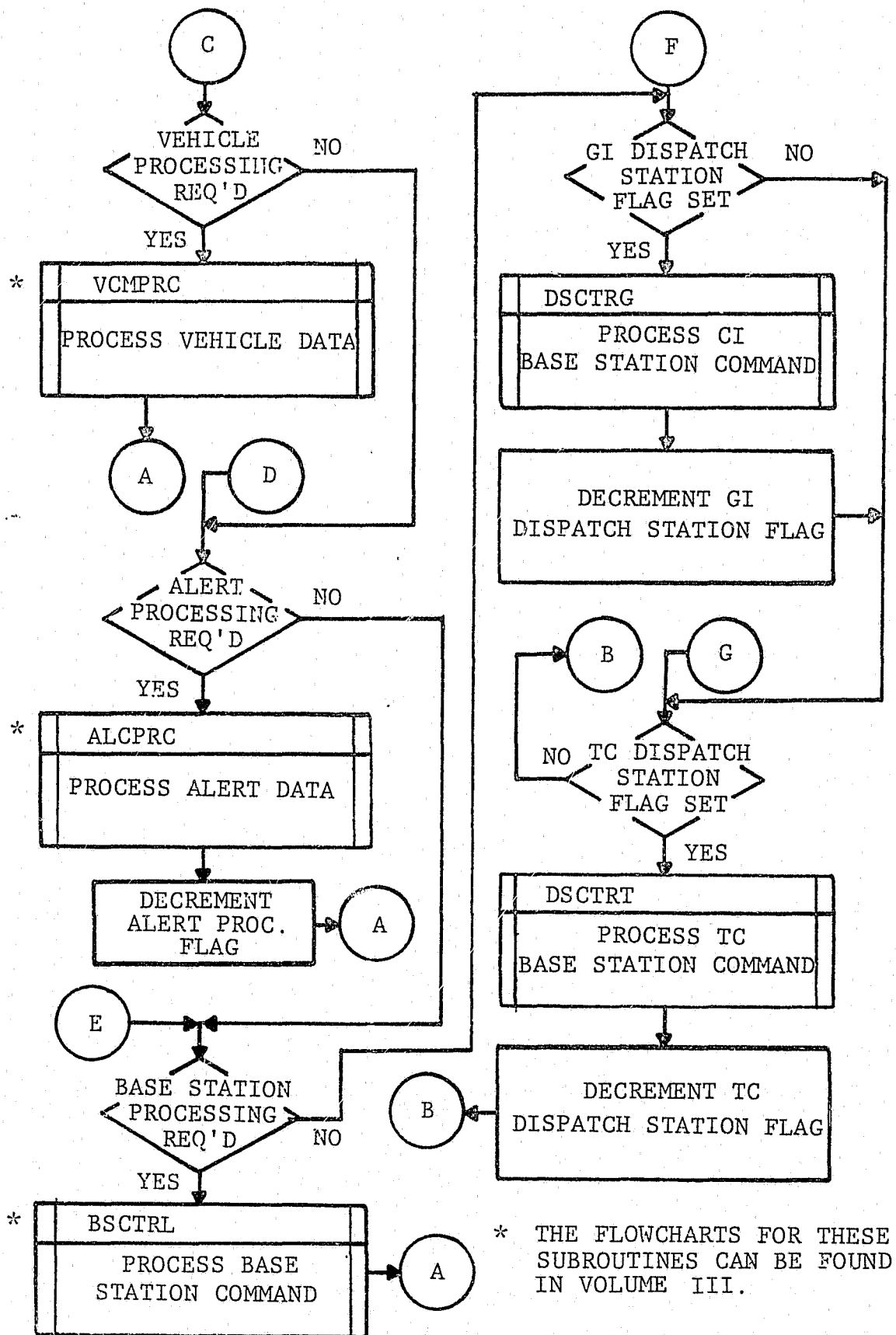


FIG. 2-46 SYSTEM DISPATCHER AND SUPERVISOR (CONTINUED)

D S U B S 2

This module is a composite of subroutines and sub-processes which support the overlay modules. It also contains tables of valid routes, passwords and devices. Flow charts for the individual subroutines can be referenced in volume III.

FIG. 2-47 SUBROUTINE MODULE

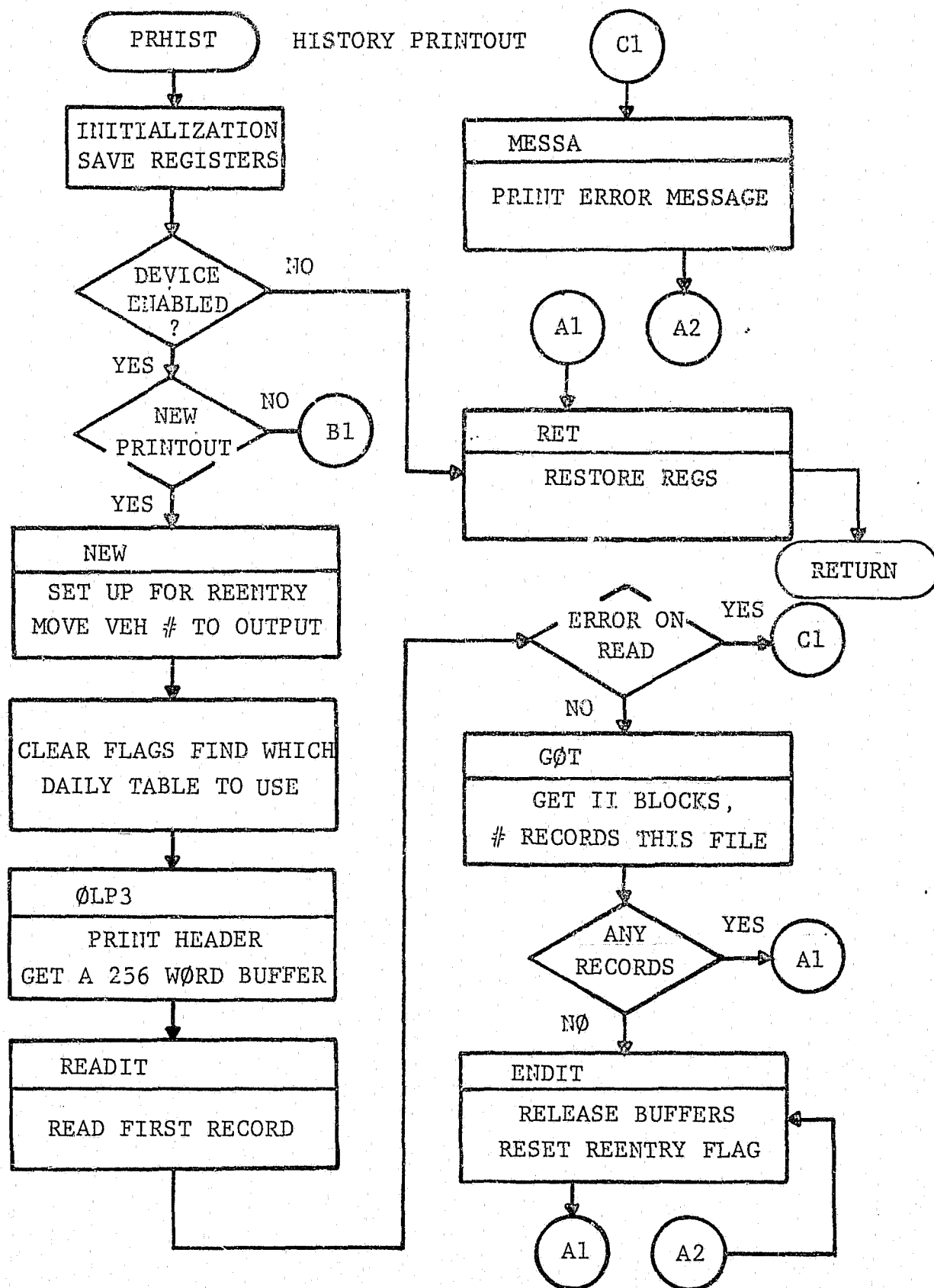


FIG. 2-48 HISTORY PRINTOUT MODULE

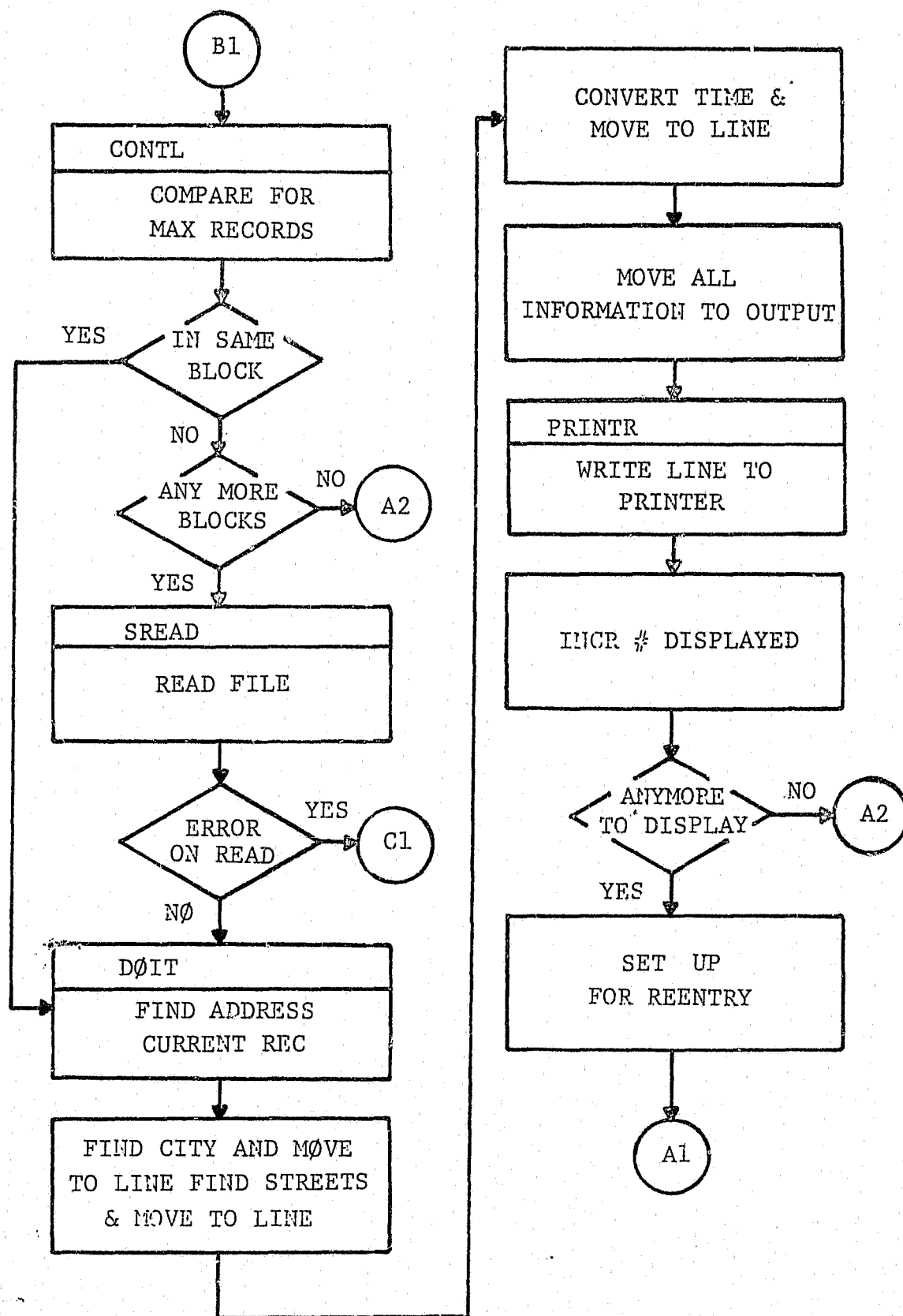


FIG. 2-48 HISTORY PRINTOUT MODULE (CONTINUED)

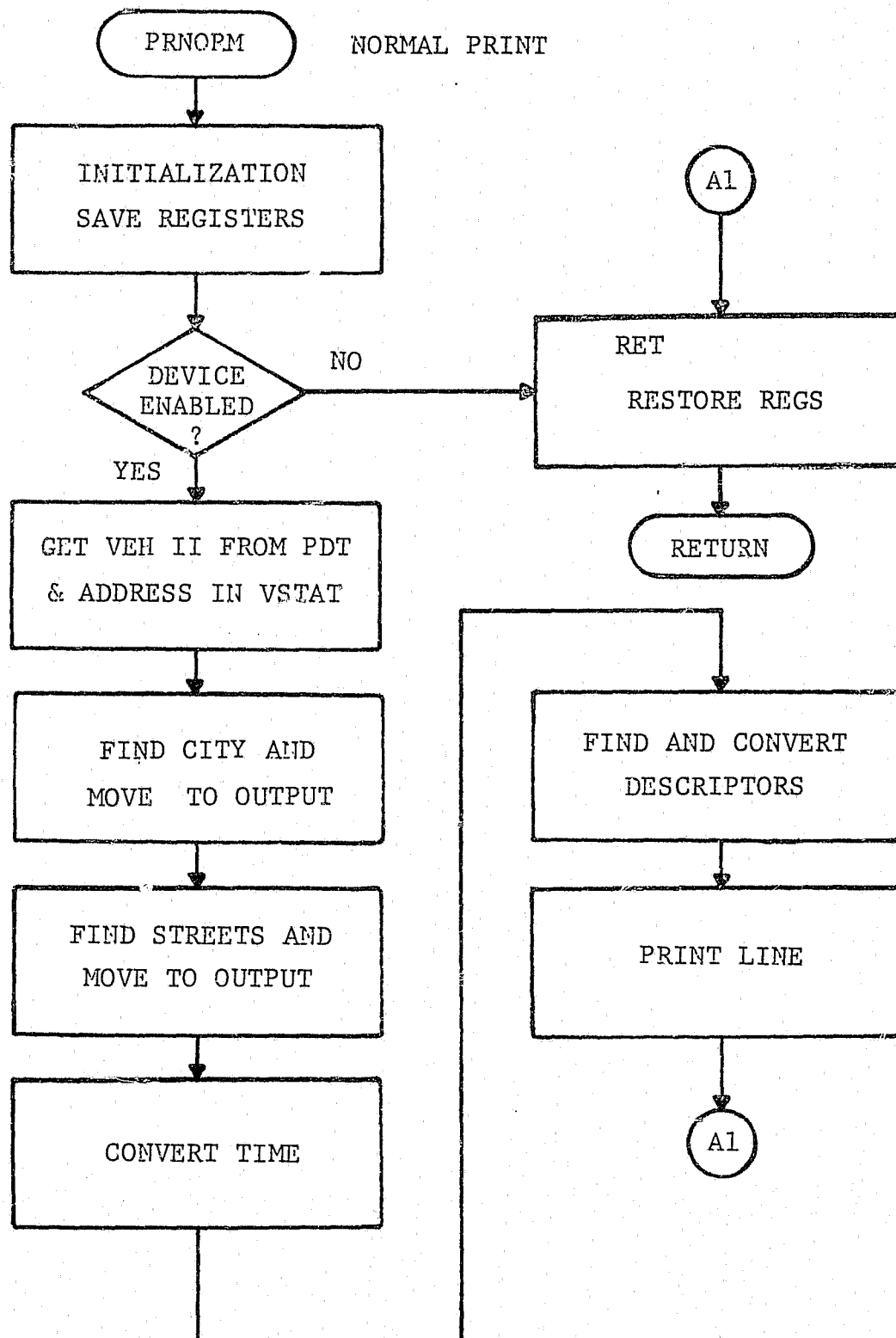


FIG. 2-49 NORMAL PRINT MODULE

(m) LOCUPD. This routine processes location status information to provide location update data for base station and dispatch station display as well as route alert printout (shown in Figure 2-50). Location data is input as a result of a vehicle declared event or a location polling request from the host computer.

(n) DSPCP. This module is a combination of subroutines. It contains the base station CRT keyboard edit subroutines, and the dispatch module hexadecimal formatter. For further information refer to Figure 2-51.

(o) LOGIT. This is the data logging control module (See Figure 2-52 for the logic flow of the various routines). It contains the routines for data logging to disk and mag tape. It accepts input data storage requests from vehicle comm, dispatch, and base station modules to store vehicle recent history data in disk files. There are three rotating files for each vehicle. It also contains the routine to save data for data logging, and the mag tape output processor.

(p) LANEXY. This is an overlay module which initializes location data, requests location input data, computes the best estimate of location x, y, and outputs the data in an array (refer to Figure 2-53 for basic flow). The limits on the approximation are defined from the integer restrictions on the input data.

(q) PFILE. This is an overlay module which determines street information from x,y data as shown in Figure 2-54. Functions included in the routine are tests for intersections in mapped area and vehicle velocity over 65 mph. Street number file pointers and city file pointers are output along with flags.

LOCUPD

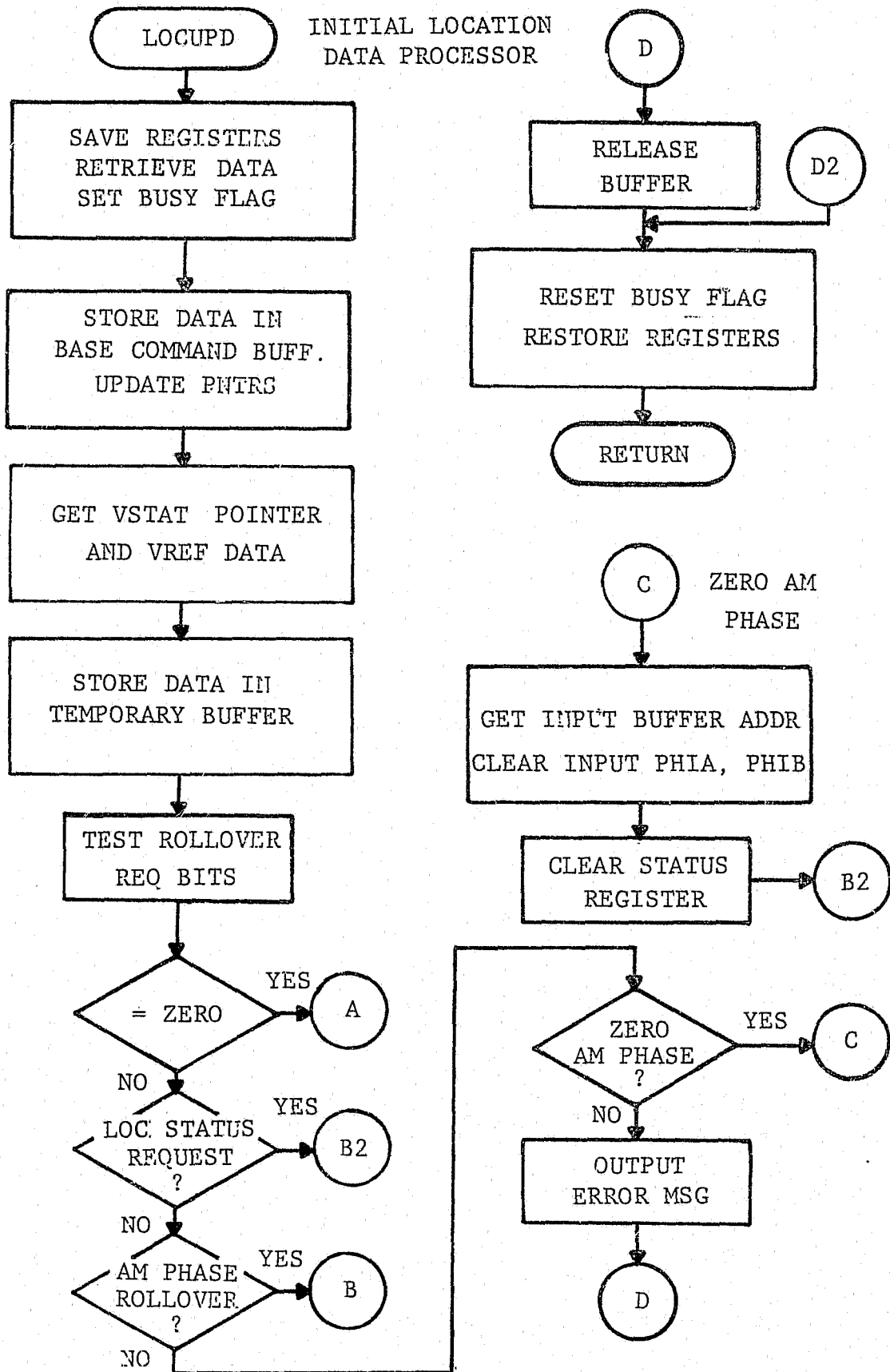


FIG. 2-50 LOCATION DATA PROCESSOR

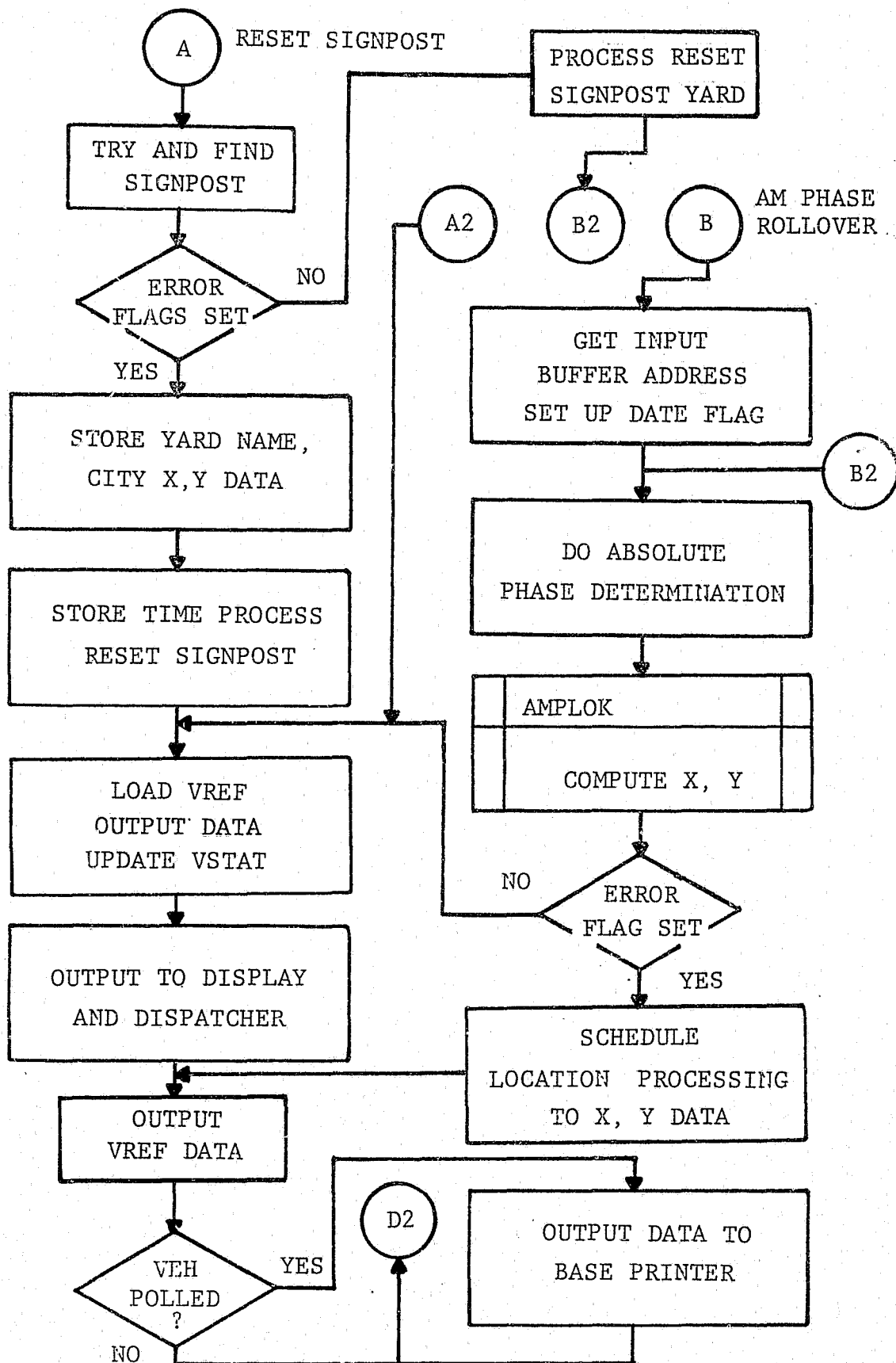


FIG. 2-50 LOCATION DATA PROCESSOR (CONTINUED)

D S P C P

This module is a combination of subroutines. It contains the base station crt keyboard edit subroutines, and the dispatch module hexadecimal formatter. Flowcharts for these subroutines can be referenced in volume III. The subroutines are;

DSUBS1 - Base station crt keyboard edit subroutines
DSFMTR - Dispatch module hexadecimal formatter.

FIG. 2-51 DISPATCH STATION SUPPORT SUBROUTINE MODULE

LOGIT

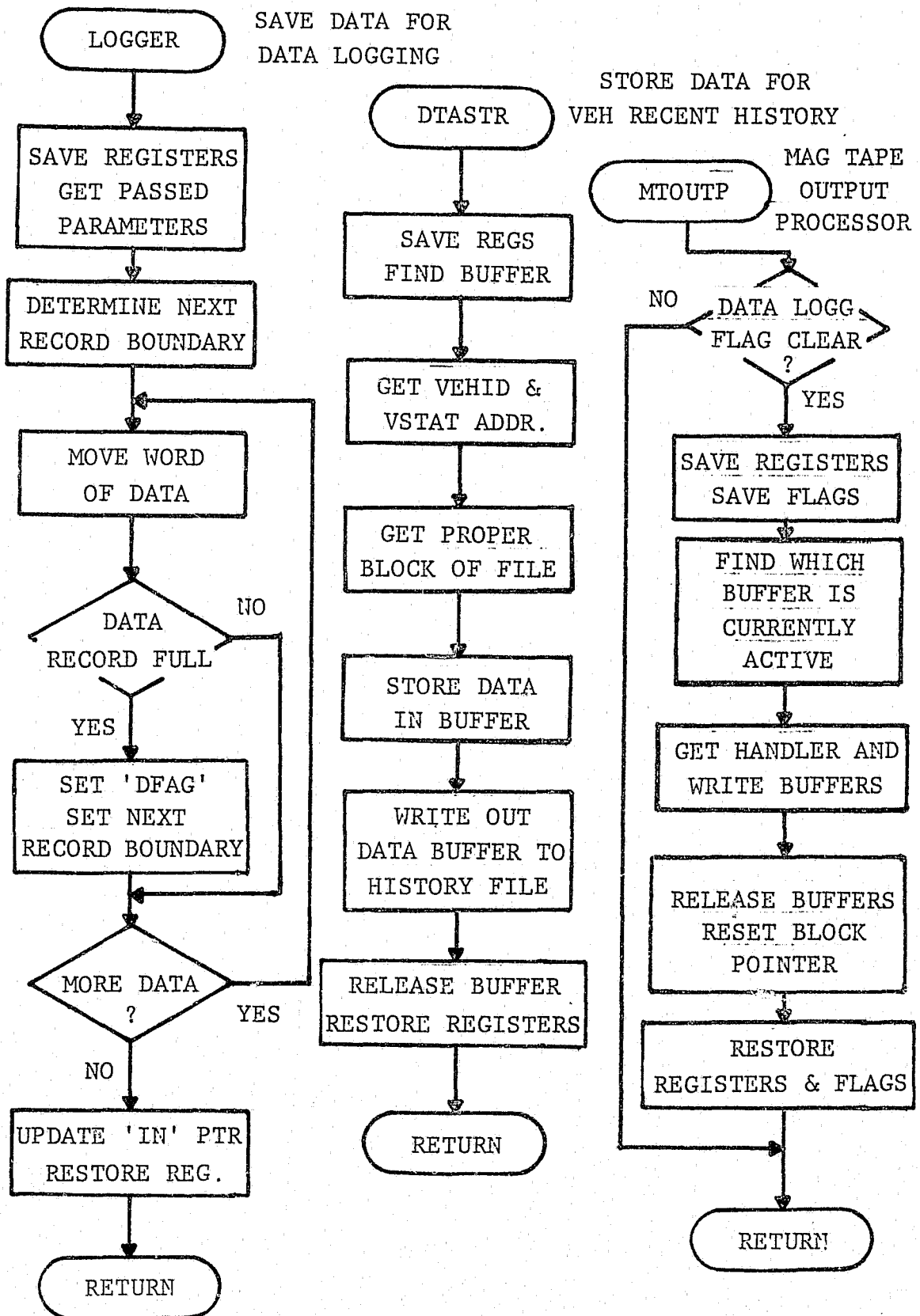


FIG. 2-52 DATA LOGGING CONTROL MODULE

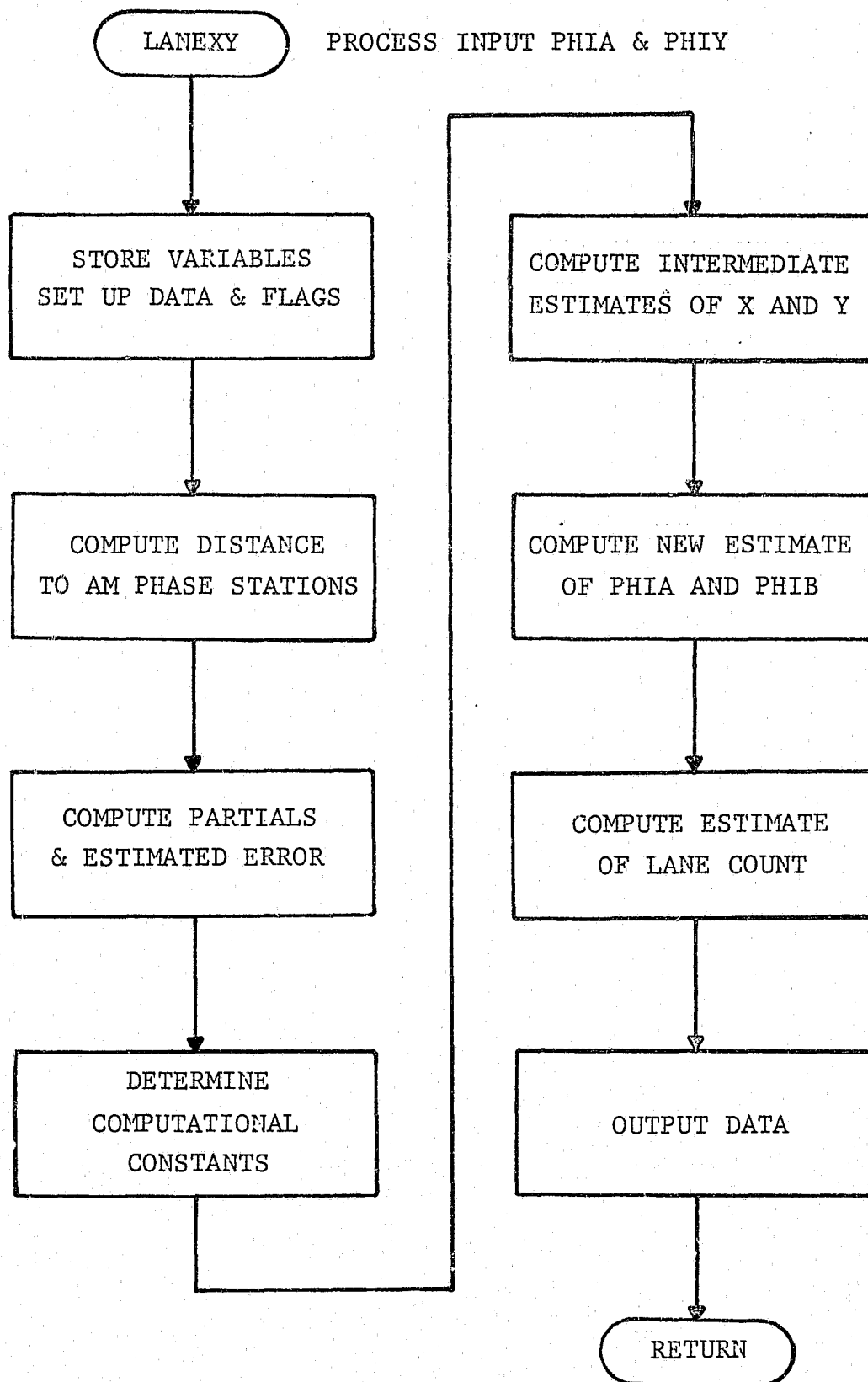


FIG. 2-53 PHIA & PHIY INPUT PROCESSOR

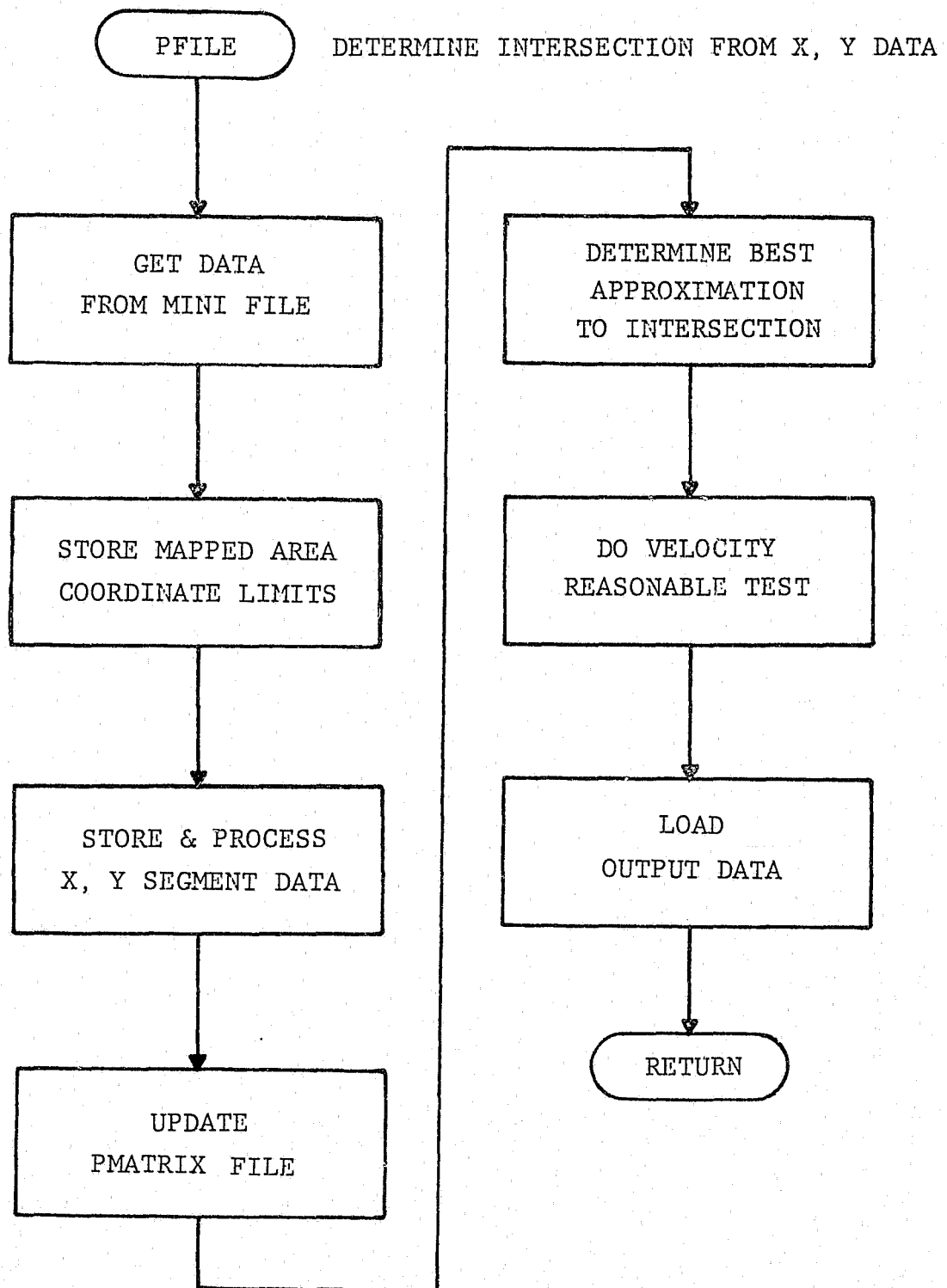


FIG. 2-54 DETERMINE INTERSECTION FROM X,Y

(r) ALERTP. This is the alert command/control overlay module. It contains the following submodules as depicted in Figure 2-55.

- o The normal sensor data processing which process the unusual sensor poll responses and sensor events to declare and clear sensor related alerts. This routine formats and outputs commands to the base station, dispatch station and recent history data buffer areas.

- o The delivery flag processor which tests for vehicle motion and cargo door status to determine if vehicle is at a delivery stop and set or clear flag as appropriate.

- o The driver alarm activated processor which tests if alarm previously activated, if not set, declares an alarm and outputs all commands, if clear but change in state, update commands, if not set previously and still not set, exit.

- o The ramload acknowledge which updates pointers and loads next command out, if done, sends complete message to base station.

- o The scrambled ramload detected which resets processing flags and outputs previous command to vehicle unit. It also handles incomplete flag logic.

- o The vehicle unit ramloader which loads the ram data from VREF files upon command from the base station.

(s) TYCPR. This is the control console output data processor overlay module (see Flow Chart in Figure 2-56). It prints the commands from the base station on the control console.

A L E R T P

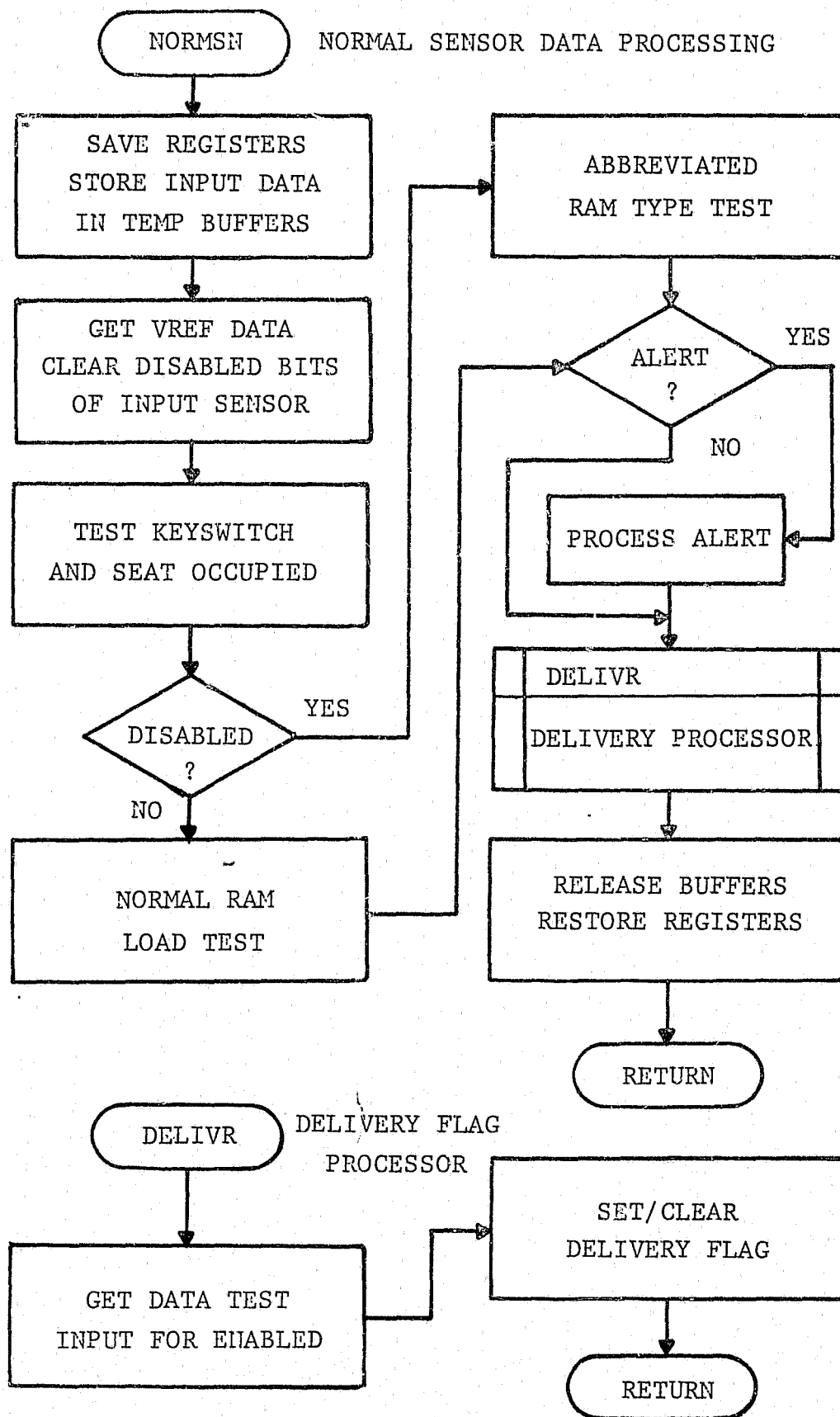


FIG. 2-55 ALERT COMMAND/CONTROL PROCESSOR

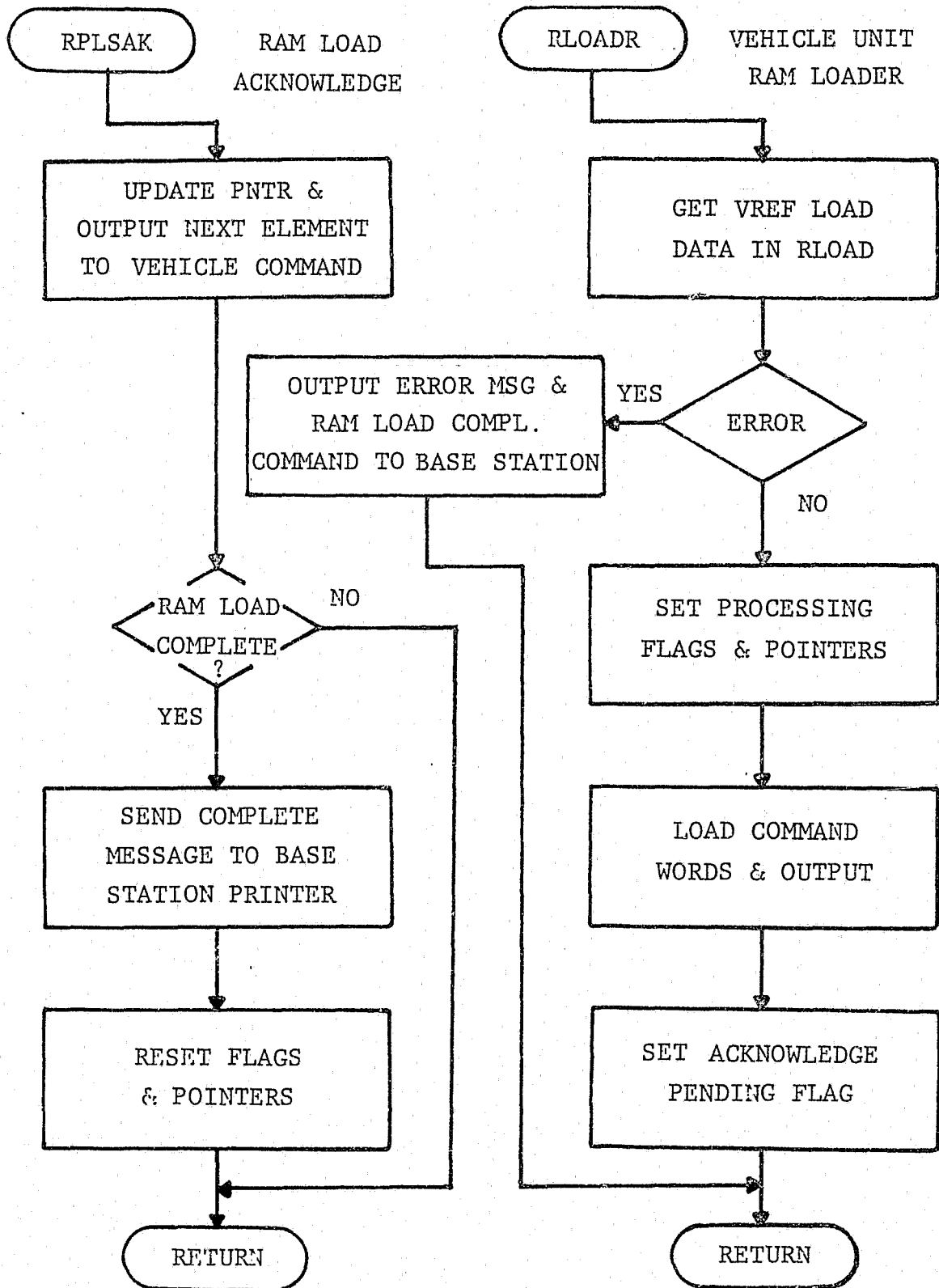


FIG. 2-55 ALERT COMMAND/CONTROL PROCESSOR (CONTINUED)

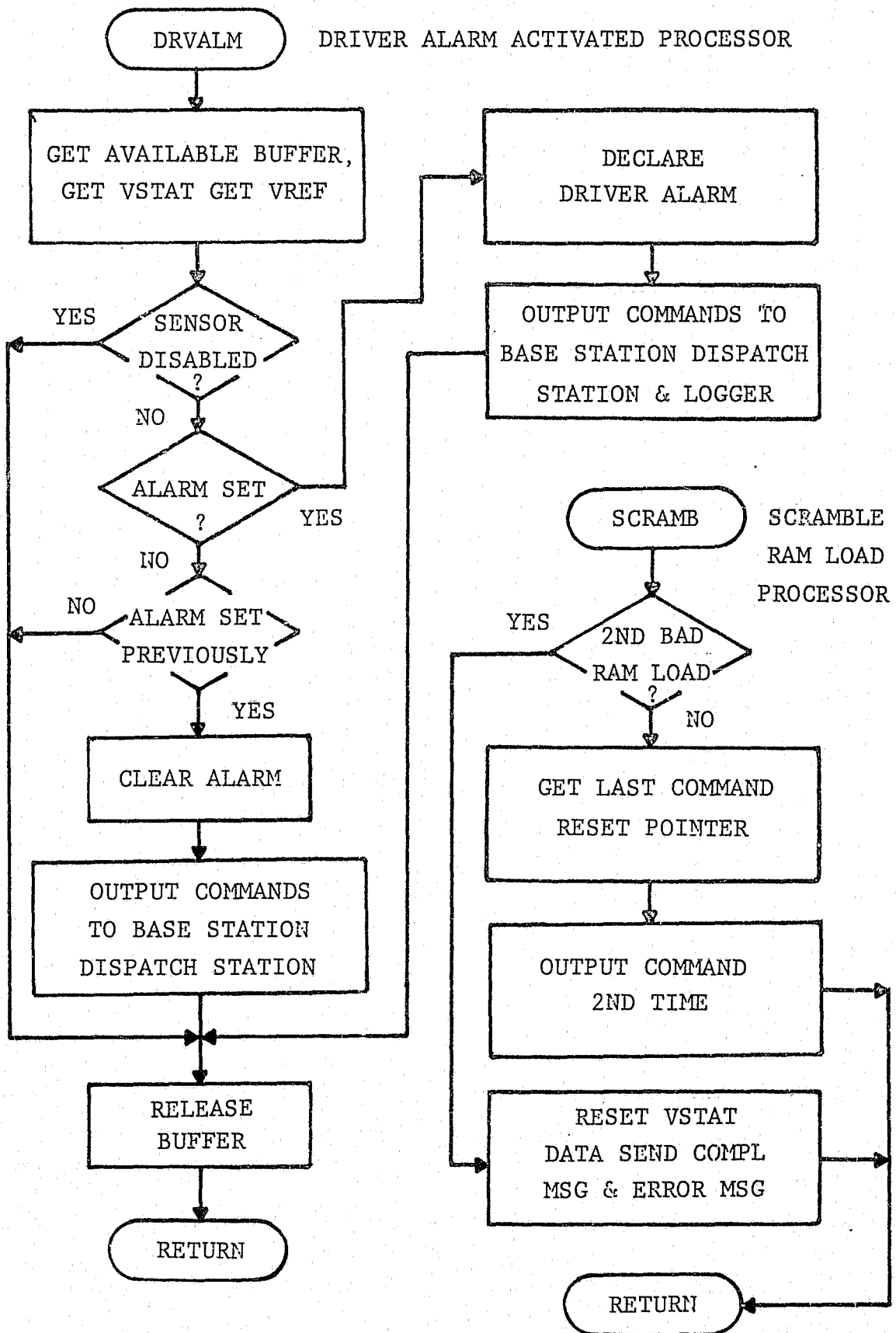


FIG. 2-55 ALERT COMMAND/CONTROL PROCESSOR (CONTINUED)

T Y C P R

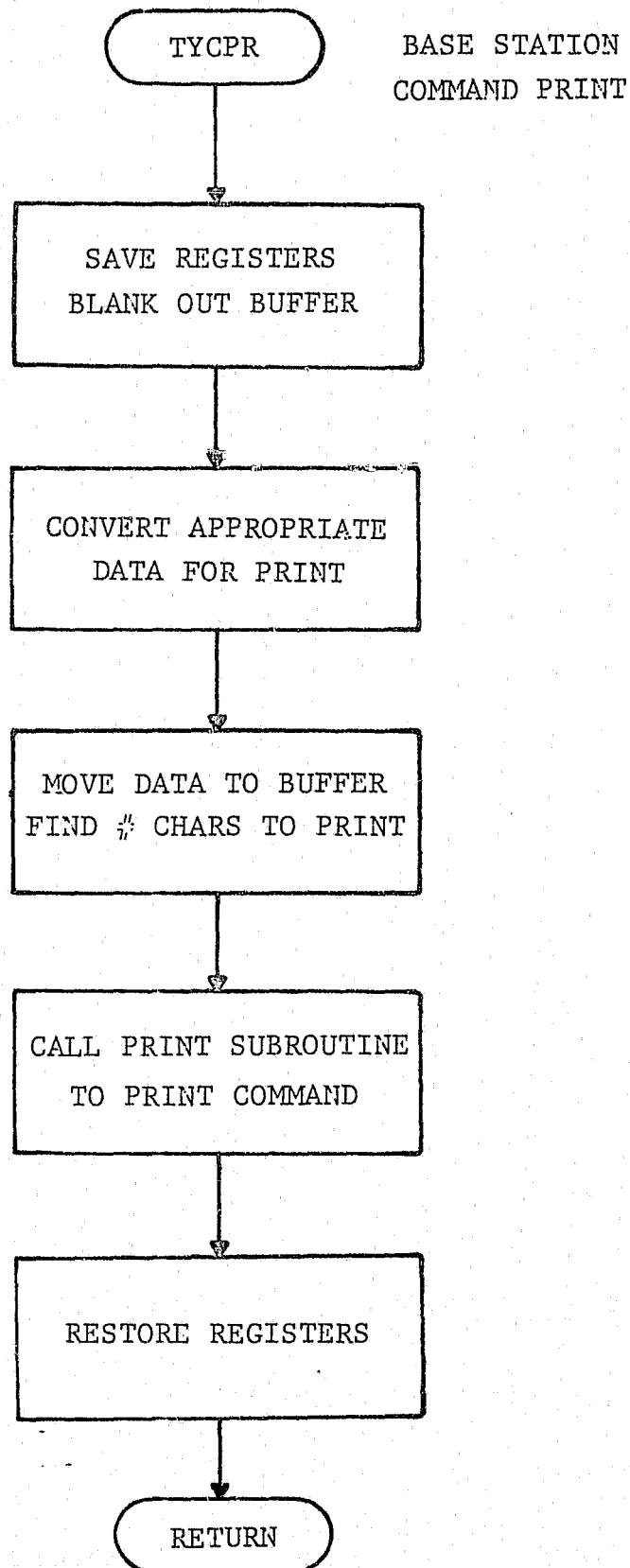


FIG. 2-56 BASE STATION COMMAND PRINT

(t) SMUPDP. This is the overlay module for the sensor, mileage, and remote alarm request processor (refer to Figure 2-57 for basic flow). It contains the following sub-modules.

- o The sensor/mileage update processor which pre-processes sensor and mileage information and provides update data to the alert/control processor, the base station processor, and the dispatch station processor. This routine schedules tasks for either polled responses or events.

- o The sensor polled response processor which pre-processes input data from vehicles in the normal mode.

- o The sensor event processor which tests for valid event on input and routes the processing to the alert/control processor if valid, or outputs an error message if invalid.

- o The sensor countermeasures processor which processes tamper and countermeasures events.

- o The mileage update processor which processes odometer input data to indicate number of feet traveled by specific vehicles.

- o The sensor acknowledge processor provides appropriate commands to either the base station processor or the alert control processor to enable update of vehicle status data.

- o The RAM load acknowledge which provides commands to the alert/control processor for valid RAM load input received from vehicle unit.

(u) RAMLOAD. This is the overlay module for the RAM load processor for the dispatch stations (See Figure 2-58). It loads the output buffer with data for transfer to dispatch stations. This processor services both dispatch stations.

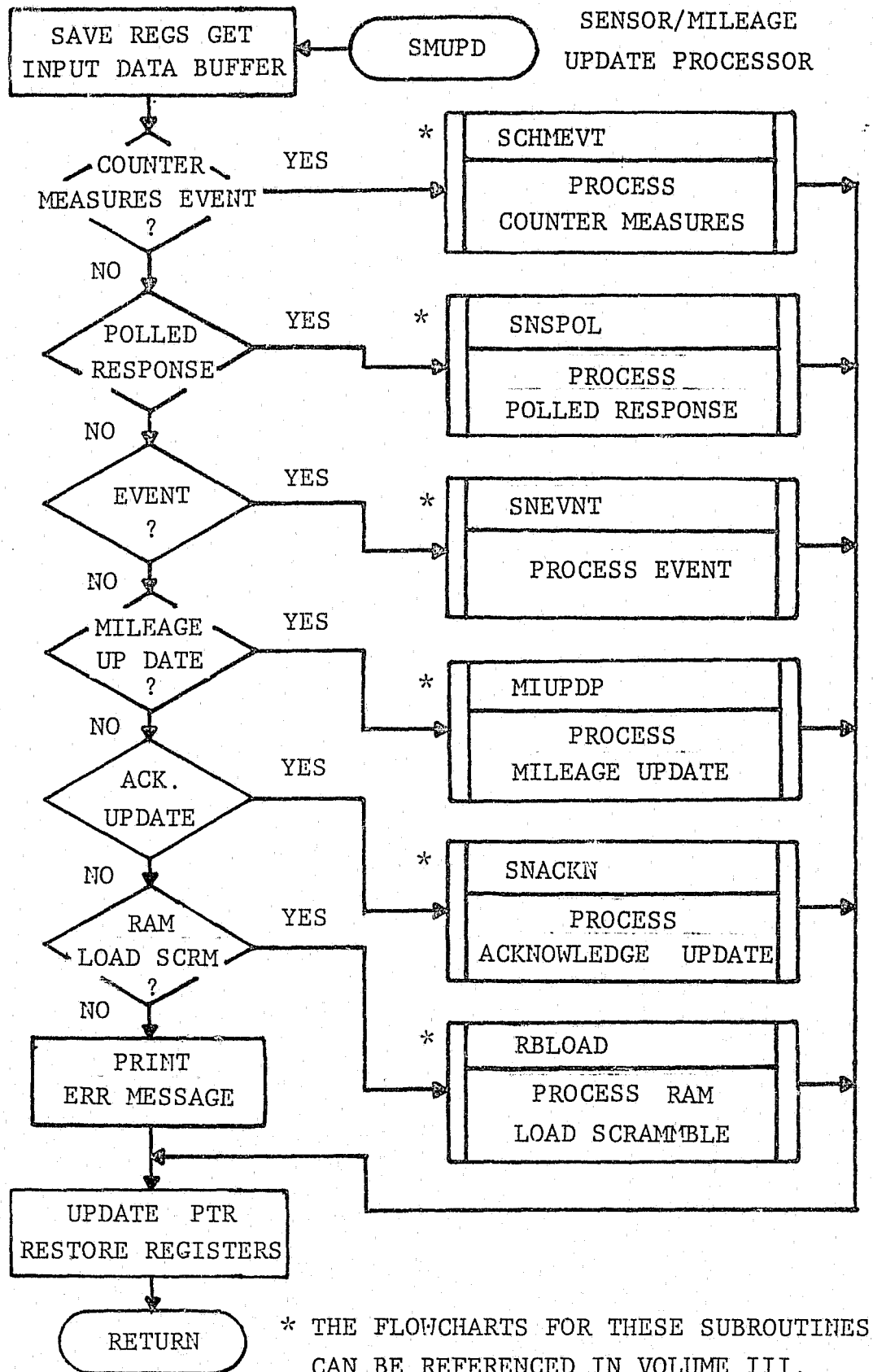


FIG. 2-57 SENSOR/MILEAGE UPDATE PROCESSOR

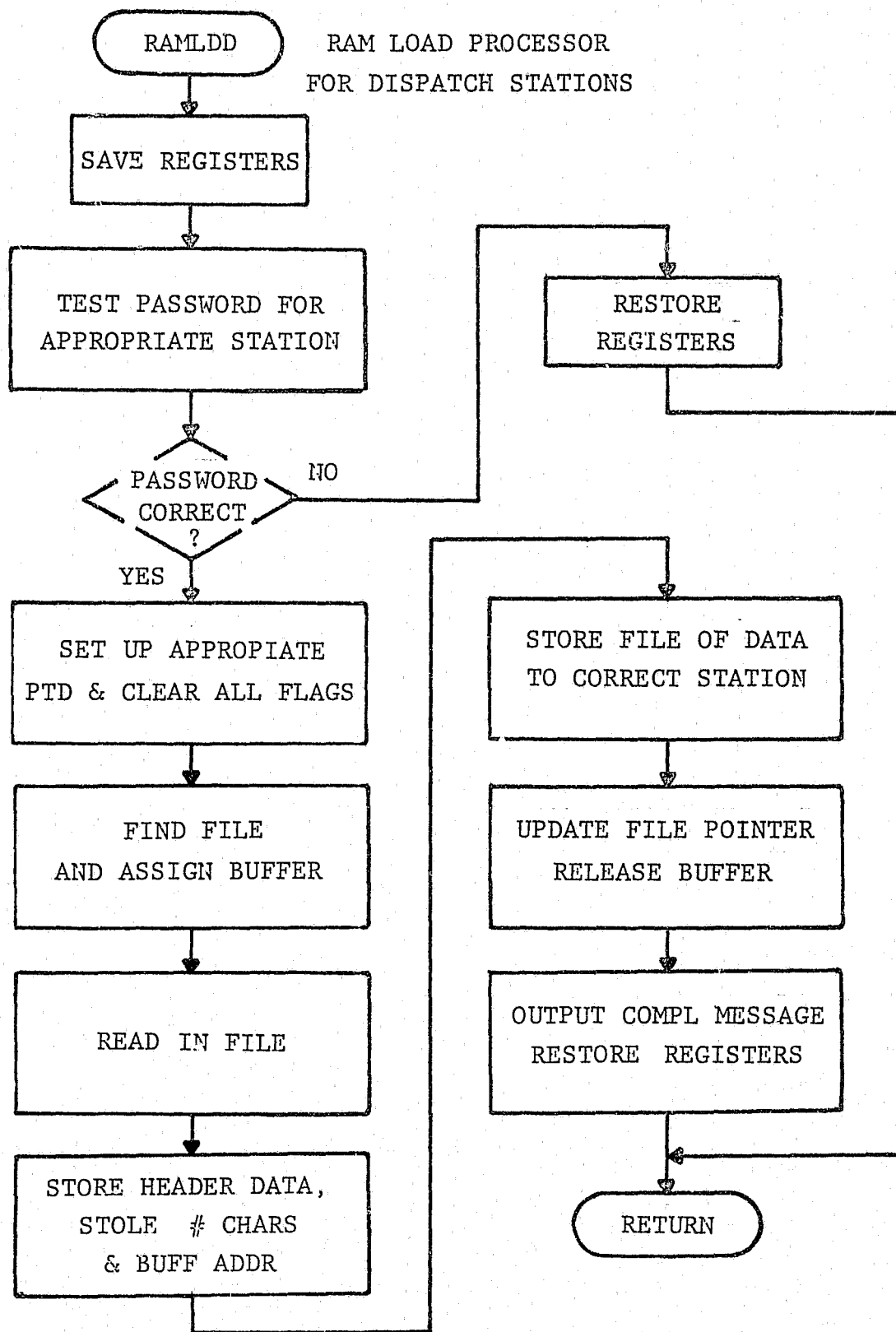


FIG. 2-58 DISPATCH STATION RAM LOAD PROCESSOR

(v) ALSTAT. This overlay module will display all the vehicles for a trucking company showing the status of the vehicle and whether an alarm is pending, and if the vehicle is enabled. It will write a full display if requested or update an existing line of the display (refer to Figure 2-59 for Display Logic).

(w) RTSTAT. This is the route status display overlay module. It will display all the vehicles for a trucking company showing their location and status as shown in Figure 2-60. It will either write a full display if a new one is requested, or it will update an existing line of the display.

(x) RAMPRC. This is the remote alarm data processor overlay module. It contains the following submodules and the basic flow is depicted in Figure 2-61.

- o The remote alarm data processor which processes input data from vehicles in the remote alarm mode. The data input includes sensor and request data.

- o The remote alarm request processor which determines the type of input and sets up required processing functions of yard entry, scrambled ram load, the power on.

- o The remote alarm communications processor which sets up the slow poll communications link for the vehicle and testing of vehicles in the remote alarm armed state.

- o The remote alarm sensor processor which processes input sensor data from vehicles in the remote alarm mode. The inputs are sensor events.

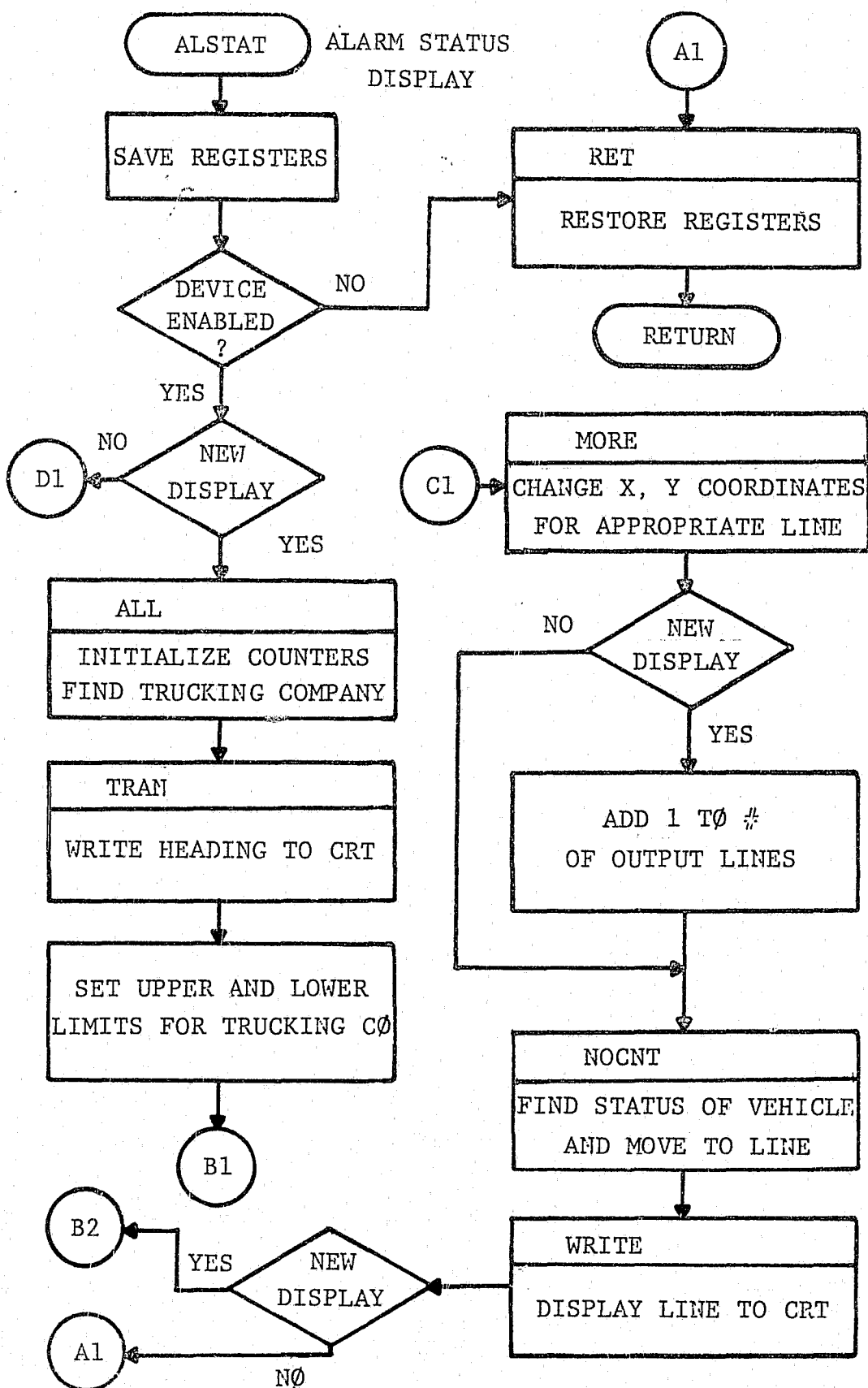


FIG. 2-59 ALARM STATUS DISPLAY

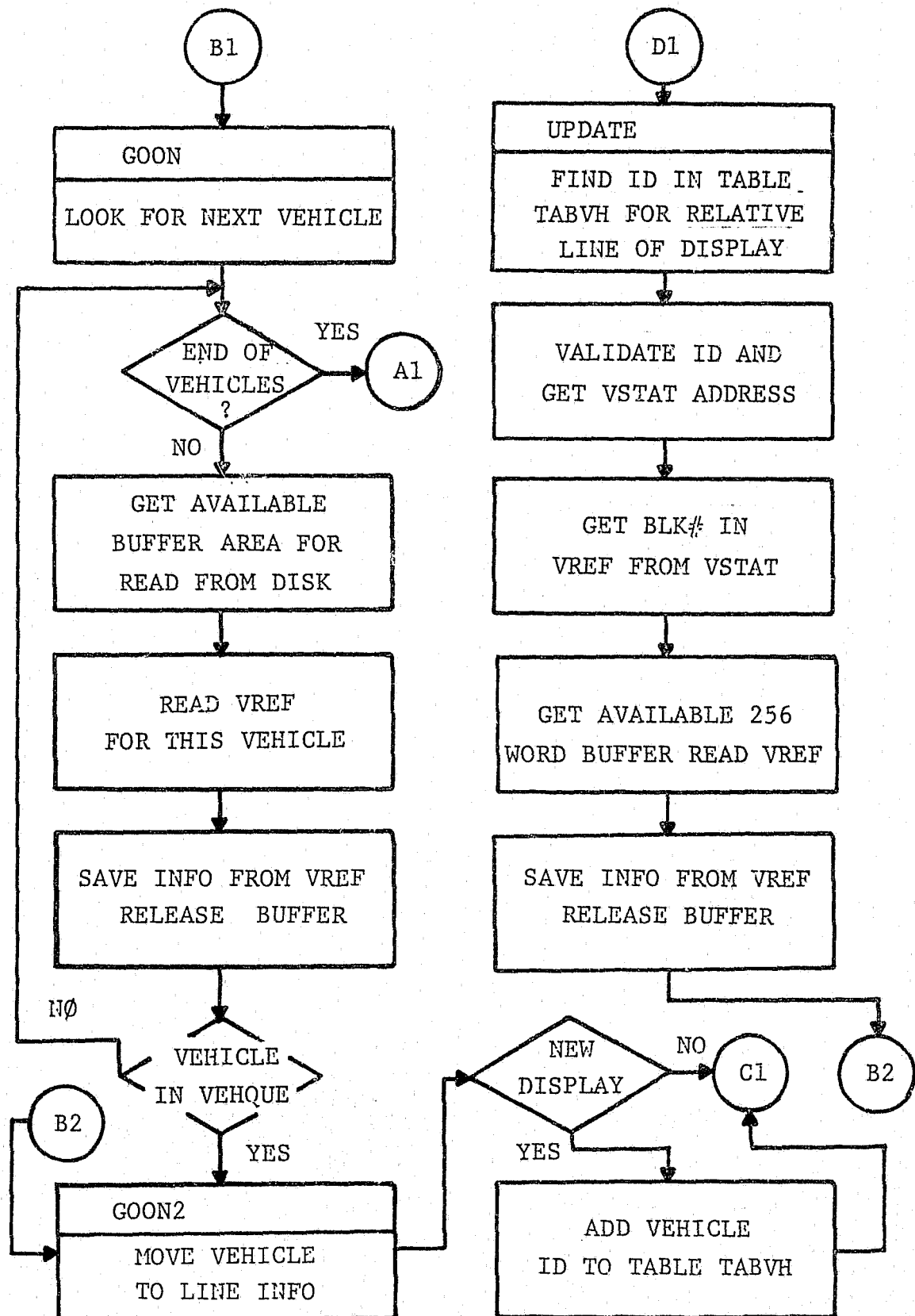


FIG. 2-59 ALARM STATUS DISPLAY (CONTINUED)

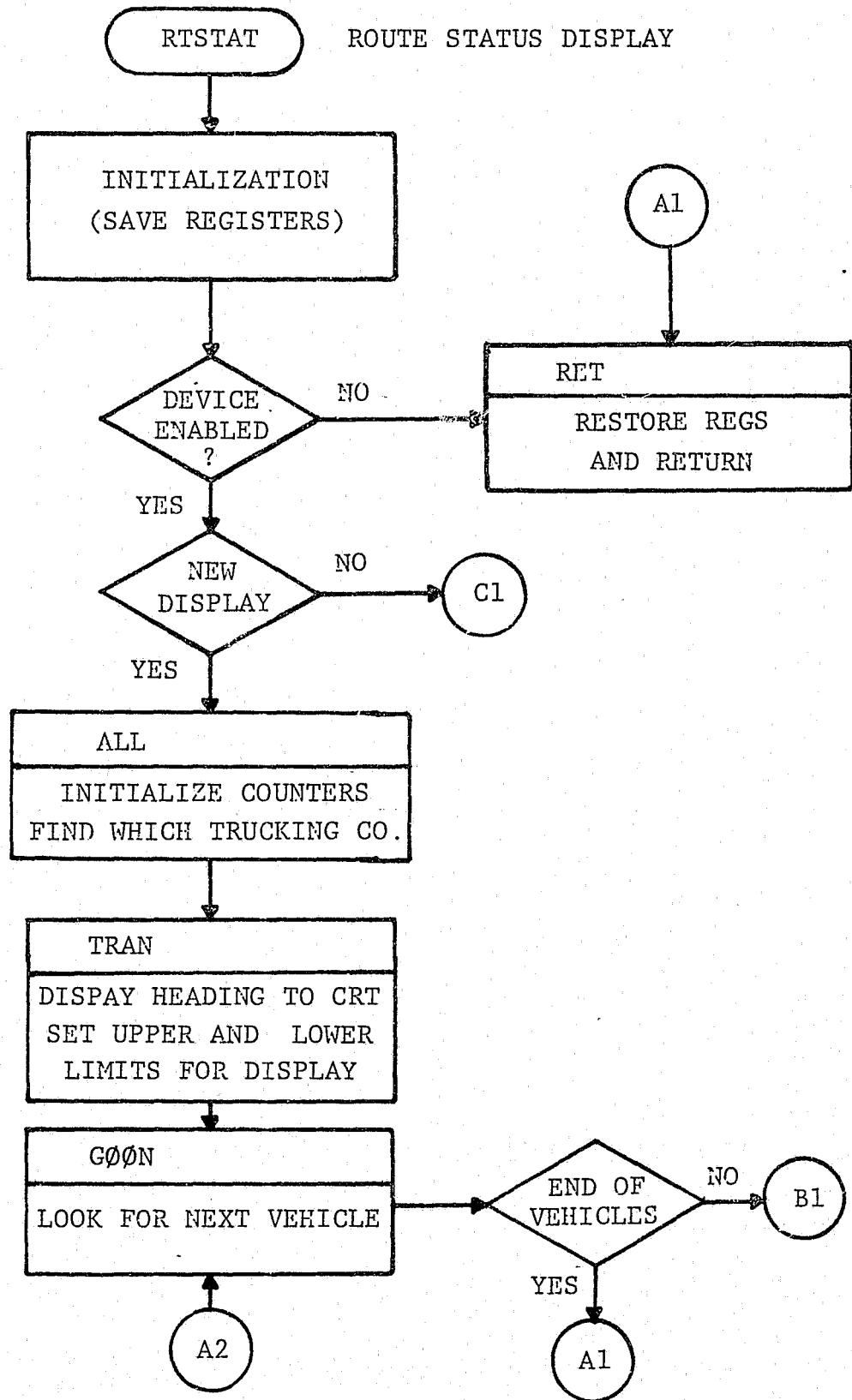


FIG. 2-60 ROUTE STATUS DISPLAY

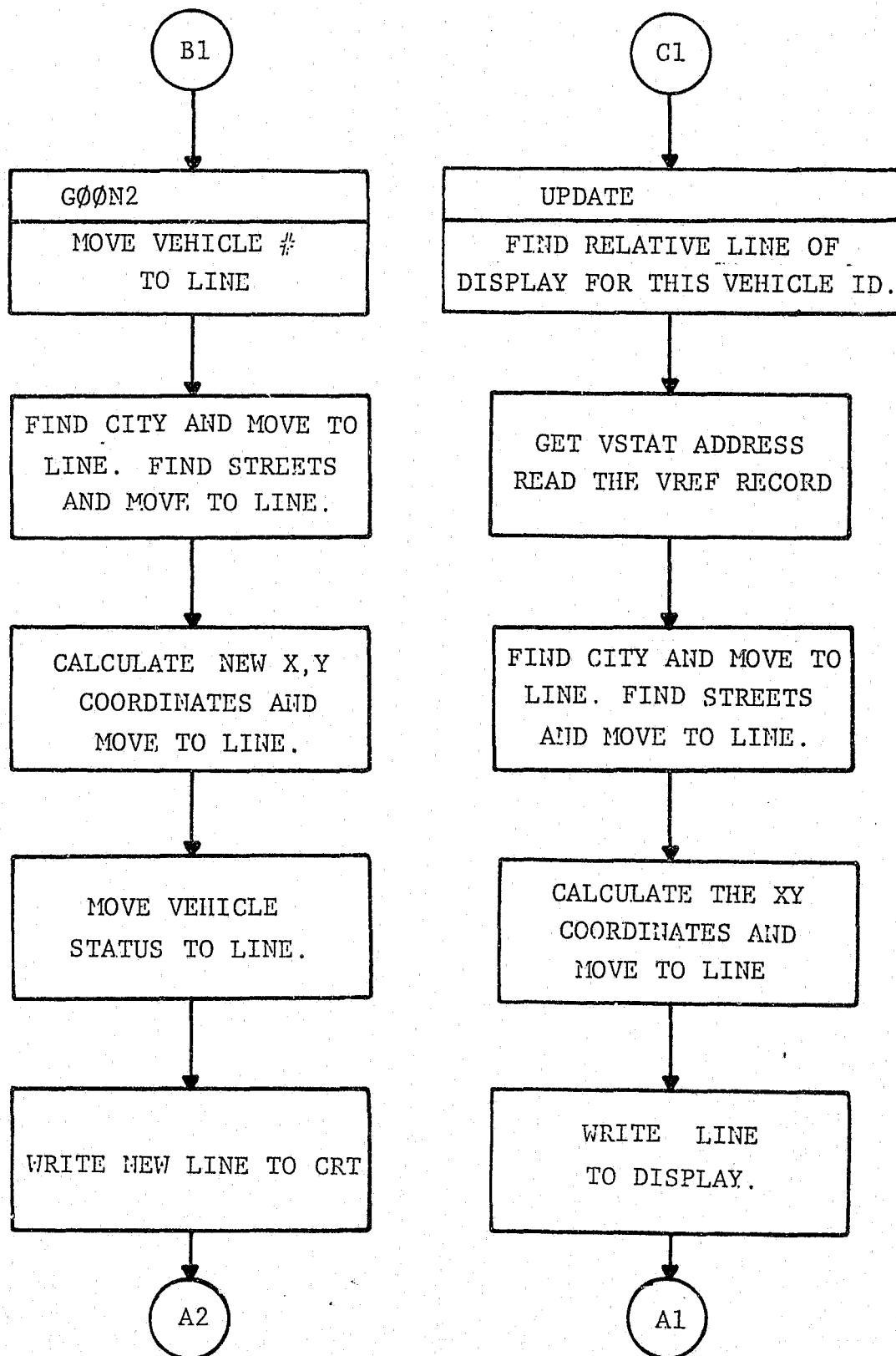
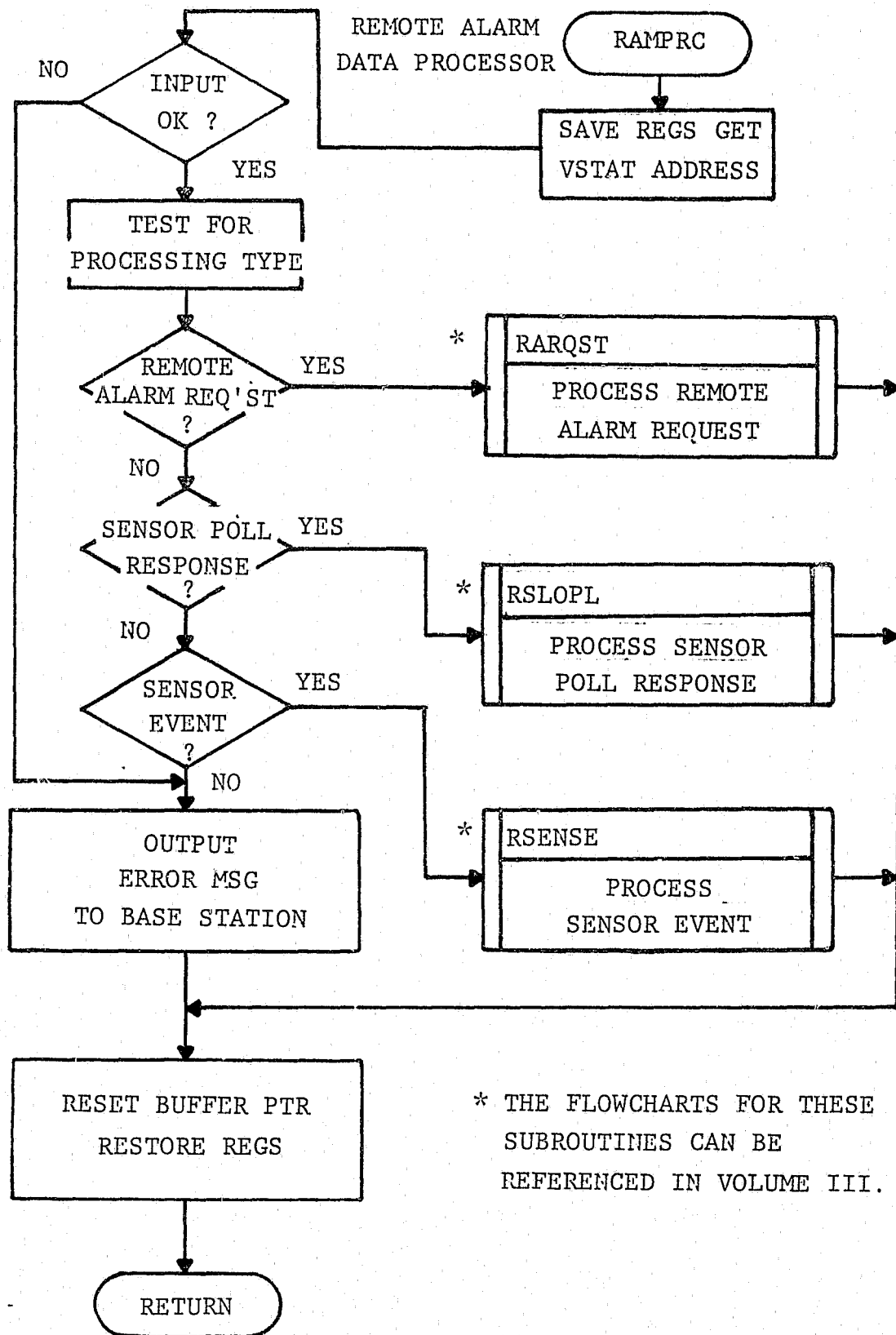


FIG. 2-60 ROUTE STATUS DISPLAY (CONT.)



* THE FLOWCHARTS FOR THESE SUBROUTINES CAN BE REFERENCED IN VOLUME III.

FIG. 2-61 REMOTE ALARM DATA PROCESSOR

(y) TYEDIP. This is the control console edit processor overlay module. This routine edits the commands from the control console and sets up the appropriate physical device table and the appropriate flag for scheduling the command requested (refer to Figure 2-62).

(z) DSEdit. This is the dispatch station edit processor overlay module. This routine edits the commands for validity as shown in Figure 2-63, and for the valid commands it sets up the appropriate physical device table and the appropriate flag for scheduling the command requested.

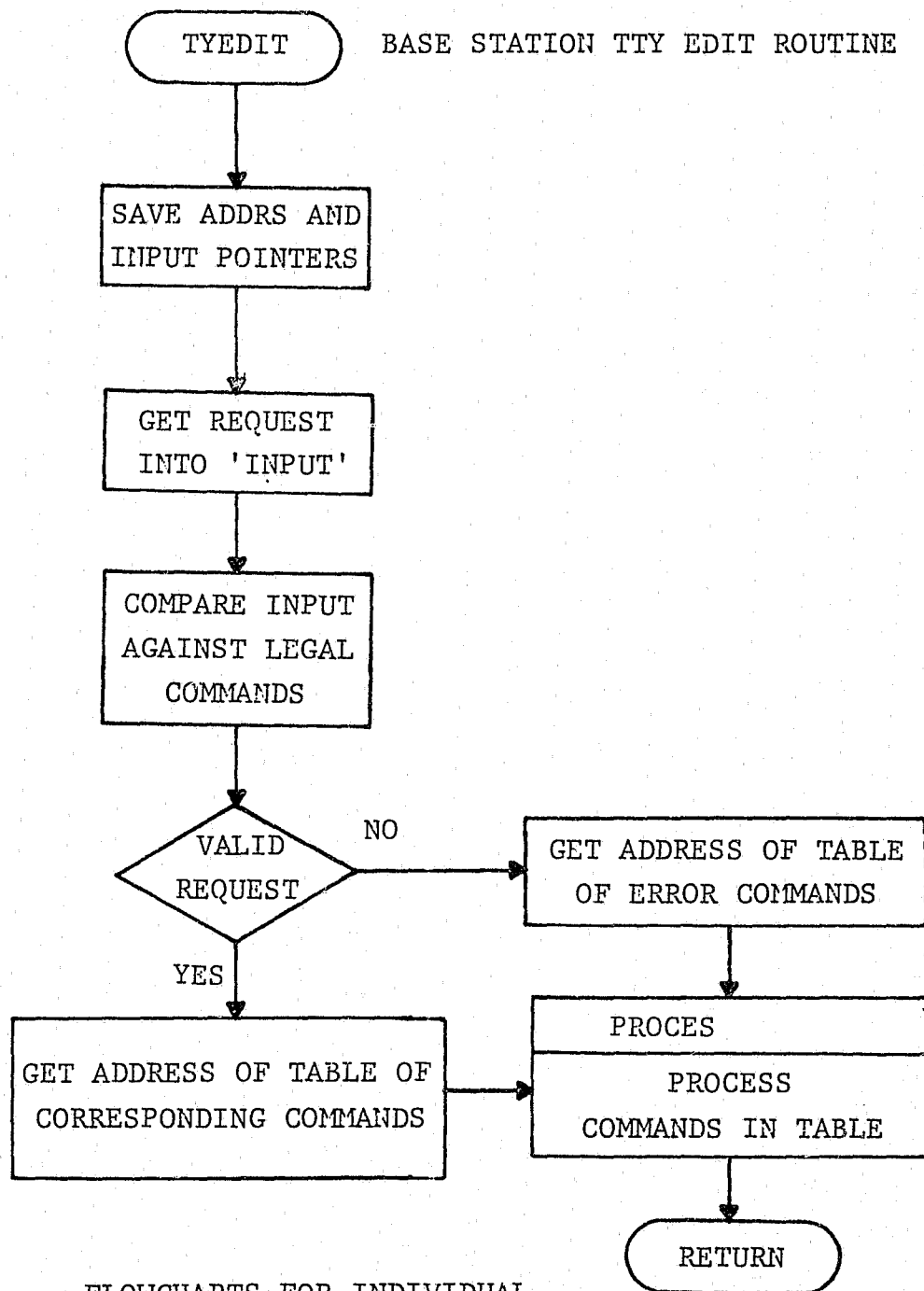
(aa) VOLAY1. The vehicle data processing overlay module (see Figure 2-64). This module contains the following submodules.

- o The absolute phase and stop data processing which determined the absolute phase data input, determines the location change and provides stop data processing.

- o Yard Entry/Exit Processor determines whether yard entry or exit exists and processes the data to provide print-out, display, recorded data and update status flags in resident and non-resident data base areas.

- o Signpost valid test processor determines if the input signpost number is valid and returns the proper AM phase data if it is valid.

- o The minifile processing routine determines the file name of the minifile of the data base which contains the x,y to street intersection data.



FLOWCHARTS FOR INDIVIDUAL
COMMANDS MAY BE REFERENCED
IN VOLUME III.

FIG. 2-62 BASE STATION TTY EDIT

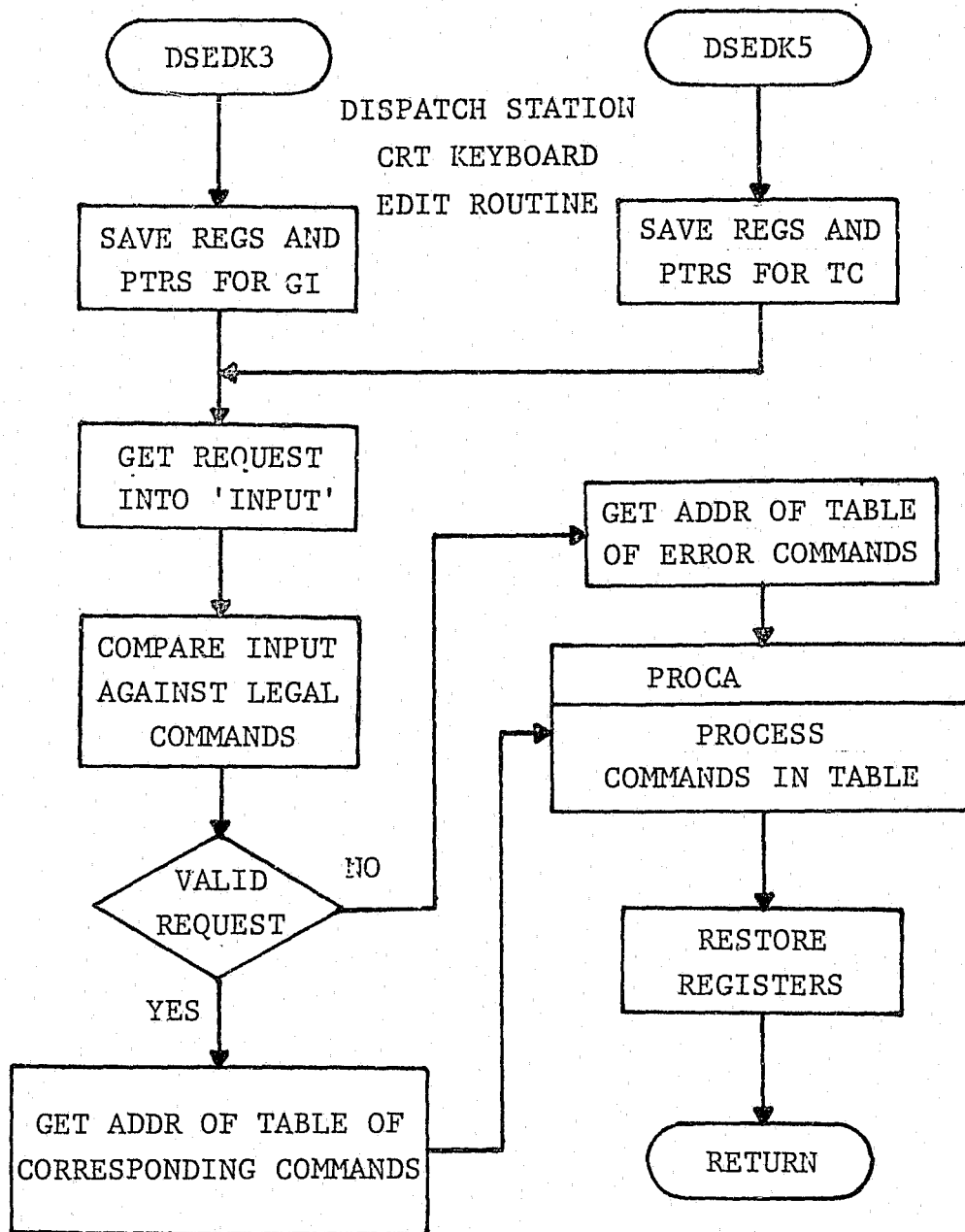


FIG. 2-63 DISPATCH STATION CRT KEYBOARD EDIT

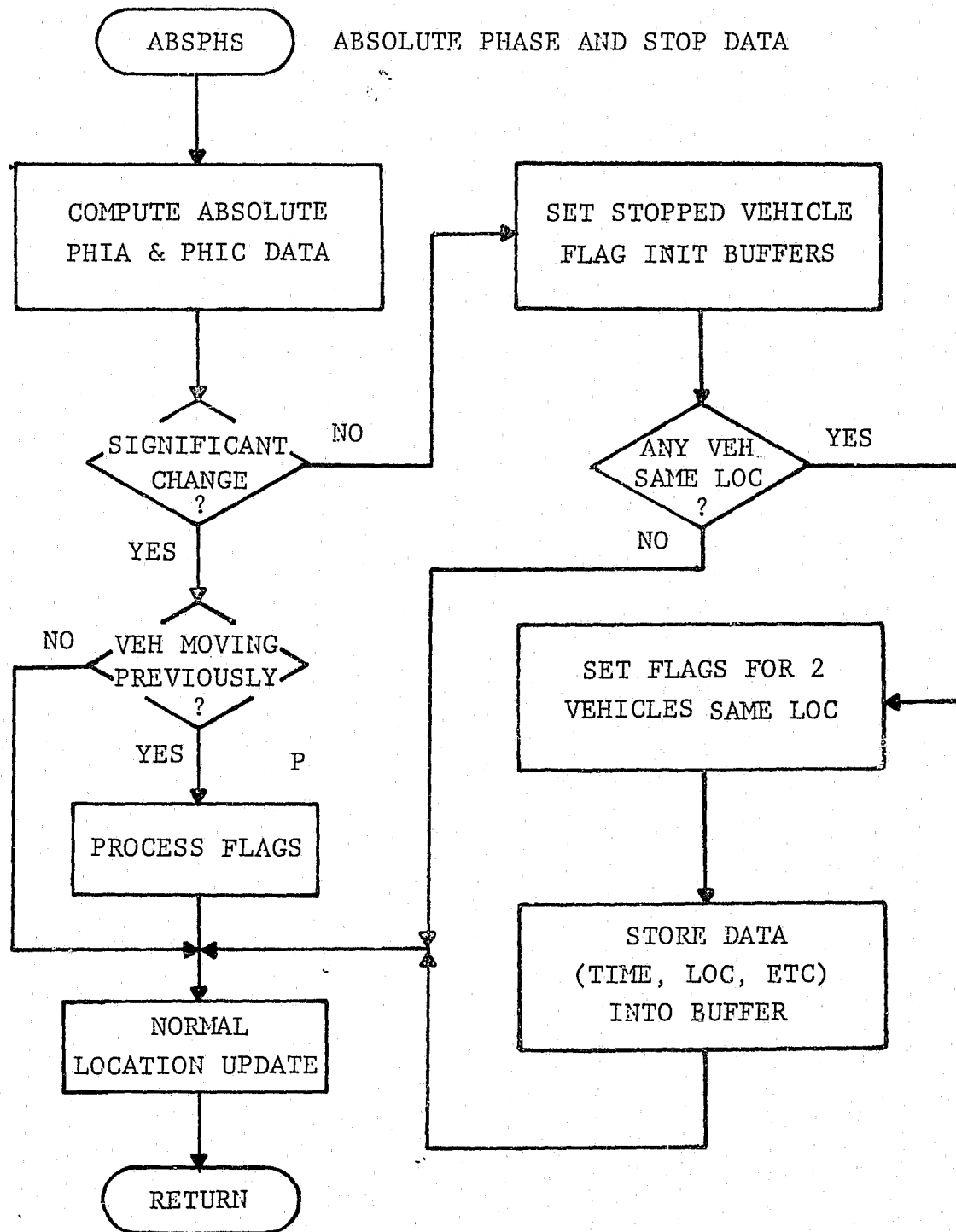


FIG. 2-64 ABSOLUTE PHASE AND STOP DATA

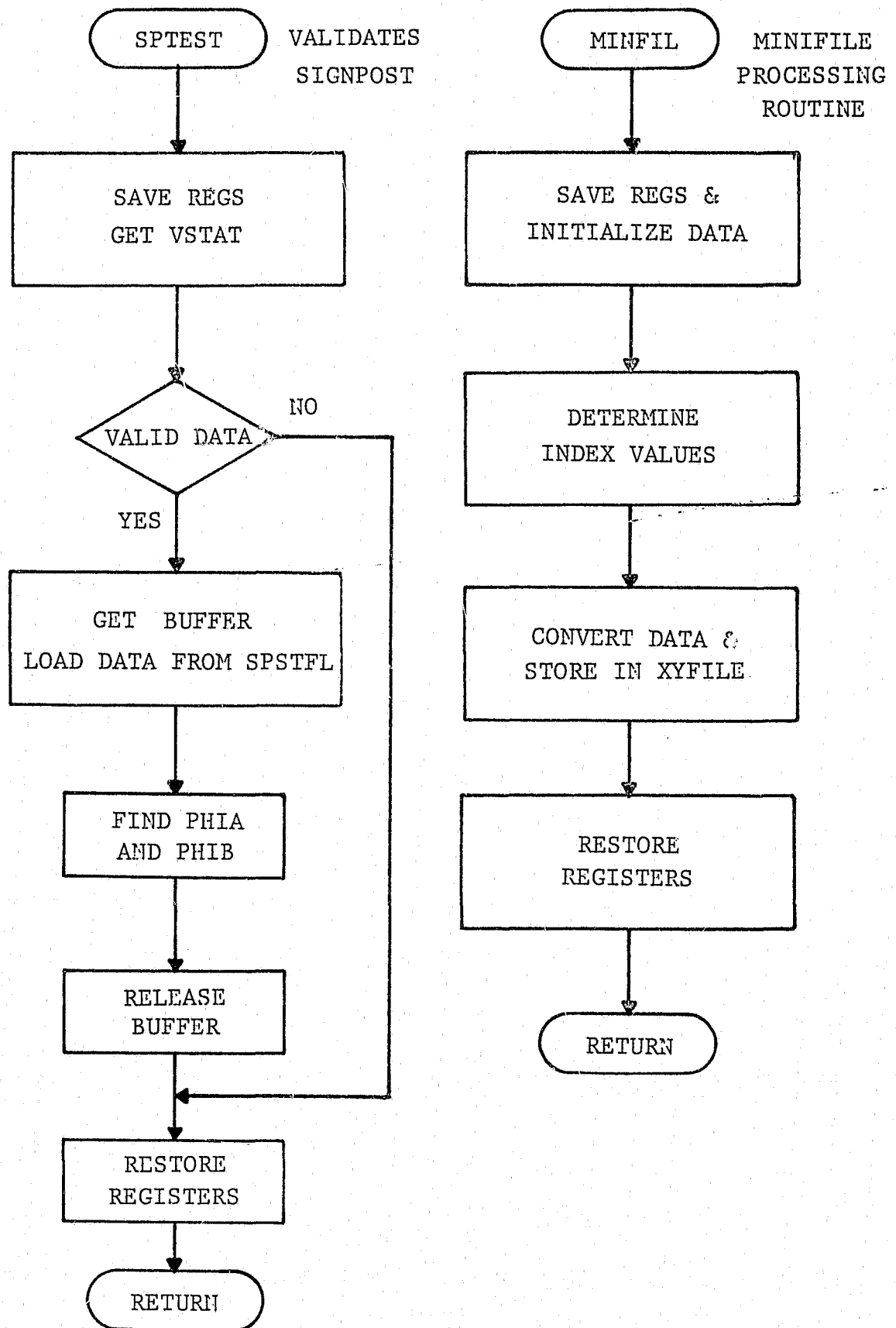


FIG. 2-64 ABSOLUTE PHASE AND STOP DATA (CONTINUED)

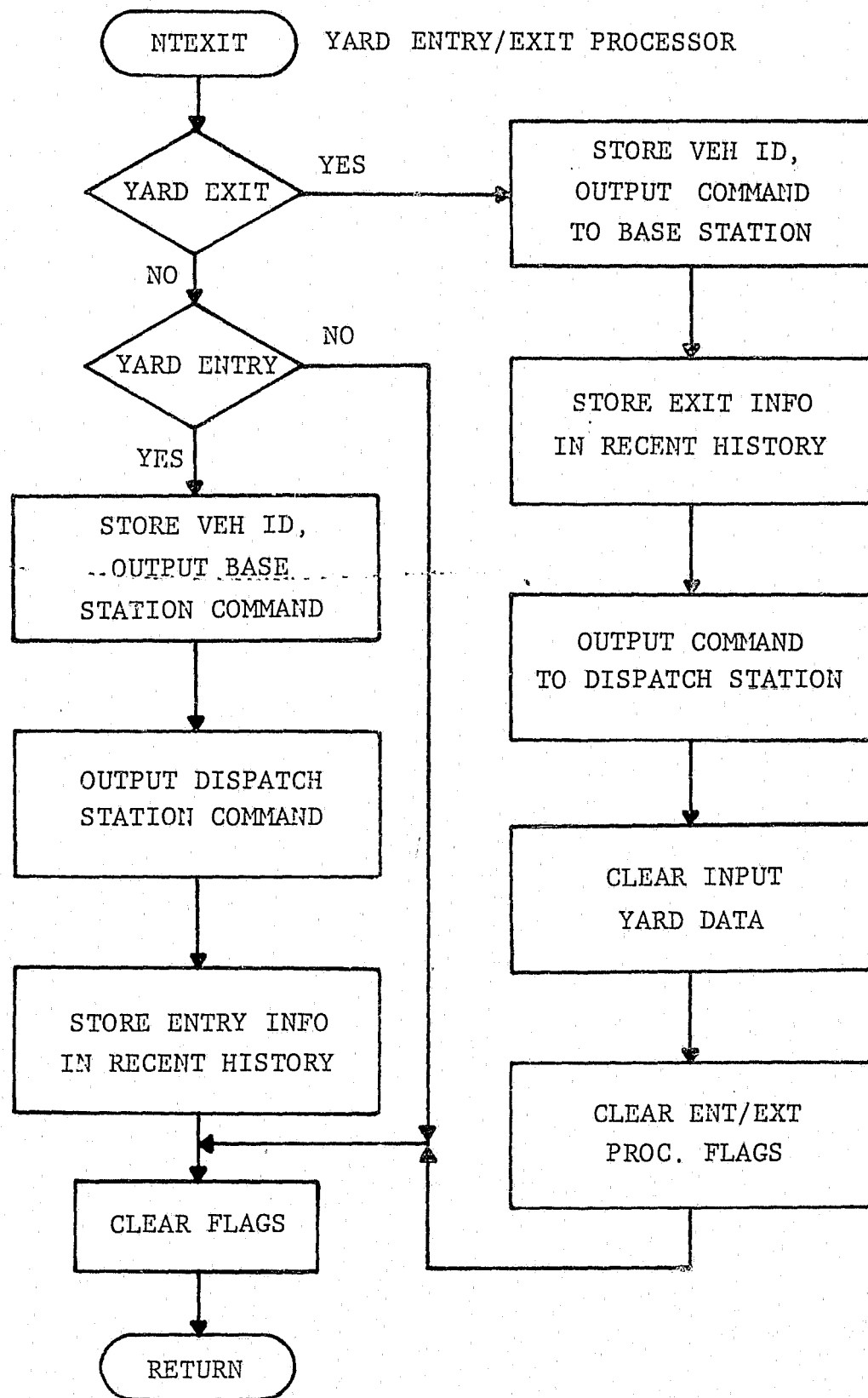


FIG. 2-64 ABSOLUTE PHASE AND STOP DATA (CONTINUED)

(ab) DOLAY1. The dispatch station data processing overlay module contains various subroutines which process the commands to the dispatch station (refer to Figure 2-65).

(ac) KBEDIT. This is the status console edit processor overlay module. This routine edits the commands from the status console and sets up the appropriate physical device table and the appropriate flags for scheduling the command requested (see Figure 2-66 for general flow).

(ad) SESTAT. The security status display overlay module displays the location, status and sensor data for a requested vehicle. It will write a full display if requested or update the location, status, or sensor information or mileage (as shown in Figure 2-67).

(10) Base Station Display/Control Processing. The base station subsystem controls the system interfaces between the base station operator, the remote elements (trucks) and the Cargo Security System software as shown in Figure 2-68. Base station command data is input using an ADM-2A CRT terminal and an LA36 DecWriter, II printer terminal. The system also processes command words from the vehicles.

The display terminal CRT keyboard controls the information on the display, initiates command sequences for the vehicles, initiates data printout to the character printer, and updates the memory resident and disk resident system data bases. There are 9 special function key commands and 18 multiple key commands accepted from this keyboard. The formats for these commands are given in Table 2-10.

D O L A Y 1

The dispatch station data processing overlay module.

Contains various subroutines which process the commands to the dispatch station. Flowcharts for these subroutines can be referenced in Volume III.

SUBPROCESSES CONTAINED IN THIS MODULE:

<u>SUBPROCESS</u>	<u>DEFINTION</u>
S401	Load Tel. #, Sensor Data, and Call Alert/Alarm Printout
S402	Output Data to Dispatch Station Formatter
S403	Load Location Data and Call Tel.#
S404	Set up Command Call Parameters
S405	Display Update Processor
S406	Output Bell CMD Flags
S407	Output Printer Data
S409	Log CMD Data and Load CMDWDC
S410	Clear DSCMD1 and DSCMD2
S411	Load PTR with Remote Alarm Data
S413	Output Data to CRT
S412	Output Data in PRTR to Char. Printer
S414	Clear Buffers in 'ISC' Display
S418	Mode Change Command
S419	Mode Change Display Update
S420	Complete the Command

FIG. 2-65 DISPATCH STATION OVERLAY MODULE

D O L A Y 1

SUBPROCESSES CONTAINED IN THIS MODULE: (Cont.)

<u>SUBPROCESSES</u>	<u>DEFINITION</u>
S421	Recent History Printout Processor
S422	Dispatch Station Halt
S300	Load Status Buffer
S301	Load Location Data in 'OUTLOC', 'TELOUT', 'VEHNUM'
S302	Determine Vehicle Color Byte and Load Color
S303	Load Make, Model, License, Mode Buffers

FIG. 2-65 DISPATCH STATION OVERLAY MODULE (CONT.)

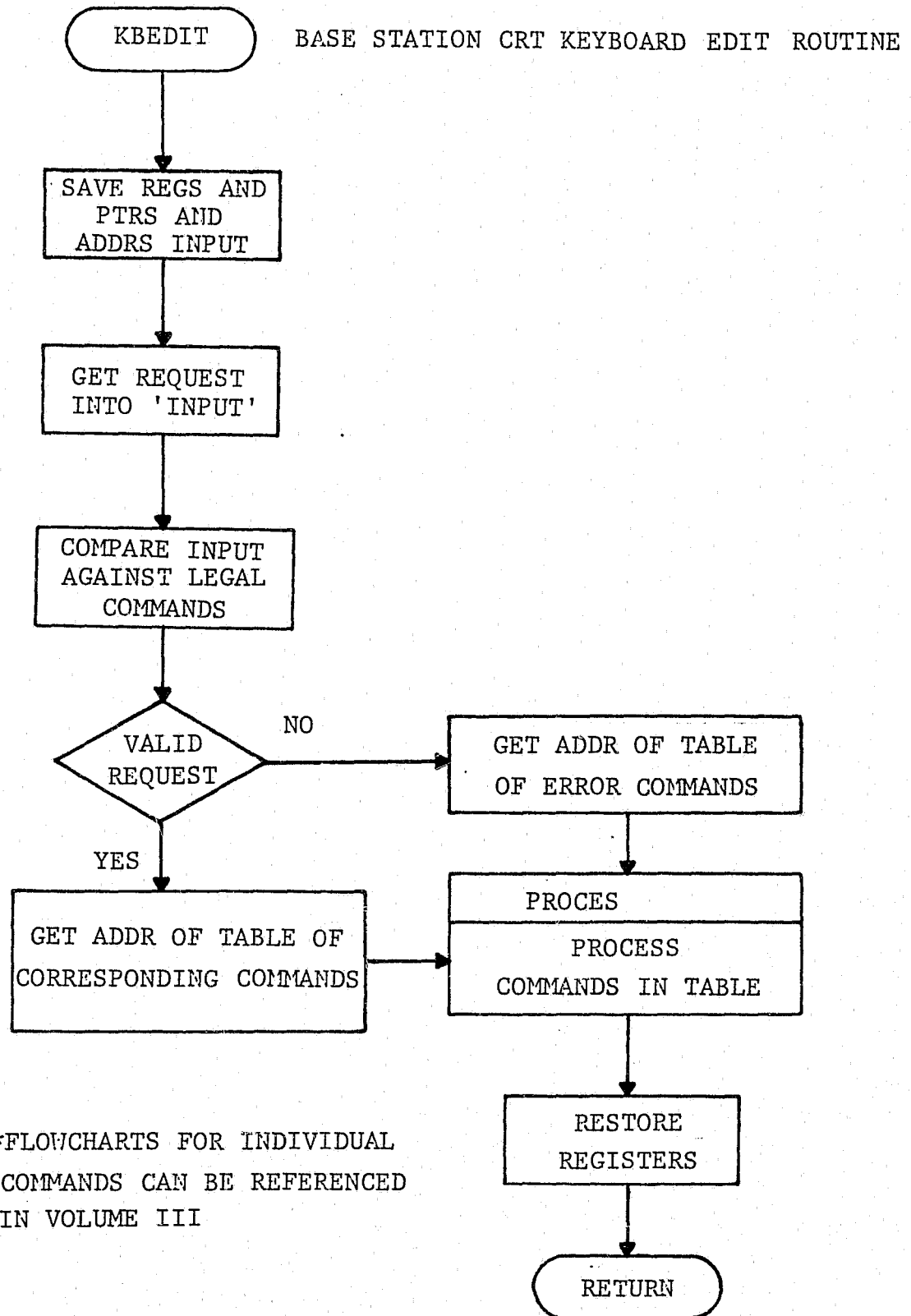


FIG. 2-66 BASE STATION CRT KEYBOARD EDIT

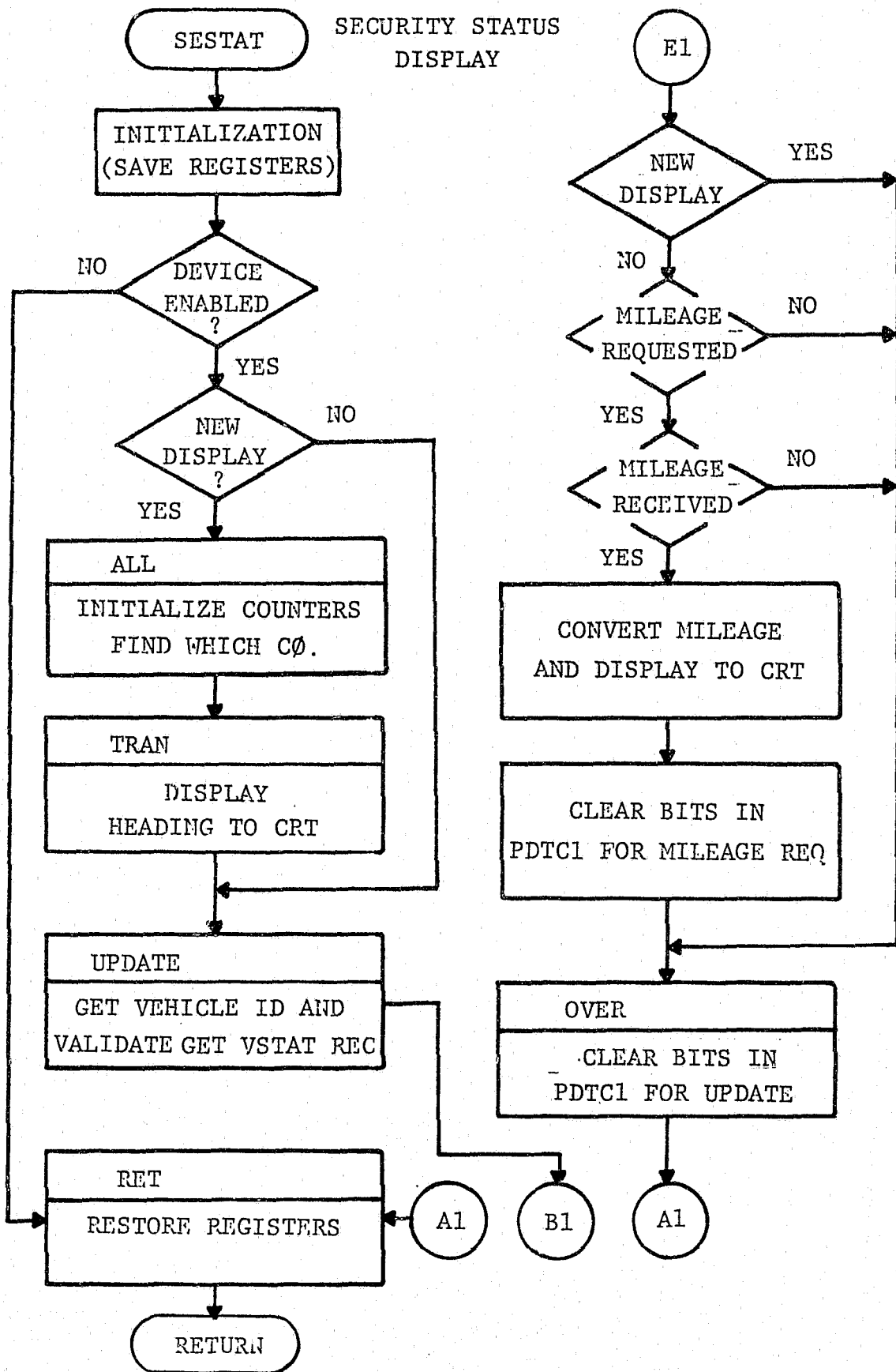


FIG. 2-67 SECURITY STATUS DISPLAY

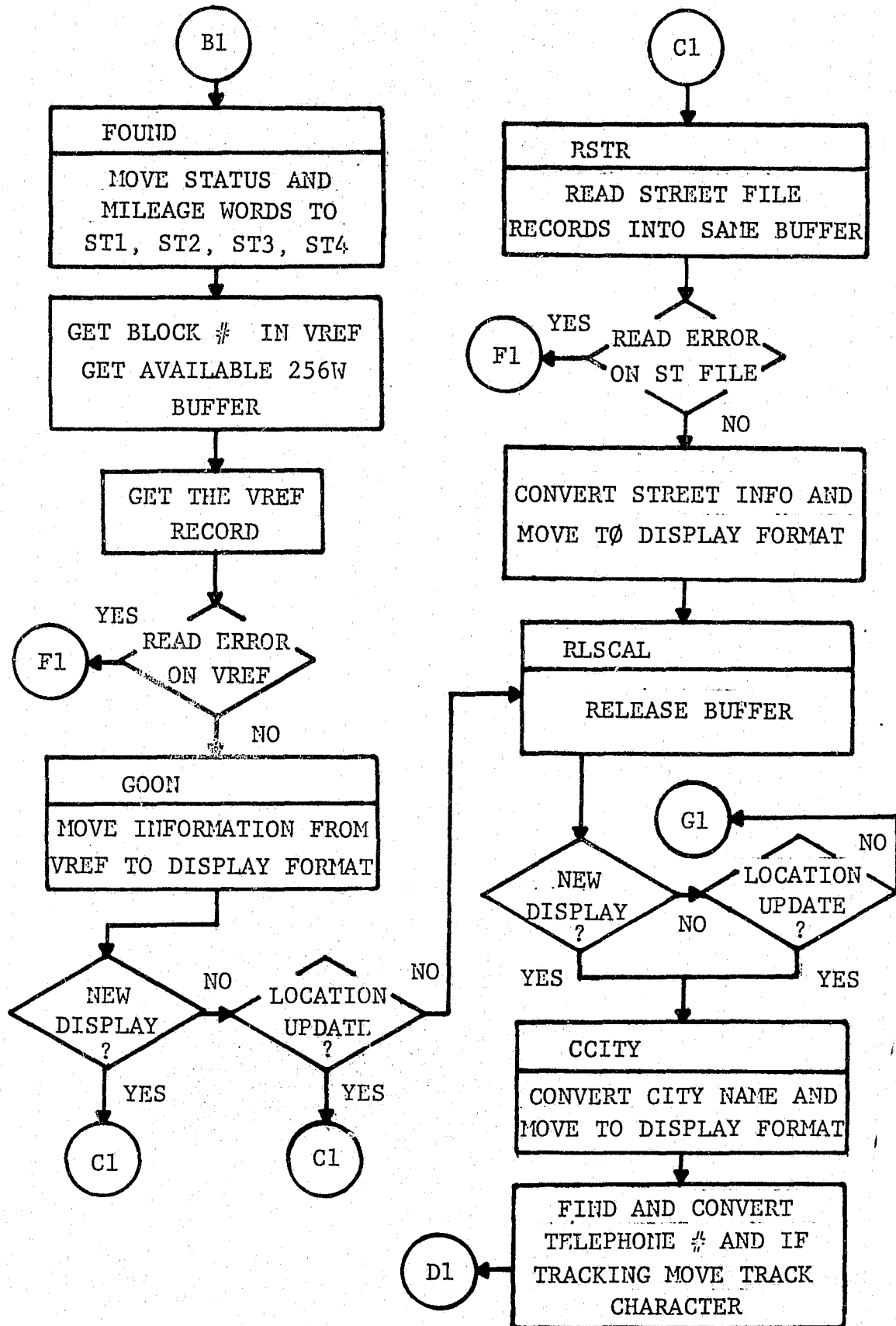


FIG. 2-67 SECURITY STATUS DISPLAY (CONTINUED)

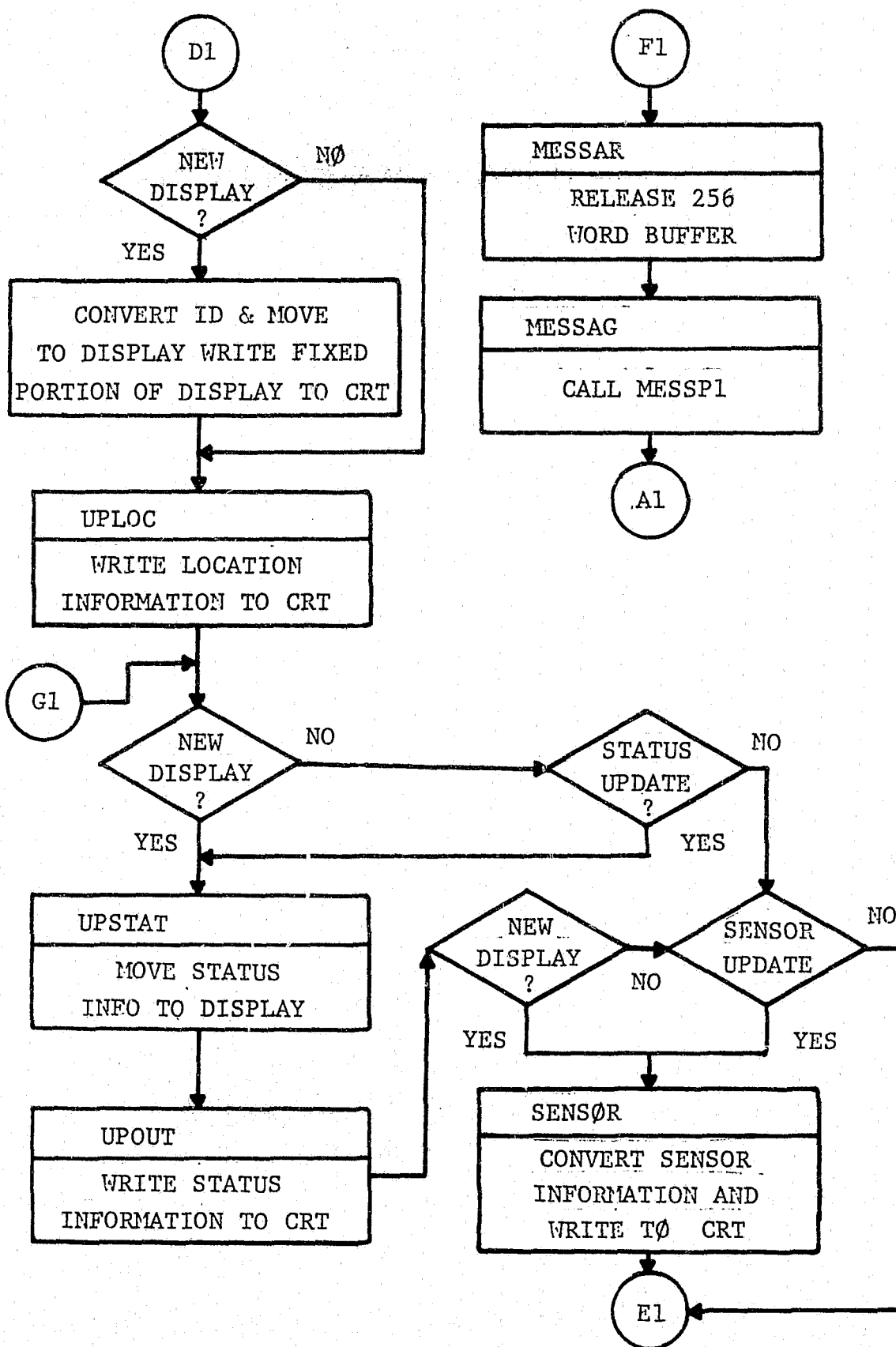


FIG. 2-67 SECURITY STATUS DISPLAY (CONTINUED)

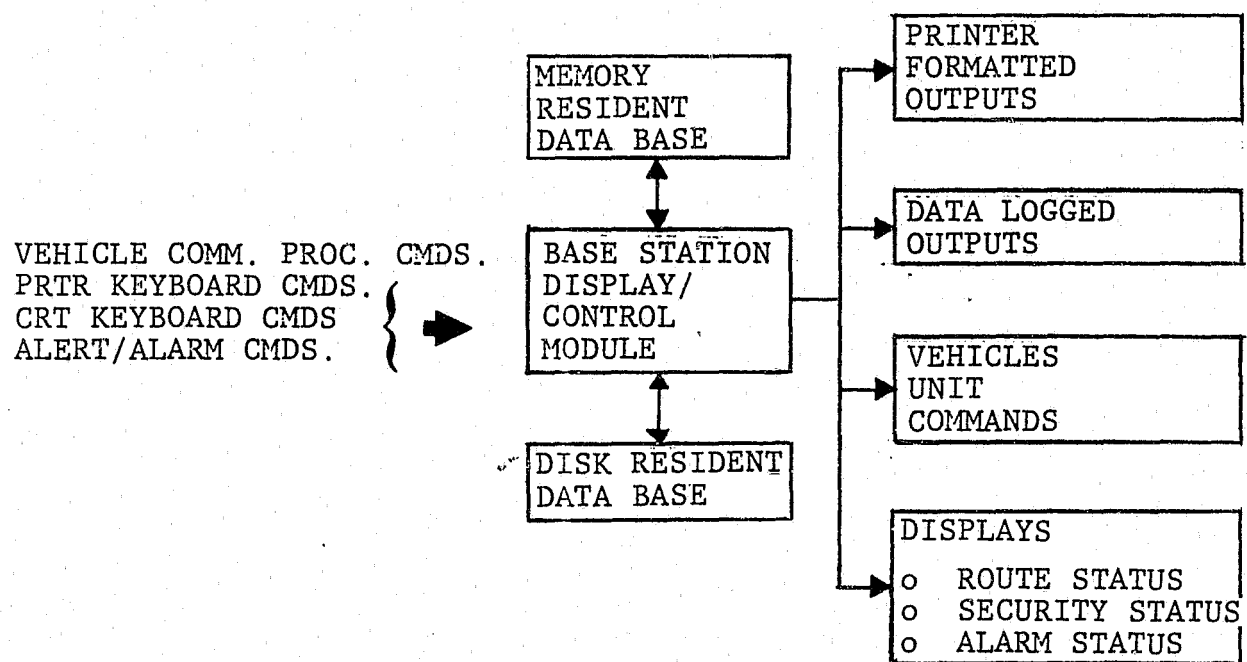


FIG. 2-68 DISPLAY CONTROL PROCESSING/SYSTEM INTERRELATIONSHIP

TABLE 2-10 BASE STATION CRT KEYBOARD ENTRY COMMANDS

<u>CHARACTERS</u>	<u>DEFINTION</u>	<u>PROCEDURE</u>	<u>DISPLAY</u>
F1	Security Status-Transcon	F1VVV	Security Status
F2	Route Status-Transcon	F2	Route Status
F3	Alarm Status-Transcon	F3	Alarm Status
F4	Security Status-GITrucking	F4VVV	Security Status
F5	Route Status-GI Trucking	F5	Route Status
F6	Remote Alarm-GI Trucking	F6	Alarm Status
F15	Disable Keyboard	F15	End
F16	Enable Keyboard	F16	Start
F7	Alert/Alarm Printout	F7	(F1, F2, F3, F4, F5, F6)
*** UE	Unit Entry	UE VVV YYT	(F2 or F5)
*** UD	Unit Delete	UDVVV YYT	(F2 or F5)
*** SD	Sensor Disable	** SDM	(F1 or F4)
*** SE	Sensor Enable	** SEM	(F1 or F4)
*** RL	RAM Load	** RL	(F1 or F4)
MR	Mileage Request	MR	(F1 or F4)
DO	Disable out of Route	DO	(F1 or F4)
EO	Enable out of Route	EO	(F1 or F4)
CA	Acknowledge alarm/Alert	CA VVV T	(F1, F2, F3, F4, F5, F6)
RA	Remote Alarm Arm	RA	(F1 or F4)
*** RR	Assign Route Number	* RR NNNb NNNT	(F1 or F4)
AA	Alarm Arm	AA VVV	(F3 or F6)
AD	Alarm Disable	AD VVV	(F3 or F6)
ADA	Alarm Disable, All	ADAT	(F3 or F6)
AAA	Alarm Arm, All	AAAT	(F3 or F6)
PW	Password	PW XX	(F16)
DA	Disable All Sensors	DA	(F1 or F4)
TR	Track Vehicle with Direction Bit	TR	(F1 or F4)

* The Second Set of numbers is optional

** RAM Load normally consists of 8 ASCII Characters - EIJLXOAP
Sensor Disable or enable consists of 1 ASCII Character 0-8

TABLE 2-10 BASE STATION CRT KEYBOARD ENTRY COMMANDS (CONT.)

Commands to Be Recorded on Data Log File

XX = Password ID

VVV = Vehicle No.

YY = Vehicle ID

T = Trucking company 1 = Transcon 2 - GI Trucking

M = Sensor No. (see table in Veh. XPT)

NNN = Route number

Under the heading DISPLAY, the numbers in parenthesis reflect the display mode which must be present in order for the commands to be accepted. The three display formats are given in Figures 2-69 through 2-71.

The keyboard is enabled or disabled through use of special function keys F15 and F16. At initialization, the control routine only accepts inputs from F16, disregarding all others. Following selection of F16, the only allowable input is PWXX, where XX corresponds to the ASCII entries in the password file. Password entry data is non-changeable. If an error is detected upon entry of a password, the system automatically performs an F15 entry to disable the keyboard.

Following the calling of a specific display through use of F1 through F6, other modes of operation are enabled for entry such as the unit entry command, provided F2 or F5 have been selected, etc. A special display processing handler takes care of receiving the keyboard commands and storing the input in a buffer as well as outputting the appropriate data to the display.

The printer terminal keyboard provides initialization data for the system and is used for specific requests for interface with the vehicle unit equipment. In addition, this keyboard enables printout of recent history data from the host computer mass storage. There are 14 multiple key commands accepted from this keyboard. The formats for these commands are given in Table 2-11. Multiple printout formats are used. These formats include error messages, vehicle status changes, responses to commands and the normal and recent history printout format. The formats for the Recent History and Normal Print are described in Figures 2-72 and 2-73.

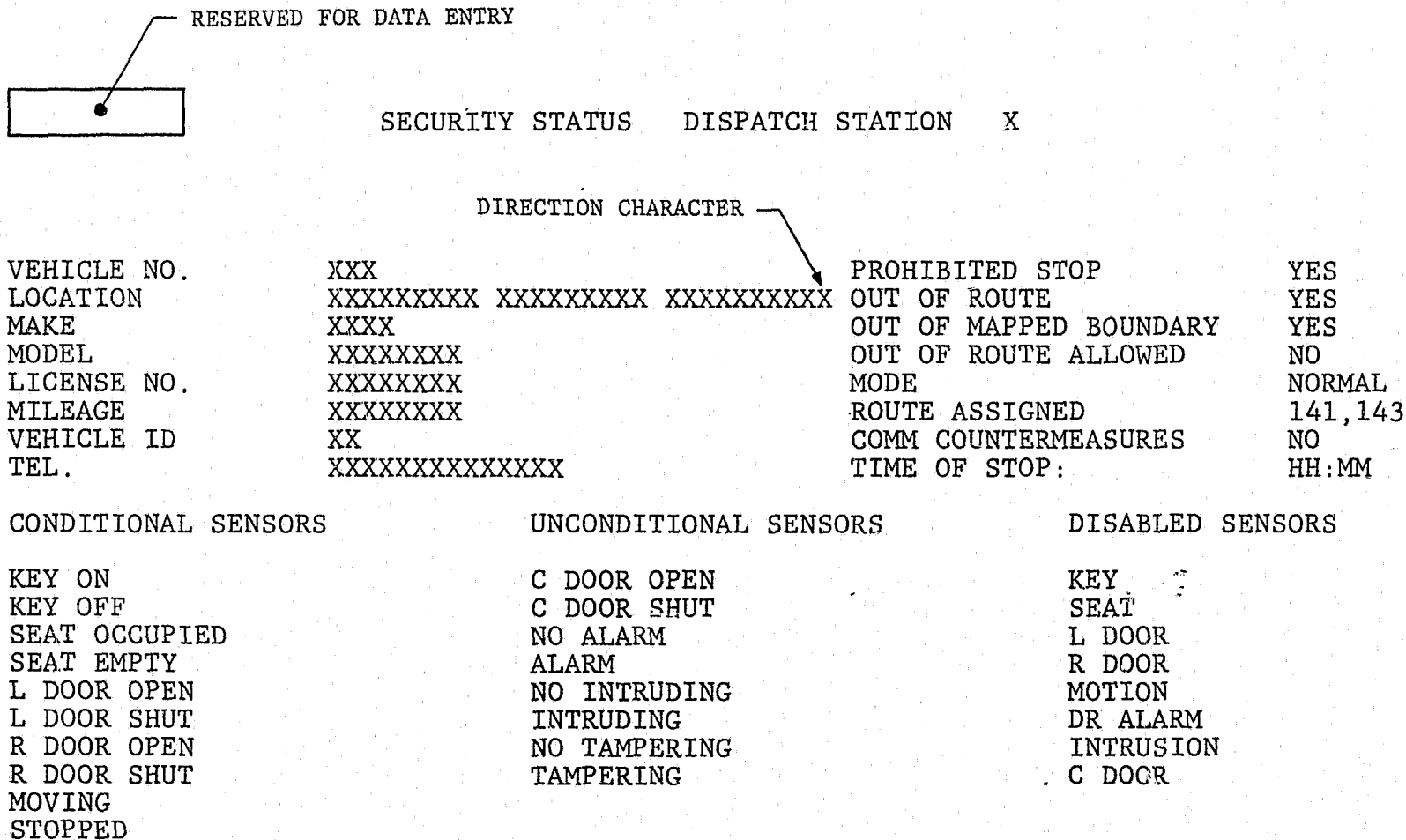
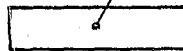


FIG. 2-69 SECURITY STATUS DISPLAY AT BASE STATION TERMINAL

RESERVED FOR DATA ENTRY



LOCATION

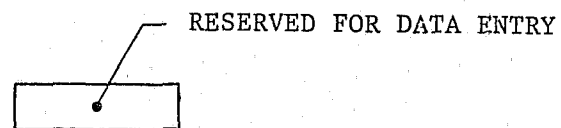
DISPATCH STATION X

STATUS

FORMAT NUMERICALLY IN SEQUENCE

986	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	OK
927	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	R ALERT
830	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	ALERT ← BLINK
834	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	ALARM ← BLINK
840	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	OK
870	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	OK
832	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	OK
944	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	OK
923	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	OK
984	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	R ALERT
886	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	ALERT
887	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	OK
945	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	ALERT
928	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	OK
872	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	ALARM
873	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	OK
854	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	OK
890	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	OK
892	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	OK
894	XXXXXXXXXX	XXXXXXXXXX	XXXXXXXXXX	OK

FIG. 2-70 ROUTE STATUS DISPLAY AT BASE STATION TERMINAL



VEHICLE	ALM	STATUS	ENBLD
986		NORMAL	*
927	*	KEY ON	*
830	*	SEAT OCCUPIED	*
834	*	L DOOR OPEN	*
840	*	C DOOR OPEN	*
870	*	R DOOR OPEN	*
832	*	MOVING	*
944	*	INTRUDING	*
923	*	TAMPERING	*
984	*	NO COMM	*
886		NORMAL	*
887		NORMAL	*
945		NORMAL	*
923		NORMAL	*
822		NORMAL	*
873			
854			
890			
892			
894			

FIG. 2-71 REMOTE ALARM STATUS DISPLAY AT BASE STATION TERMINAL

TABLE 2-11 BASE STATION CHARACTER PRINTER ENTRY COMMANDS

CHARACTERS	DEFINITION	PROCEDURE	FORMAT
ZA	Zero AMPhase, Vehicle only	ZAVVV1	Fig 4
ZA	Zero AMPhase, Vehicle and Proc.	ZAVVV2	Fig 5
LR	Location Request	LRVVV	Fig 6
MR	Mileage Request	MRVVV	Fig 7
SR	Sensor Request	SRVVV	Fig 8
ZO	Zero Odometer	ZOVVV	Fig 9
DE	Device Enable	DEZZ	Fig 10
DD	Device Disable	DDZZ	Fig 11
AC	Manual Acknowledge	ACVVV	Fig 12
DL	Load Dispatch Station Processor	DLZZ	Fig 13
* TI	Time Entry	TIHHMMSS	Fig 14
* ST	Start of Shift	STT	Fig 15
* DA	Date Entry	DADD- MMM- YY	Fig 16
RH	Vehicle Recent History Printout	RHVVDVT	Fig 17

VVV = Vehicle No.

ZZ = Device Code

UUU = Ticks

D = Delta Time, 0 = Today, 1 = Yesterday, 2 = 2 Days ago,

T = TruckingCompany 1 = Transcon, 2 = GI Trucking

* Data To Be Logged In Data Log File

TABLE 2-12 DEVICE ASSIGNMENT TABLE

Transcon Dispatch Station	GI Trucking Dispatch Station	Base Station
C5 CRT Screen	C3 CRT Screen	C1 CRT Screen
K6 CRT Keyboard	K3 CRT Keyboard	K1 CRT Keyboard
P3 Character Printer	P2 Character Printer	P1 Char. Printer
K7 Character Printer Keyboard	K4 Char. Printer Keyboard	K2 Char. Printer Kybd.
C6 Alarm CRT Screen	C4 Alarm CRT Screen	HC Host computer
K8 Alarm CRT Keyboard	K5 Alarm CRT keyboard	

VEHICLE NO. XXX

TYPE	27 CHARACTERS	TIME STOP TIME (HHMMSS)	DURATION MIN.
D	DELIVERY STOP		
ALERT	ALERT (SEE TABLE FOR DESCRIPTION UNDER DURATION HEADING)		
ALARM	ALARM (SEE TABLE FOR DESCRIPTION UNDER DURATION HEADING)		
EDL	ENTER DELIVERY ROUTE (NO DURATION DATA)		
NDS	NON-DELIVERY STOP GREATER THAN 5 MINUTES		
ALC	ALERT/ALARM CLEAR (INCLUDE TIME, NO DURATION)		
RACT	REMOTE ALARM ACTIVATE BY DISPATCH/ALARM CRT		
RADT	REMOTE ALARM DEACTIVATE BY DISPATCH/ALARM CRT		
MILE	MILEAGE SUMMARY		

DURATION DESCRIPTORS TABLE

ALERT	ROUTE ENTRY	ROUTE ENTRY
	YARD EXIT	YARD EXIT
	YARD ENTRY	YARD ENTRY
	*OUT OF ROUTE	OUT OF ROUTE
	OUT OF BDRY	OUT OF MAPPED BOUNDARY
	UNAUTH STP	UNAUTHORIZED STOP
	XXX, SME LOC, STPD, XXX	TWO TRUCKS AT SAME LOCATION
	KY OFF, MOV	KEY OFF, MOTION
	ST MSY MOV	SEAT EMPTY, MOTION
	RDR, MOV	R DOOR OPEN, MOTION
	RDR, STORE	R DOOR OPEN, SEAT OCCUPIED
	LDR, RDR	L DOOR OPEN, R DOOR OPEN
	RDR, KON	R DOOR OPEN, KEY ON
	ST MTY, KON	SEAT EMPTY, KEY ON
	LDR, KON	L DOOR OPEN, KEY ON
	CDR, MOV	CARGO DOOR OPEN, MOVING
	COR, STOCK	CARGO DOOR OPEN, SEAT OCCUPIED
	CDR, LDR	CARGO DOOR OPEN, LEFT DOOR OPEN
	CDR, KON	CARGO DOOR OPEN, KEY ON
	YYY MILES	MILEAGE SUMMARY
ALARM:	CNTR MSR	COUNTERMEASURES
	STP OUT OF RT, CDR	STOPPED, OUT OF ROUTE, CARGO
		DOOR OPEN
	DRVR ALM	DRIVER ALARM

*ONLY OCCURS THE FIRST TIME DETECTED UNLESS RESET BY ENTRY INTO ROUTE

FIG. 2-72 VEHICLE RECENT HISTORY PRINTOUT FORMAT

DATE - 31 FEB 1976

VEHICLE NO.

927	ALERT	26TH / SOTO	/ VERNON	10:40	(SEE FORMAT #1)
927	ALARM	26TH / SANTA FE	/ VERNON	01:30	DRV ALM

FIG. 2-73 NORMAL PRINTOUT

G. Dispatch Station

The cargo security program utilizes two identical dispatch stations for the purpose of displaying and printing vehicle location and status data to dispatcher and security personnel.

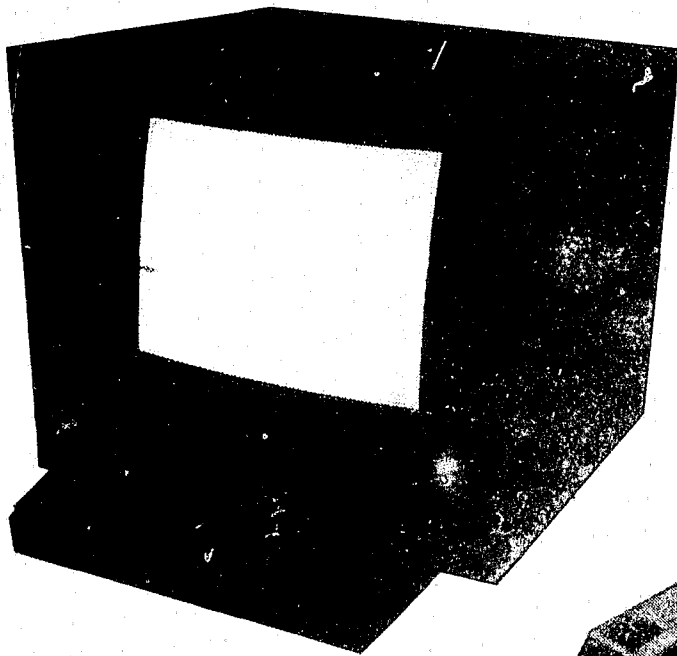
Each dispatch station is comprised of a primary terminal, a communications modem for interfacing the primary terminal to the base station, a printer, and a secondary display terminal (Figure 2-74. Note: composite picture of all 3 units).

The primary terminal incorporates a microprocessor for local processing and control, and forms the interface with the base station via landlines and modems.

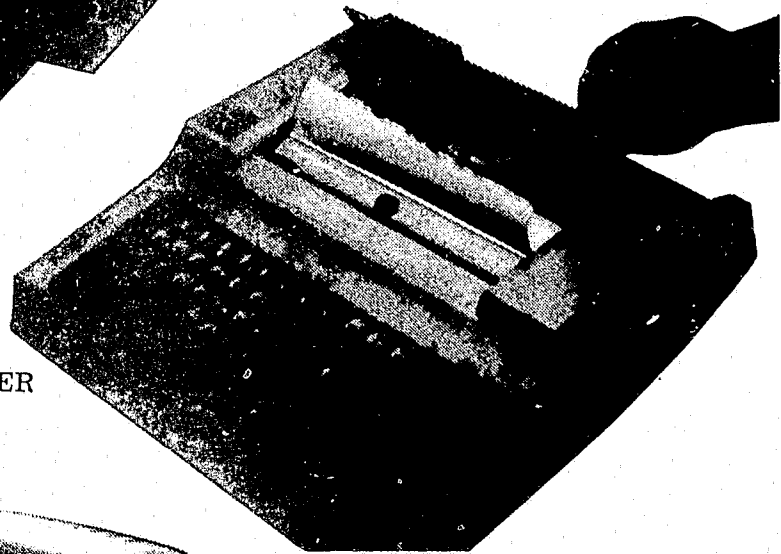
The display and printer formats are structured to meet the operational requirements of a trucking company for vehicle status reporting and retrieval of operating histories. These formats and the system control procedures are detailed in the system operations manual (Appendix A).

1. Overview. The dispatch station hardware which is used at each trucking company's site is shown in the block diagram of Figure 2-75. This hardware interfaces to the base station computer over leased telephone land lines through a Bell 202F, 1200 bit per second modem.

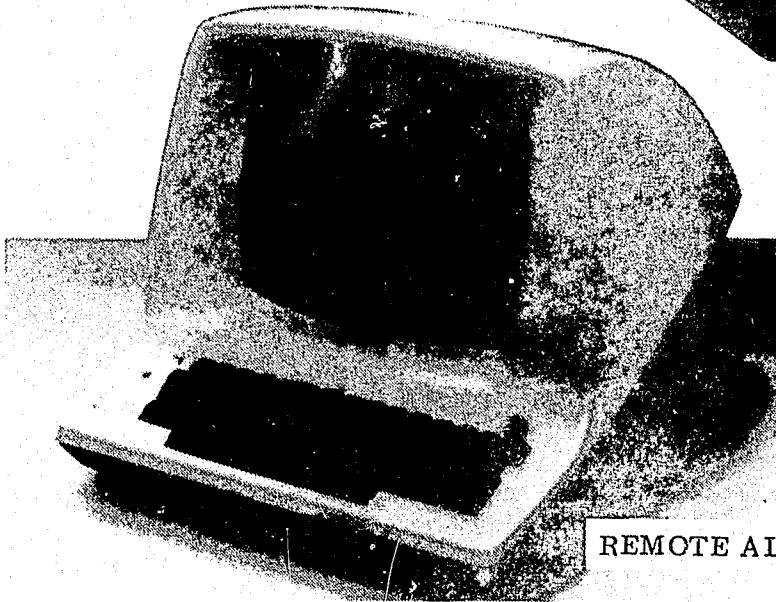
By using an intelligent terminal as the main data processing unit at the dispatch stations, it is possible to use low speed modems and still provide the correct display for dispatcher viewing in a fraction of a second. This is accomplished by having the base station computer continuously send small data packets of update information over the land lines to the microprocessor in the terminal. The microprocessor, which continuously monitors for such data, packs the incoming packet in its own files in the terminal.



DISPATCHER CRT



PRINTER



REMOTE ALARM CRT

FIG. 2-74 CARGO SECURITY DISPATCH STATION EQUIPMENT

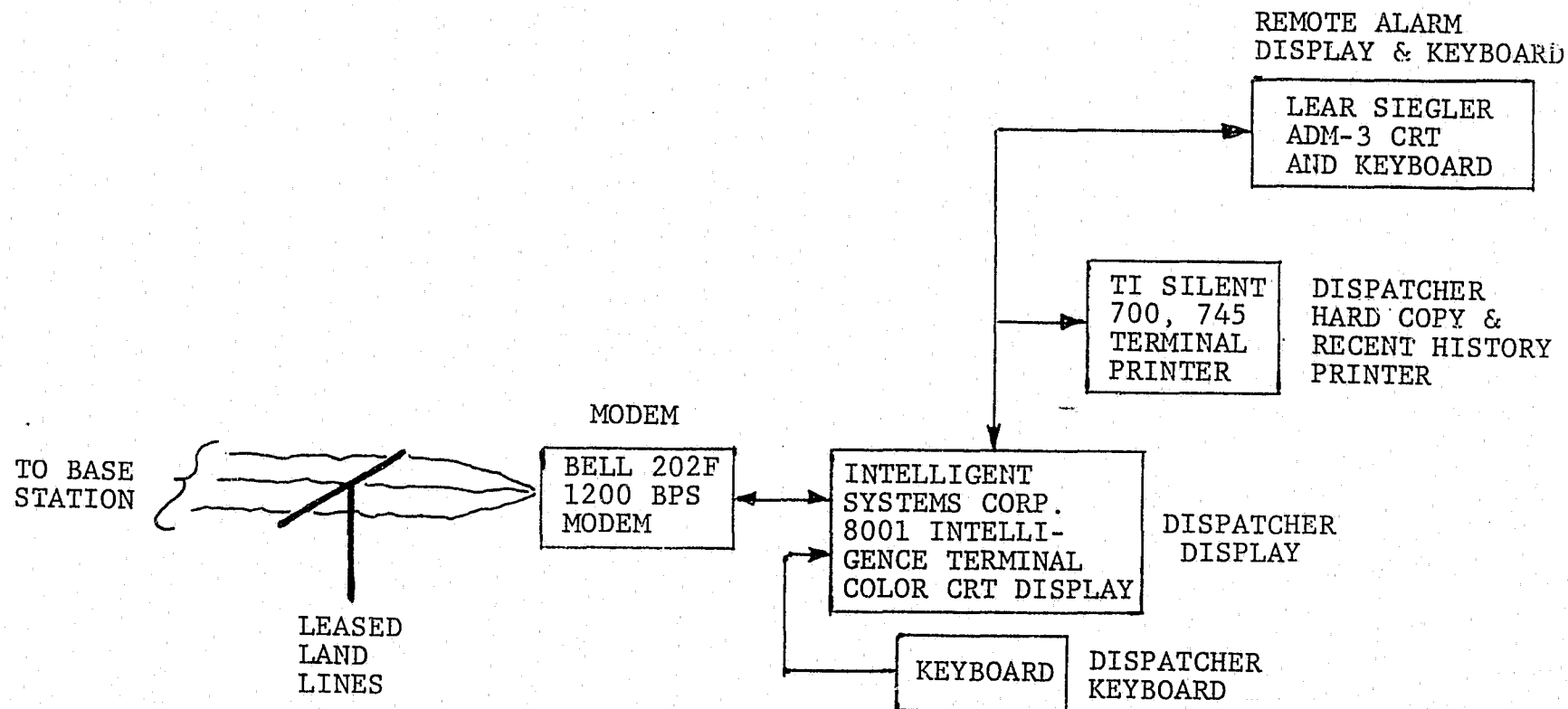


FIG. 2-75 DISPATCHER STATION HARDWARE BLOCK DIAGRAM

Upon receipt of a base station command to change the display or upon receipt of a significant new item of alert/alarm information, the microprocessor automatically retrieves the information from the stored file and displays the information on the screen for the dispatcher.

In the case of the alarm update, the microprocessor also enables a "beeping" bell to further call attention to a changed condition on a truck so the dispatcher will be aware of an imminent cargo theft situation so he can take appropriate action.

The microprocessor further takes the updated information in its files and distributes it through an I/O port to either the remote alarm display or to the TI Thermal printer where the alert/alarm information is printed as hard copy.

The most significant item of equipment in dispatch hardware is the intelligent terminal. This terminal is manufactured by the Intelligent Systems Corporation and employs an 8080 microprocessor to perform the functions described above. It has a high quality, flicker-free display which employs either colors in displaying the information to the dispatcher. Thus, by color coding, items of various degrees of importance can be distinguished at a glance.

During normal daytime operation the terminal also transmits over its own I/O port to the TI printer an abbreviated form of any updated display information so that hard copy is available on all previous transactions between the dispatcher and the base station.

Thus, during normal daylight operations the terminal continuously displays the status of all trucks in the system for that one trucking company. (Only trucks for a given trucking company are sent to the terminal for that trucking company.)

By using the keyboard the dispatcher can call information on any one specific truck which might have an alarm system associated with it. The dispatcher can also shut off the bell or call for a summary display of all trucks.

During nighttime operations the remote alarm display and keyboard is used (although it links to the same terminal I/O port as the printer). The terminal hardware and software automatically distinguishes if the information is to the printer or to the remote alarm by means of differing data rates. The I/O port in the intelligent terminal is programmable as to data rate under program control. Thus, by setting a high data rate to the remote alarm display, the printer will ignore it because the printer is set by switches to accept only low data rate data. Conversely, by reprogramming the I/O port to a low data rate for the printer, this data is rejected by the remote alarm because the remote alarm CRT is set by a switch setting to accept only high data rate data.

The remote alarm display contains a keyboard as an integral part of it for use in the after hours mode by security personnel who may call up different displays for remote alarm status of various trucks as well as shut off the bell and other functions.

In summary, the dispatch station hardware consists of five major items: the modem interfacing the display station to the base station, the intelligent terminal interfacing to the modem and to all the remaining three peripheral items (keyboard, remote alarm display/keyboard, and the TI printer).

2. Intelligent Terminal Software. This subsection describes the software used in a functional form, and includes detailed flow diagrams of each of the modules. A detailed program listing appears in the appendix volume III.

It should be noted that since there was no assembly available from ISC for this software, the code is all in Hexadecimal Machine language, and the listings provided in the appendix reflect this level of coding.

a. Functional Description. Figure 2-76 is a flow diagram of the overall system operations. The operation is divided into two parts: start-up and normal operation. The color terminal at the dispatch station starts up independently of the base station and must be initialized as the first step of the start up procedures. When power is first applied or the CPU Reset key is struck, the ISC is disconnected from the base station, and the following procedure is employed, to connect the system:

(1) Establish communication. This is done by putting the terminal in the half-duplex mode (it comes up as stand-alone). This is the ESC,H sequence of keys.

(2) Parity must be disabled since the base does not check for parity. This is the CNTRL,N sequence of keys.

(3) The modems are 1200 CPS. Since the terminal comes up after CPU reset at 9600 BPS the baud rate must be changed. This is the ESC,R4 sequence of keys. This is followed by a four-character password. The first character actually received at the base station are the R and then the password. This alerts the computer to expect the remaining proper sequence. An incorrect password is ignored and the CPU reset must be done again.

(4) Parity is re-enabled (CNTL 0) and

(5) the device I/O byte of the microprocessor is initialized to expect commands and data from the keyboard. This byte must be changed to allow the computer to command the terminal. This is the long sequence ESC,P, S, F. 9, Ø, ØØ, CR . The ESC P causes no

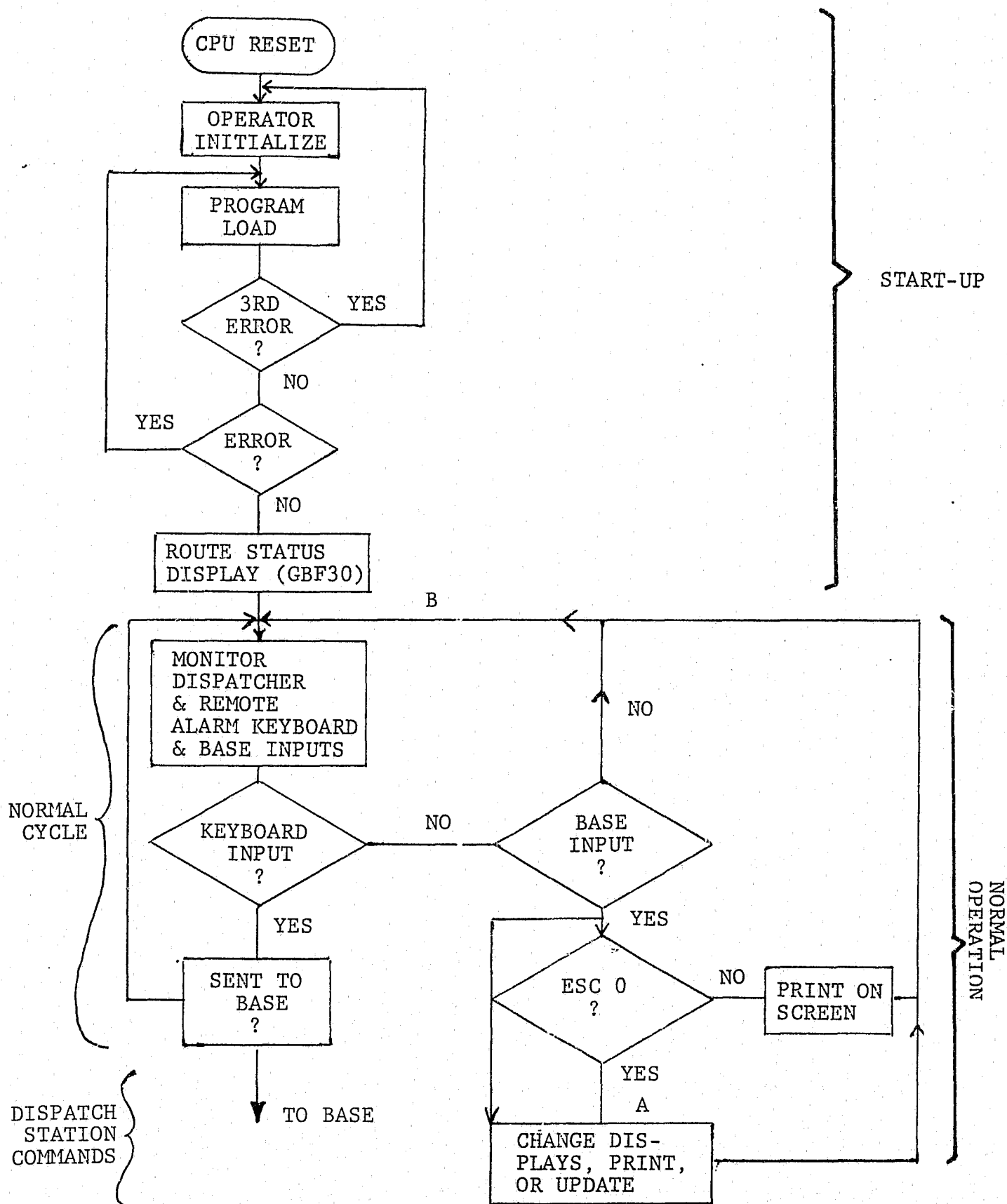


FIG. 2-76 OVERALL FLOW DIAGRAM

characters to be transmitted to the base until the carriage return. This switching of devices causes the keyboard to be disabled from commands to the CPU Operating System. The sequence has also put the terminal into its inherent CPU operating system wherein it is expecting data or commands (from the base station).

(6) Upon receiving the last CR the base computer starts loading the operating program and fills the truck data files. All data (except commands) are transmitted in the Intel Hexadecimal format both in program load and in normal operations. The CPU operating system does a checksum on all incoming data and sends a question mark (?) to the base if an error is encountered. If three errors are detected, the base computer assumes there is a hardware problem and disconnects. The CPU reset procedure is required for a system restart under these circumstances.

(7) Following program load, the base commands the Route Status format to be displayed on the primary terminal.

Table 2-13 summarizes this startup procedure in terms of operator action and display feedback.

The system now enters normal operation. The heart of normal operation is the "normal cycle" routine which continuously checks for a remote alarm keyboard input, a dispatcher keyboard input, or an input from the base station. Any keyboard inputs are sent immediately to the base station computer, following which the checking loop is resumed.

A base station input causes control to be shifted to the CRT operating system (another inherent operating system for normal CRT operations of the ISC) by enabling the automatic interrupts in the "normal cycle" module.

TABLE 2-13 DISPATCHER START-UP PROCEDURE

COMMAND	RESPONSE ON CRT SCREEN
(CPU RESET)	YOU ARE NOW IN THE 8001 CRT MODE = (Note 1: The (=) is the CURSOR and not the equal sign.) (Note 2: You will hear an audible "beep" at this point.)
(ESCAPE)	No Change
H	No Change
(CTRL - N)	No Change (Note: The (-) between two keys means depress both keys simultaneously; in this case the CTRL key and the N)
(ESCAPE)	No Change
R4	No Change
XXXX	These 4 characters are the password. (The X's are different for each Trucking Co.)
(CTRL - O)	No Change (Note: The O is the letter O, not the number zero which is written as a Ø.)
	YOU ARE NOW IN THE 8001 CRT MODE = (Note: This is written in green, purple, yellow, and blue.)
(ESCAPE)	No Change
P	INTERCOLOR 8001 CPU OPERATING SYSTEM - =
S9F9Ø(SPACE BAR)	INTERCOLOR 8001 CPU OPERATING SYSTEM - S9F9Ø 82-= (Note: The second line is written in Red.)
ØØ	INTERCOLOR 8001 CPU OPERATING SYSTEM - S9F9Ø 82-ØØ -
(RETURN)	No Change, until route status Display appears.

This CRT operating system will cause the character received from the base station to be printed on the screen and then return the system to the normal cycle. If the received characters for the sequence (ESC 0), the CPU operating system awaits data to be filled in memory or dispatch station commands to be given. These data can be truck status update, data to be printed, data to be sent to the remote alarm or a truck identification number for the Security Status Display. The commands and their functions are discussed later in this section.

b. File and Buffer Operation and Layout. The program is organized around two buffers and 1 file. The first 256 byte buffer starting at B200 Hex is for printer or remote alarm data. It is loaded directly by the base station computer. The second buffer is at B300 Hex and is also 256 bytes long. It is also loaded directly by the base station computer with updates on truck information of the truck number for a Security Status display.

The file is organized into two basic parts. The first or "variable" file between A100 Hex and ACDO Hex is composed of 25 subfiles each 126 bytes long. (See Figure 2-77). Each sequenced subfile is a different truck and contains all pertinent information on a specific truck.

The first byte of any "variable" subfile is the alert/alarm color to be displayed on either of the two possible displays as a color bar. The vehicle number designated by the trucking company, vehicle make, model, license number, accumulated daily mileage route, mode (normal or remote alarm) are all eight-byte sub-subfiles with a \$ as the terminating character.

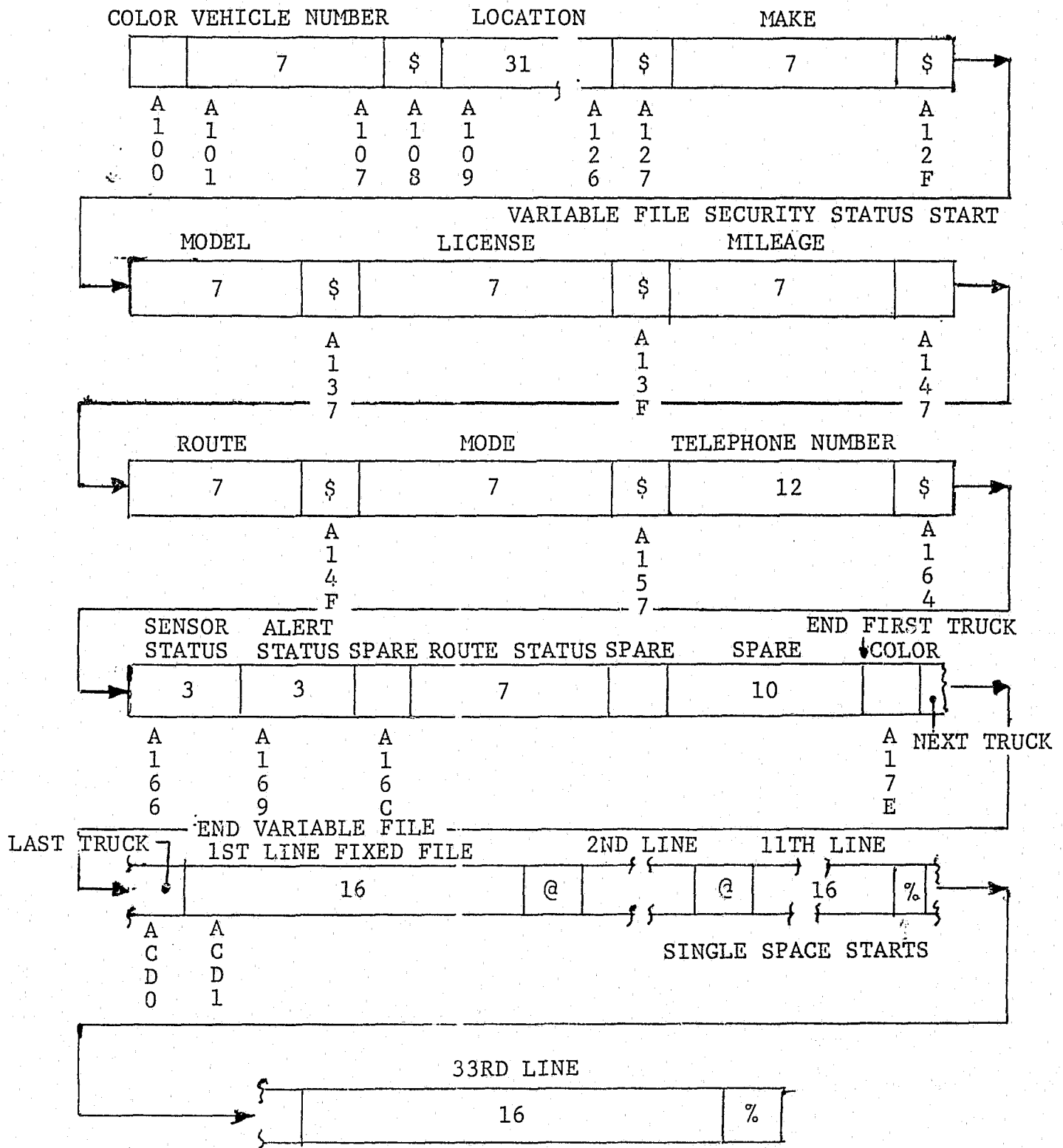


FIG. 2-77 TRUCK FILES MEMORY LAYOUT (VARIABLE AND FIXED)

Truck location data is a 31-byte subfile and the city police telephone number for that truck location is a 12-byte subfile, next is a 6-byte sub-subfile of sensor and color information to be displayed on the Security Status Displays followed by 7-bytes for route status (O.K., Alert, Alarm, etc.) and 10 bytes of spare are also present. The last three of these do not require the \$ termination.

After the variable file, the "fixed file" comes next between ACD1 Hex and AFO2 Hex. This consists of 33 subfiles each 16 bytes long which contain the fixed display information. The first 10 are terminated with the @ (double spaces on display) character and the rest with % characters (single space on display).

All termination characters are interpreted differently by the main program as discussed later in this section.

c. Dispatch Station Commands. Figure 2-78 provides an overview of the basic executive scheme. When an ESC 0 sequence from the base is received, the inherent CPU operating system allows loading of data directly into either of the buffers. The base station then sends GBFXX commands. These are G, or Go-to commands which cause the resident program to begin execution at the various BFXX memory locations. The 7 GBFXX functions may be summarized as follows:

GBF10--A no-op command causing program control to be given to the "normal cycle" routine. (See Figure 2-79).

GBF40--A subroutine call from the resident program to the subroutine "BEL" which is incorporated in the CRT operating system. This, in turn, causes the bell to beep once and then returns to the normal cycle (as all routines do).

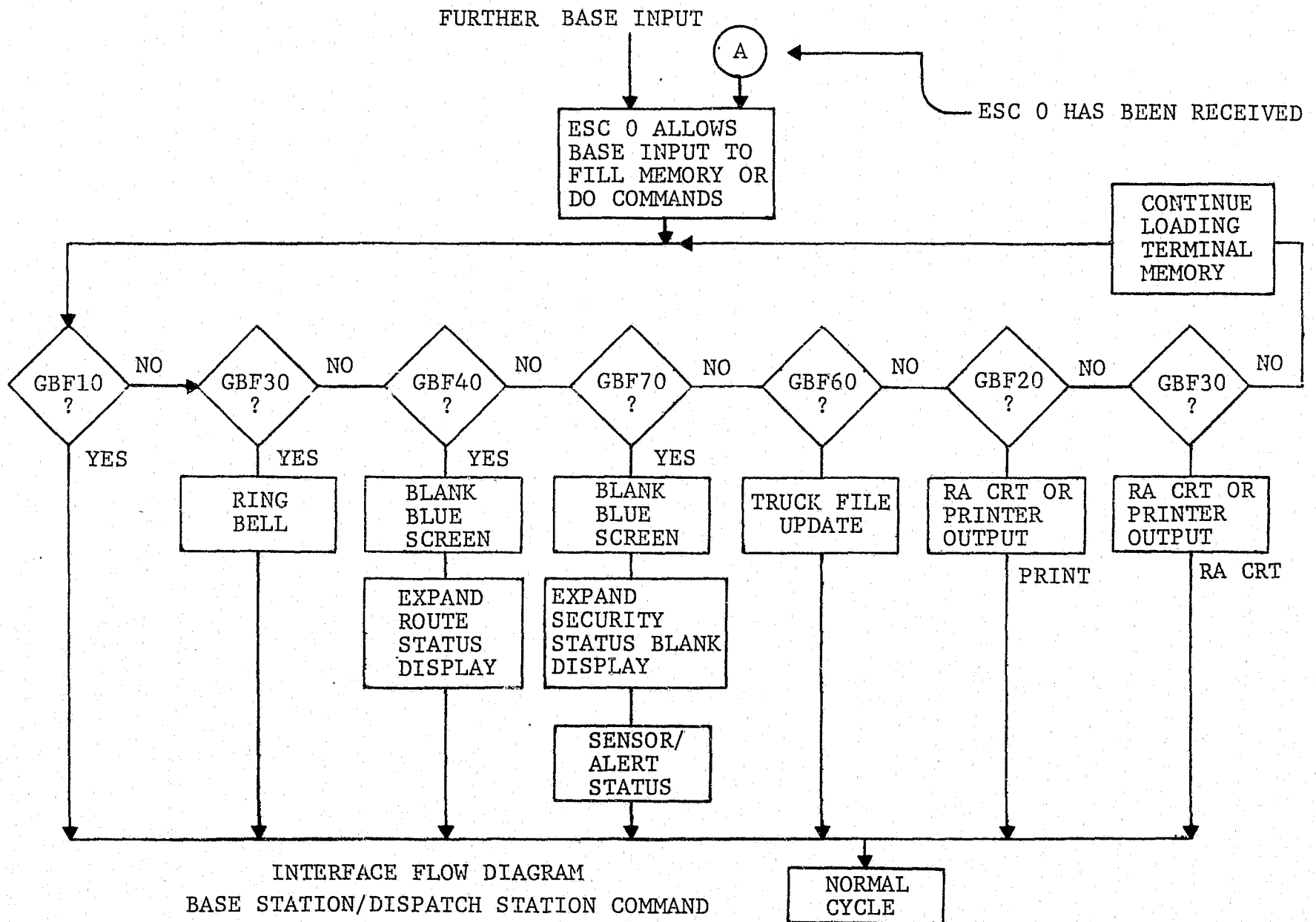


FIG. 2-78 DISPATCH STATION COMMANDS

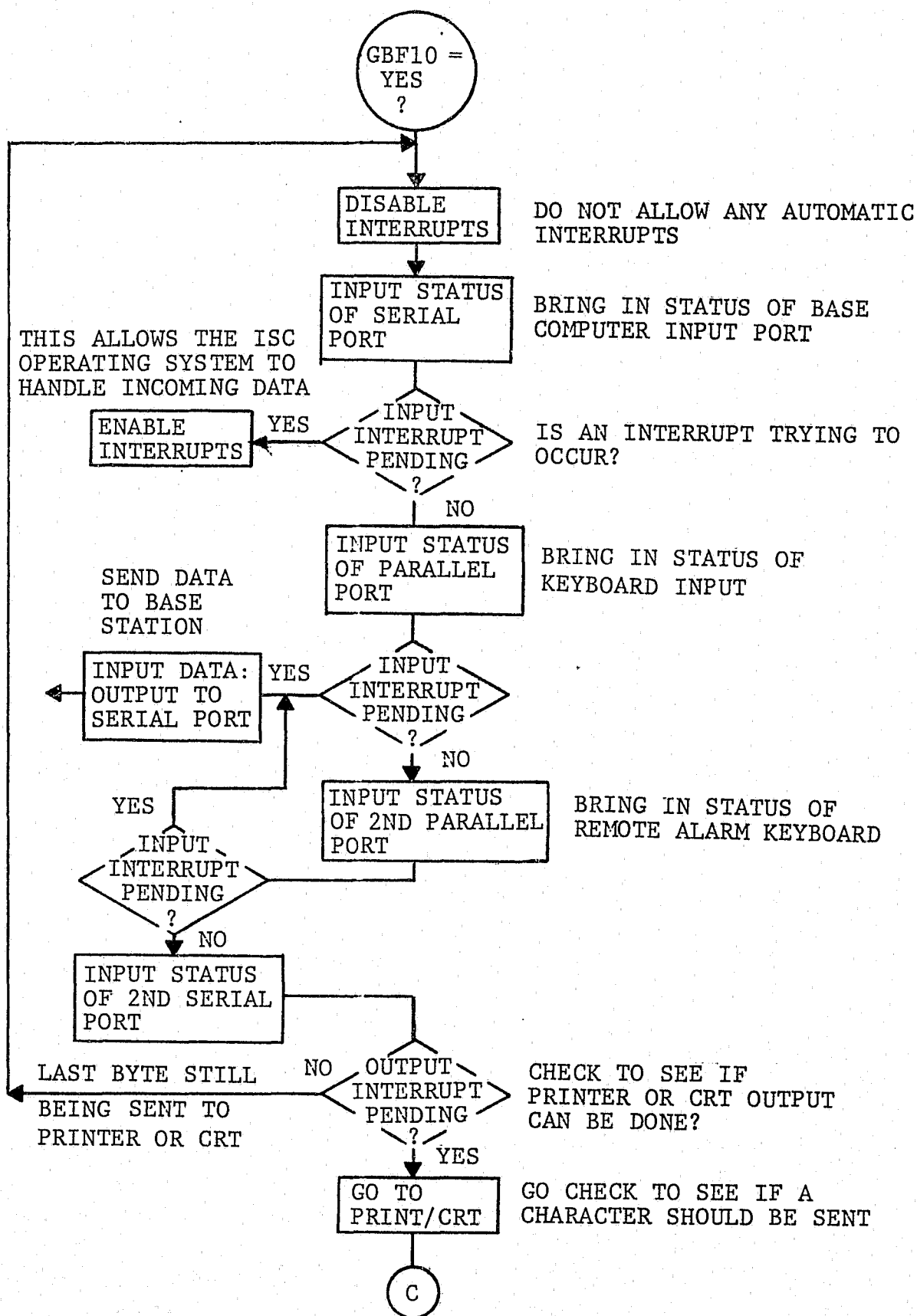


FIG. 2-79 NORMAL CYCLE

GBF80--This initially calls the "blank blue screen" routine which paints the screen with a light blue background. The "route status expand" then prints dark blue characters on the screen. It retrieves needed information from the "variable" file as needed to construct the Route Status display, then accesses the fixed file and variable file to construct the appropriate Security Status display as above. It next enters "Sensor/Alert" which deletes the unused sensor states and forms the Alert/Alarm color bars.

GBF60--This is entered after the base station has loaded the status buffer at 3300 Hex. The program transfer this information to the correct variable file.

GBF20--This is entered after the print buffer at B200 Hex has been filled by the base station. The program then transfers the data via the 2nd ISC port to the printer after setting the base rate to 300 BPS.

GBF30--This program is identical to GBF20 except for a different entry point which sets the baud rate to 9600 BPS and thus causes the data to be displayed on the CRT.

All programs return to the normal cycle which then checks continuously for further keyboard or base inputs.

d. Detailed Module Description. Referring to Figure 2-78, the operation of the various modules is as follows.

" No-operation (Figure 2-80) - The function of this module is to transfer program control from the inherent CPU operating system to the normal cycle of the resident program and consists of a go-to statement to the starting address of the normal cycle.

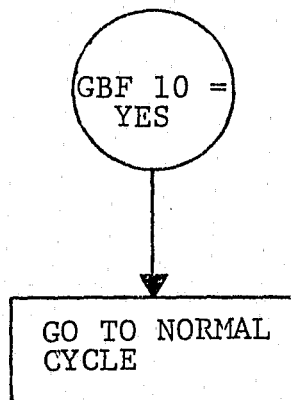


FIG. 2-80 NO OPERATION

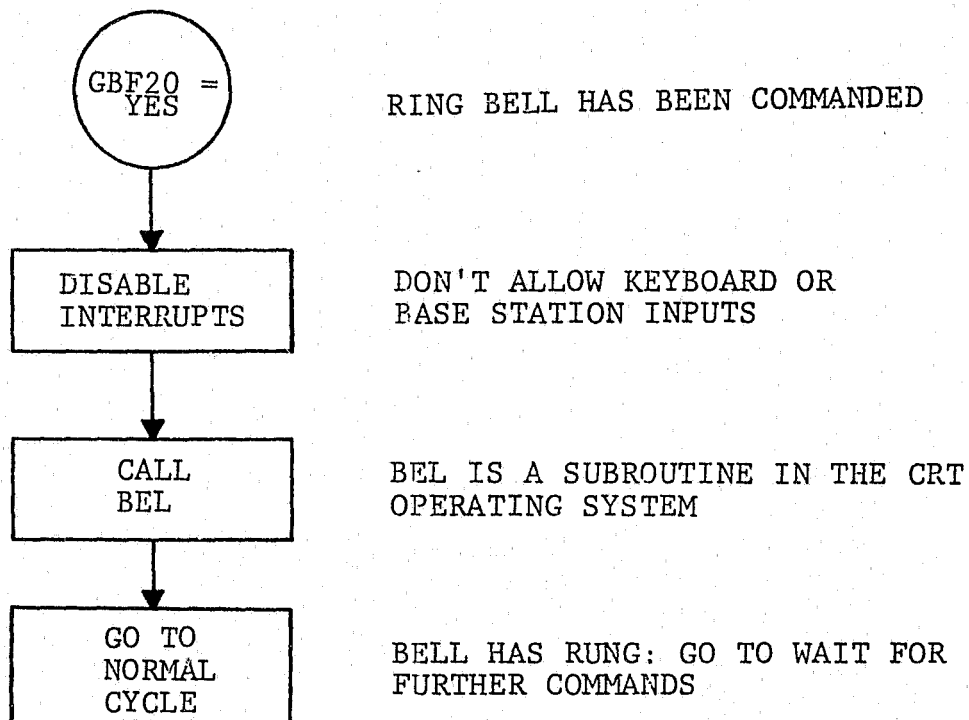


FIG. 2-81. RING BELL

Bell Module (Figure 2-81) - Upon receipt of the GBF20 command from the base station, the resident program first disables the interrupt so that any keyboard interrupts cannot cause the program to lose control. A call is then made to the BEL program which exists in the ISC CRT operating system. This subroutine causes the bell to ring once and then returns to the normal cycle mode.

Screen Subroutine (Figure 2-82) - On receipt of either GBF30 or GBF40 commands a call is made to this module which paints the whole face of the screen in light blue background color in preparation for the dark blue characters to be placed on the screen. A screen pointer is first set up to point to the memory location corresponding to the left hand corner of the screen for the background byte that will be the light blue background color of that particular screen location. Two counters are then set up to enable the counting of 48 lines display and the 80 character positions of each line. A blank foreground character is then moved to that screen location so that any existing character that is there will be removed and the background color for that screen, "cyan" or light blue, is then moved to the next byte which corresponds to the background color of that screen location. The screen pointer is incremented by 1 and this process continues until all 80 characters on that line have been painted a blank light blue (cyan) color. The line counter is then decremented to go to the next line and the above process is repeated to color the light blue background color in the next line. This process is also continued until all 48 lines of the display have been colored a light blue at which time return is made to the calling module.

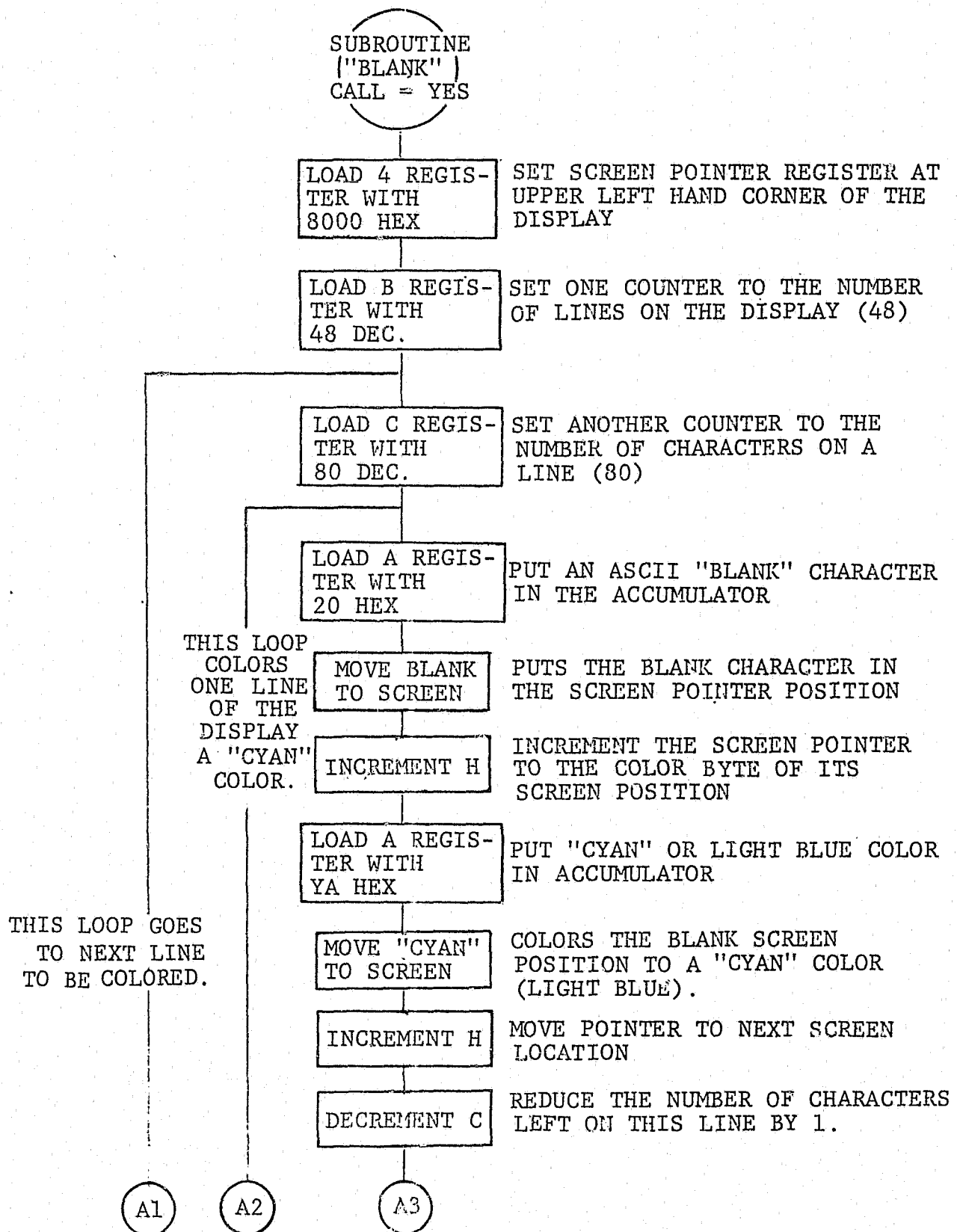


FIG. 2-82 BLANK BLUE SCREEN

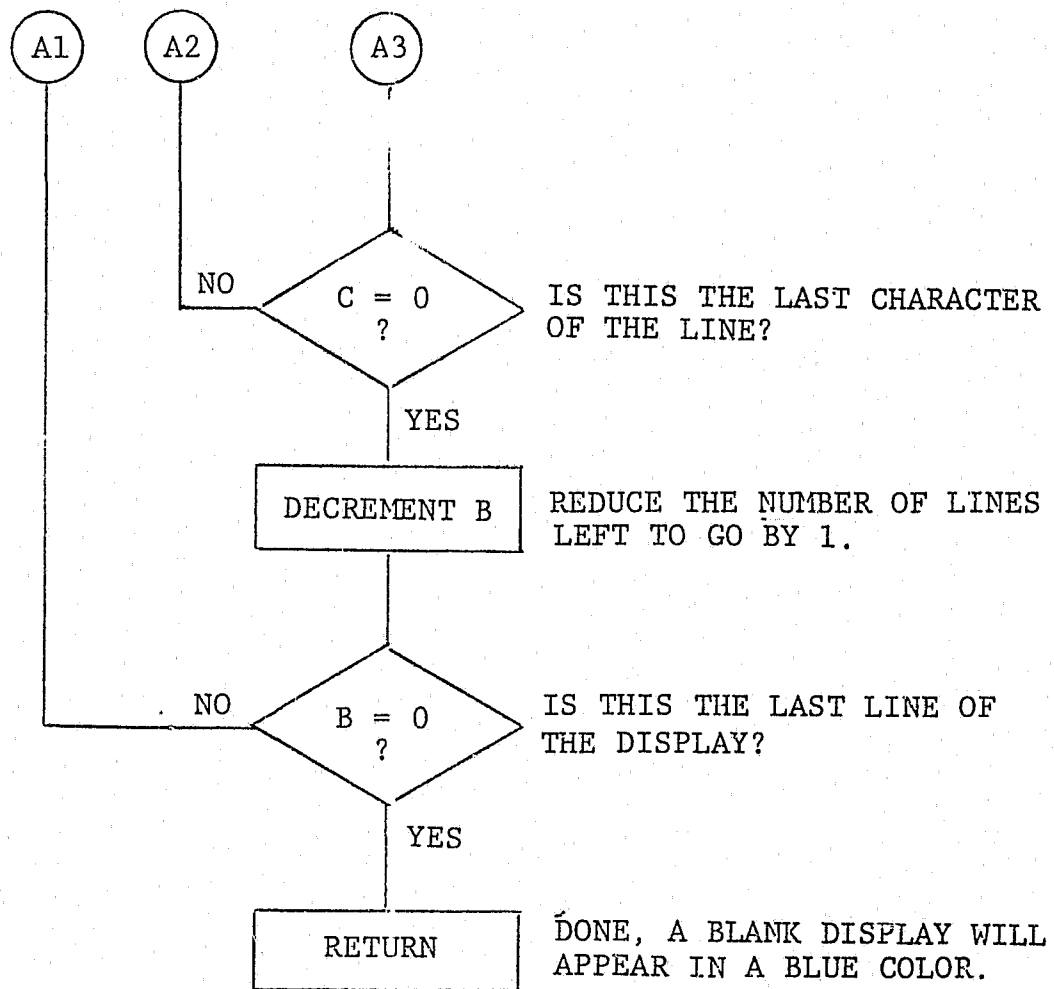


FIG. 2-82 BLANK BLUE SCREEN (CONT.)

Expand Route Status Module (Figure 2-83) - This module displays characters corresponding to a particular route status situation for up to 22 trucks on the blank blue background described above. The screen pointer is first initialized to the left upper screen position and one line down and the starting busfile memory locations corresponding to color alert status, truck number, location, and alerts/alarms are stored in registers. Seven blank characters (the color of which correspond to the color byte) are placed on the screen at this time giving the color bar with the color corresponding to the alert/ alarm status of that particular truck. The truck number subfile pointer is then entered at the subfile location discussed above and seven characters are transmitted from the truck variable file to the next seven screen locations. This shows the trucking company truck number on the screen. Seven blanks are then left on the screen and 29 characters of truck location are then printed in a similar manner. This is followed by 18 blanks after the location at which time the alert/alarm status such as O.K., alarm, alert, etc. is printed on the screen. The screen pointer is then forced to increment a line to provide double spacing. The truck subfile address pointer locations for the above four subfiles are then incremented by 126 to cause the next truck in the file to have its information printed on the screen. The number of trucks corresponding to the line counter initialized at the beginning is incremented by 1 so that the next truck in the file can be printed on the screen. As soon as whole routine goes through the 25 counts it was initialized at, the screen has all the 20 trucks' status on it and then returns to the normal cycle.

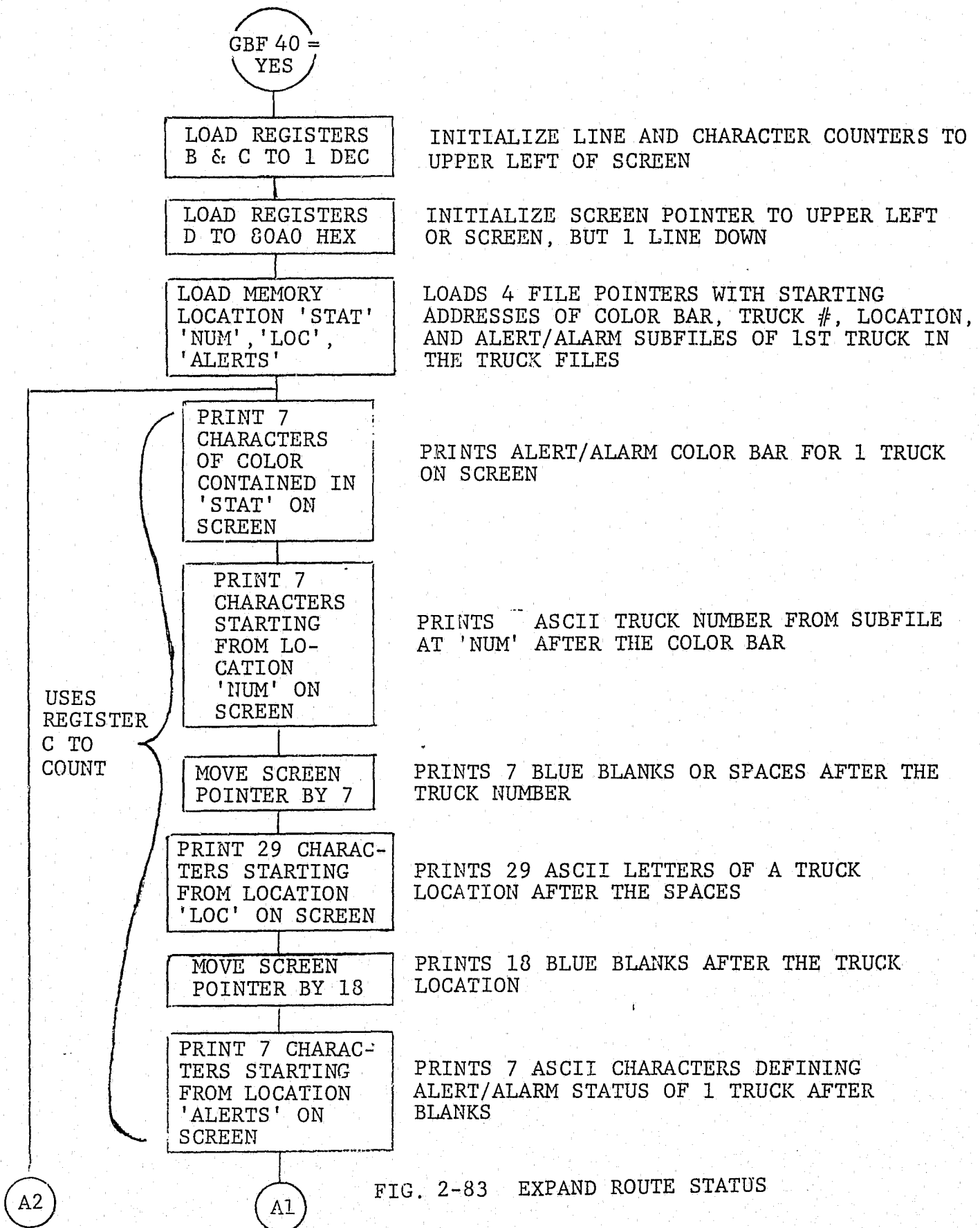


FIG. 2-83 EXPAND ROUTE STATUS

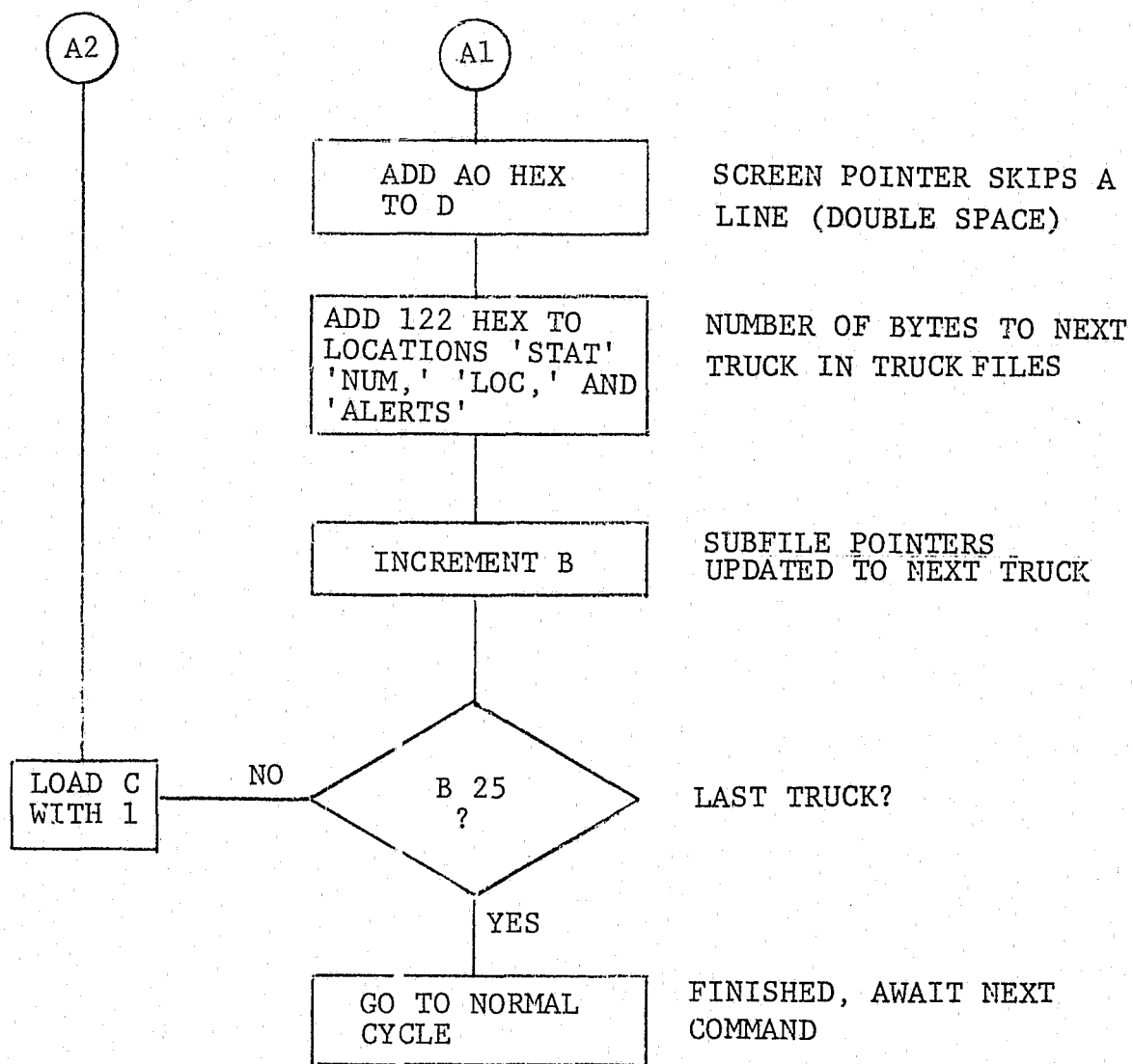
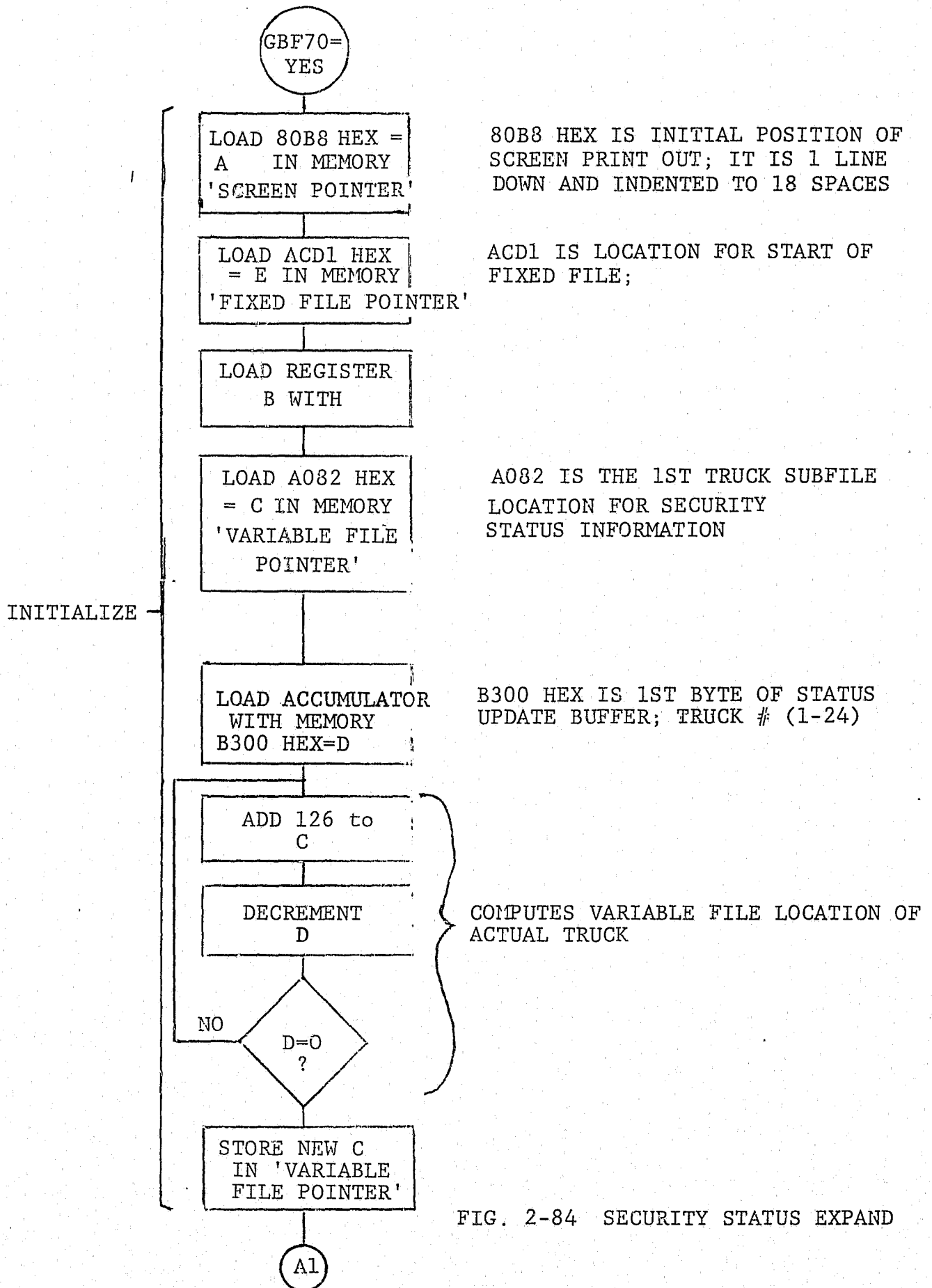


FIG. 2-83 EXPAND ROUTE STATUS (CONT.)

Expand Security Status Display (Figure 2-84) - After the blank blue background is put onto the screen this module is entered if the command was GBF40. There is an extensive amount of initialization because data must be taken from the variable file associated with the file truck number in the status buffer at B300 Hex. In addition, there is a fixed file which contains in sequence all the information which is to be printed onto the security status display for each and every truck, and this must also be initialized. The computation is then made to locate the starting of the variable file information for the particular truck in question in the status buffer. Information is stored in the variable files with terminating characters at the end of each subfile of the variable file and fixed file associated with that truck. The first twelve lines of the screen are printed and double spaced. The fixed file information on the left of the screen is taken from the fixed file. As soon as the ampersand terminating character of the fixed file is reached, the logic picks up the location of the first subfile of the variable file information for that truck. It starts printing it on the same line as the fixed file subfile was printed. It continues to print until it encounters a dollar sign (\$) terminating character of the variable file as shown earlier in the file description. The logic then switches back to the fixed file to pick up the next item of fixed file information after the screen has been double spaced to the next line. The above logic is repeated until the first percent sign termination character is reached. The percent sign is a terminating character for the sensor states which are printed single spaced on the screen below the truck status double spaced display. At the conclusion of a particular line of data when the percent sign is reached, the screen



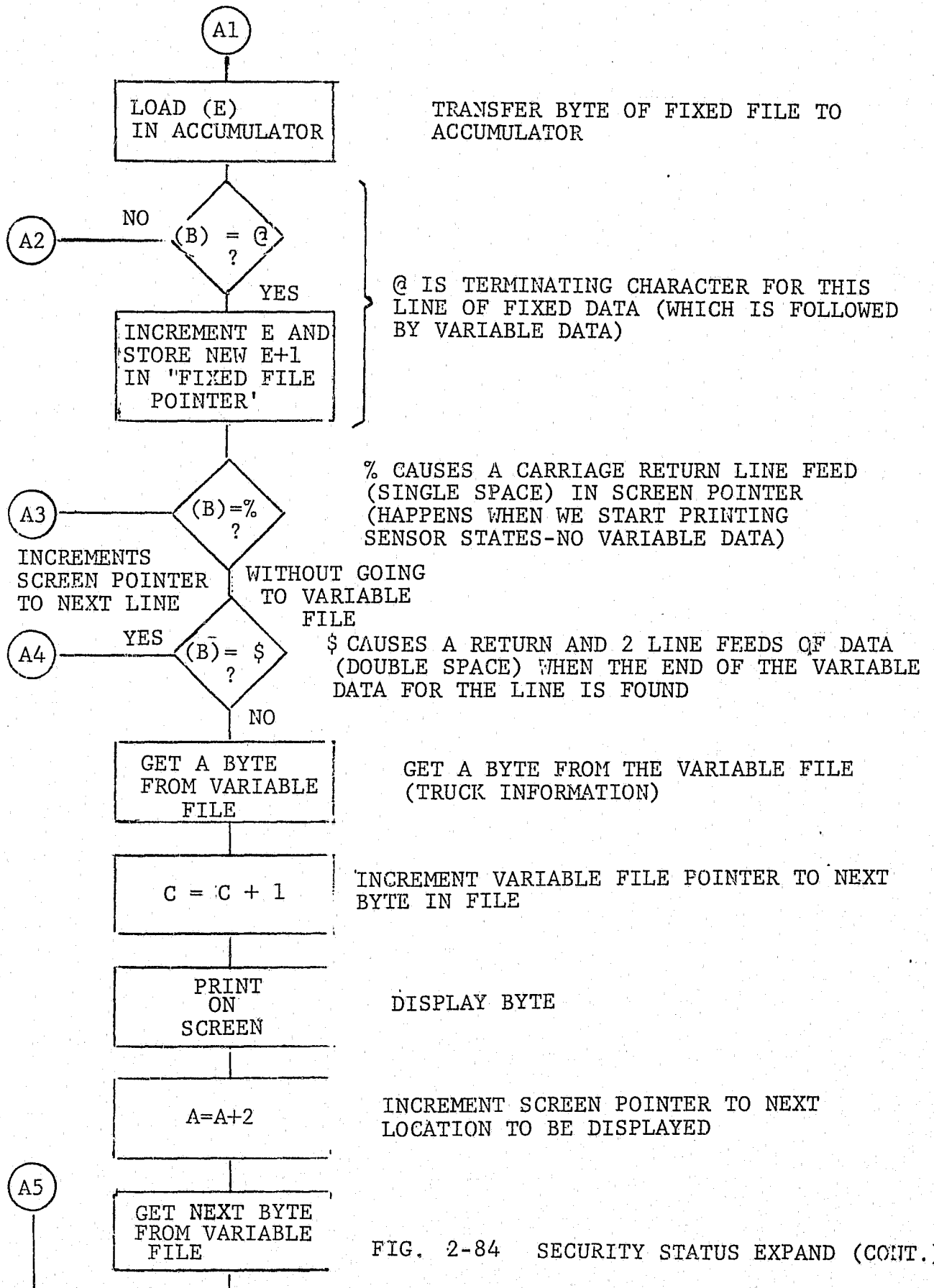


FIG. 2-84 SECURITY STATUS EXPAND (CONT.)

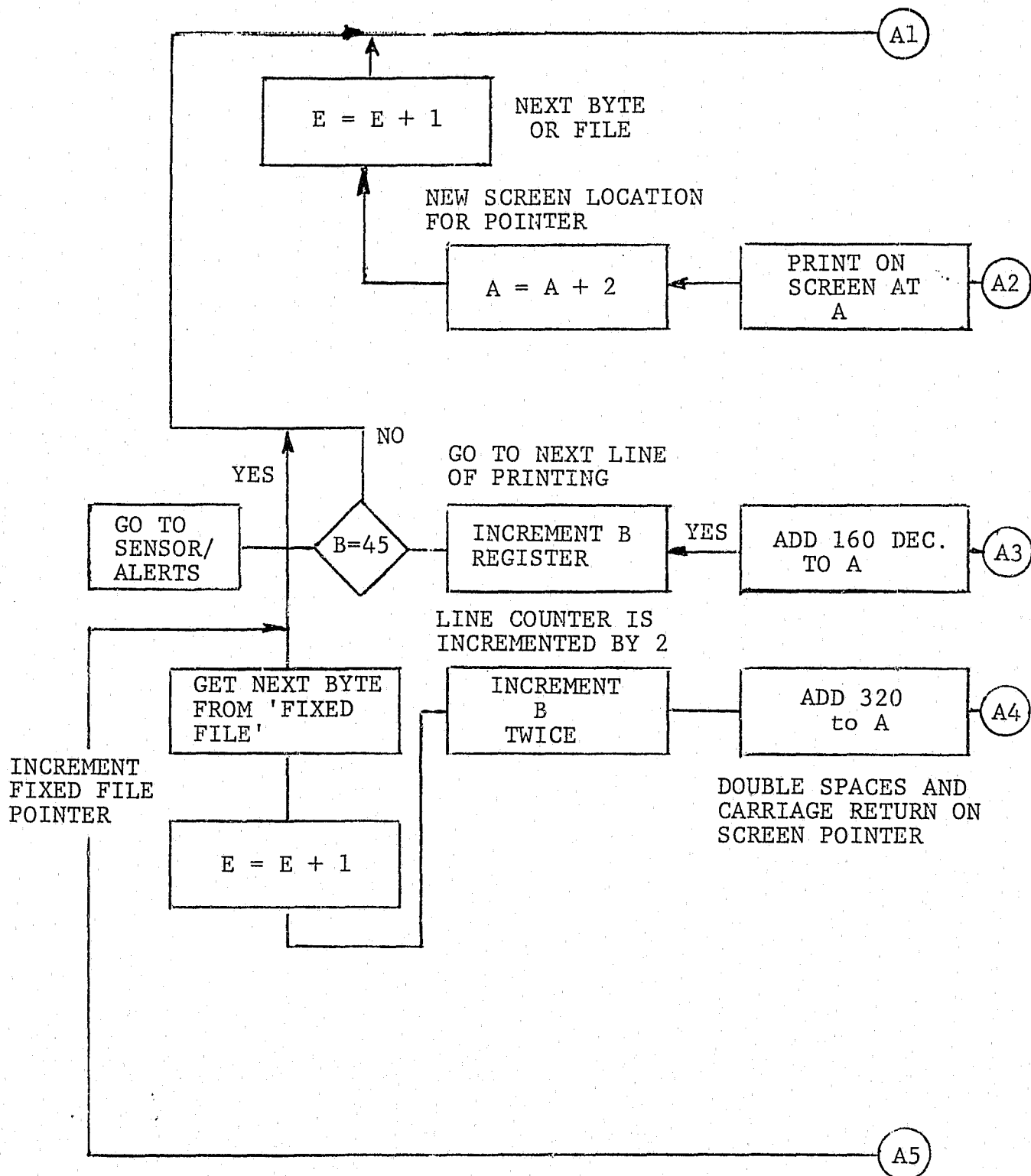
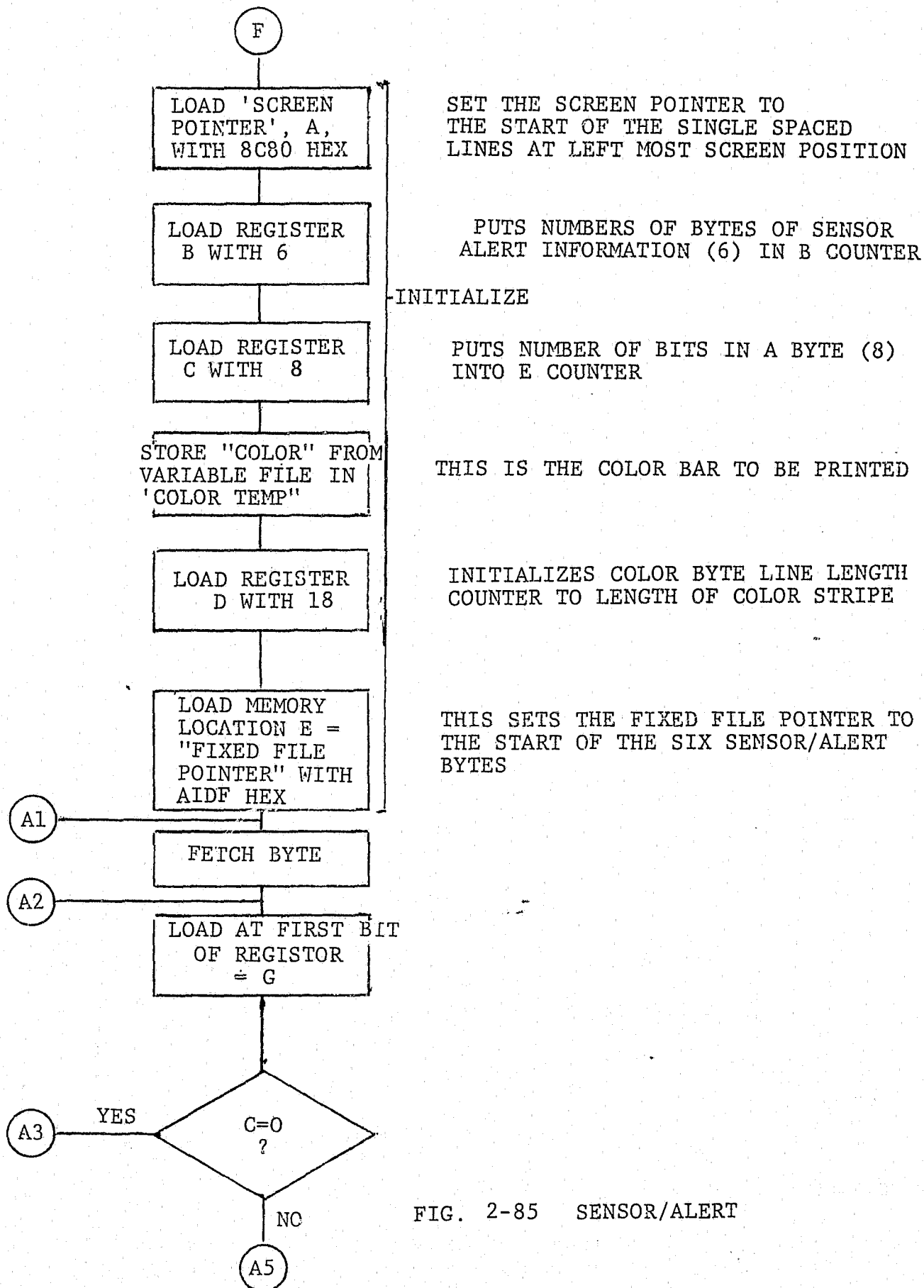


FIG. 2-84 SECURITY STATUS EXPAND (CONT.)

is single spaced and the next subfile of the fixed file is printed onto the screen. This process is continued until 45 lines of data have been printed. The screen at this point appears with all the fixed file information and every possible sensor state (both on and off) is displayed. All variable file information associated with that particular truck appears such as its location, police department telephone number, etc. on the screen correctly. However, since sensors cannot be in two states at once, one line associated with every sensor must be erased. Further, the color bars printed to the left of any given sensor need to be printed in order to show which sensors caused the alert condition.

At this point, the module exits to the sensor/alert module shown in Figure 2-85 which accomplishes the erasing of lines and the coloring of bars. There are six bytes per file which are associated with these two functions of erasing lines and coloring in bars. The first three bytes (or 24 bits) define which 24 lines need to have color bars printed beside them. A one state defines that there should be a color stripe, a zero state defines that there should not be a color stripe. After the system is initialized by pointing the screen pointer to the upper left of the screen, by locating the first byte of the six, and setting up the registers to the print the color stripe, the first bit of the first byte is examined. If it is a "one", 18 characters of color taken from the color status byte of that truck's variable file are printed on the screen. If the byte is zero the screen pointer is shifted down to the next line. The next bit of the byte is then examined. When 8 bits have been checked the next byte is transferred for examination and the process is repeated. When the first three bytes have been examined, a different mode is entered



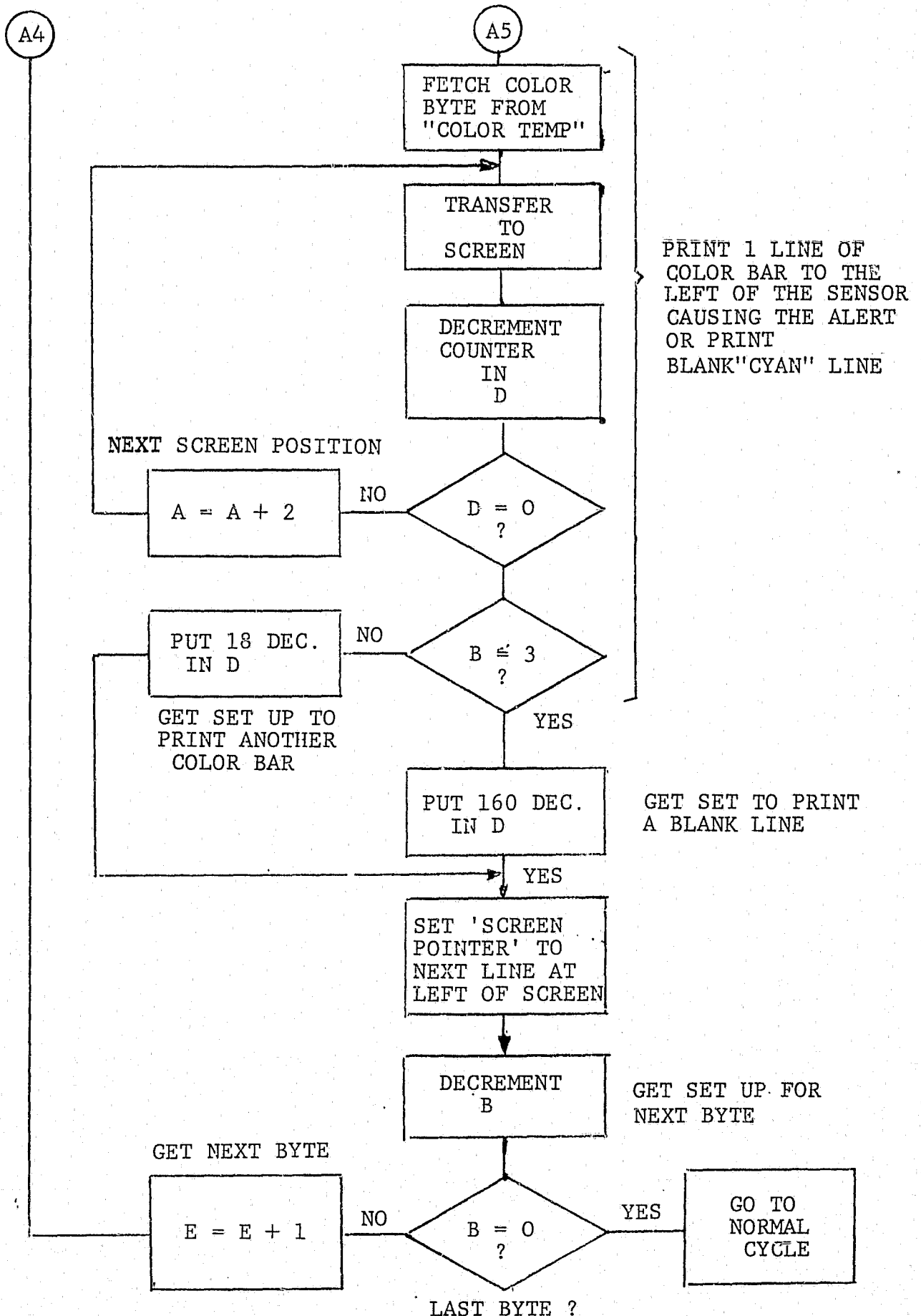


FIG. 2-85 SENSOR/ALERT (CONT.)

CONTINUED

3 OF 4

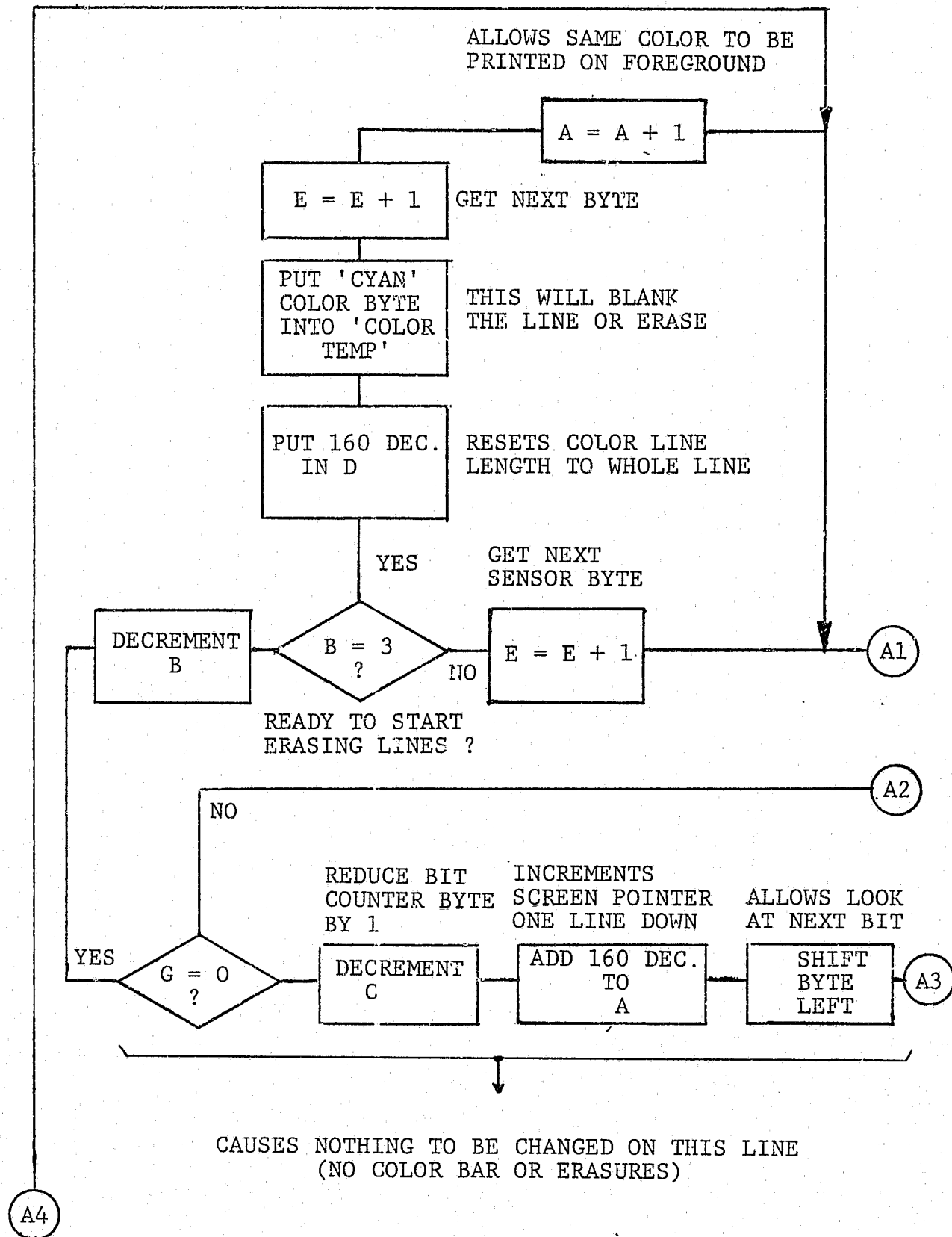


FIG. 2-85. SENSOR/ALERT (CONT.)

whereby instead of color bytes these 24 lines of sensor status data are either erased or not erased according to the status of each bit. There are three bytes of 24 bits to state whether these 24 lines should be erased or left as is. After the sixth byte is checked the Security Status display is completed and a return is made to the normal cycle.

Remote CRT/Printer Module (Figure 2-418) - The operation of both these peripherals is identical except that the I/O port they are both attached to is set to a different baud rate for the remote CRT as opposed to the printer. If it is a remote alarm output, the baud rate is set for 9600 bits per second. If it is the printer, the port is set to 300 bits per second.

The first operation performed following the establishment of the baud rate is set is to set a pointer to the first byte of the printer/CRT buffer which contains the data to be transferred. A flag is set indicating that printing is in progress. This flag will be checked at the conclusion of the first pass through the module following which the program returns to the normal cycle and checks that no interrupts from the keyboard are pending. (This is a lengthy module and provisions must be made to allow the operator to command the base station).

The first byte of the buffer is then transferred to the second I/O port if it is not the terminating character. After incrementing the buffer pointer, the normal cycle is re-entered and interrupts are checked for. At the conclusion of one pass through the normal cycle, a return is made to this routine to check if the flag has been set to zero. If it has not, printing continues.

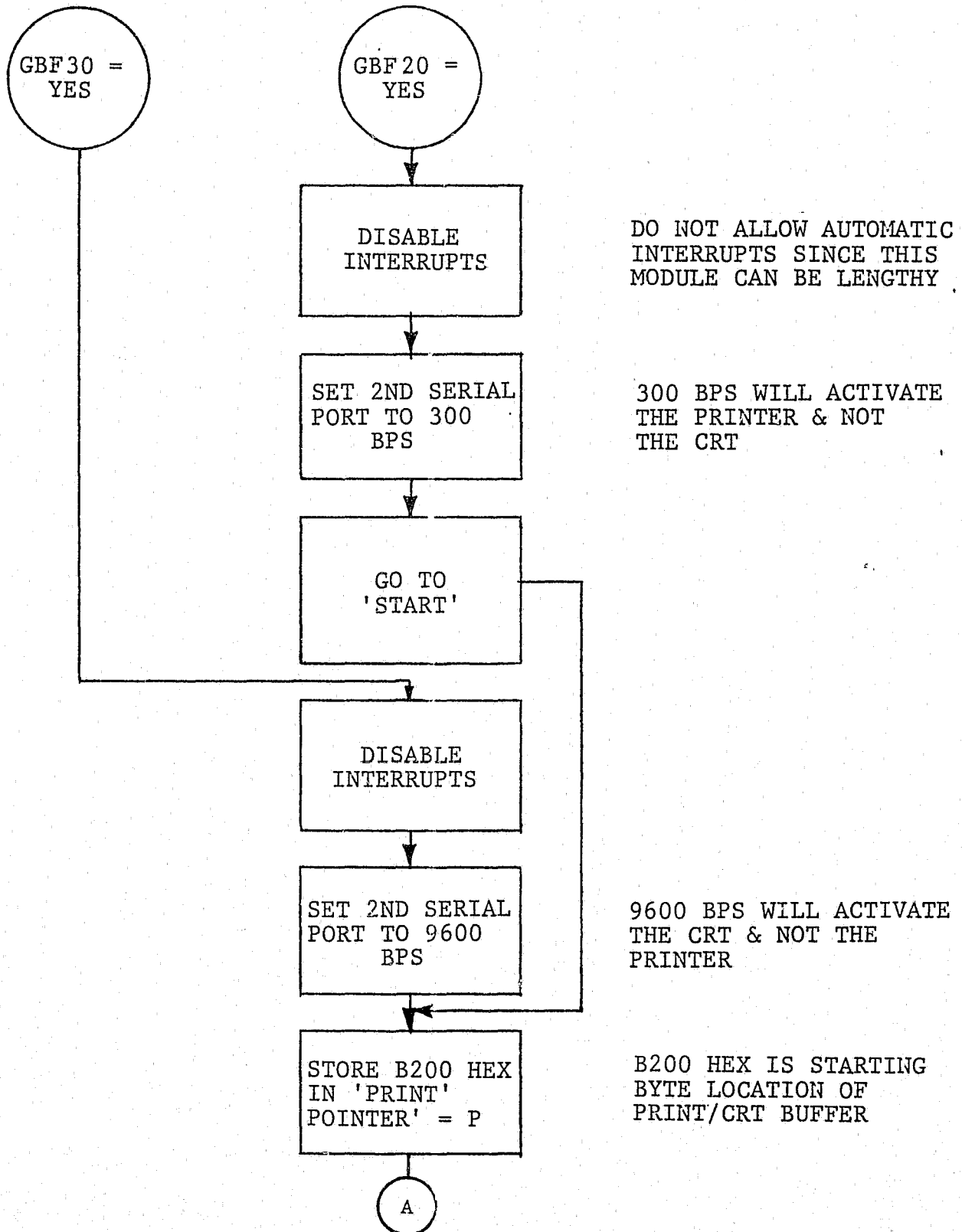


FIG. 2-86 REMOTE ALARM OR PRINTER OUTPUT

THIS ALLOWS KEY-
BOARD OR BASE
STATION POLLED
INTERRUPTS TO
OCCUR

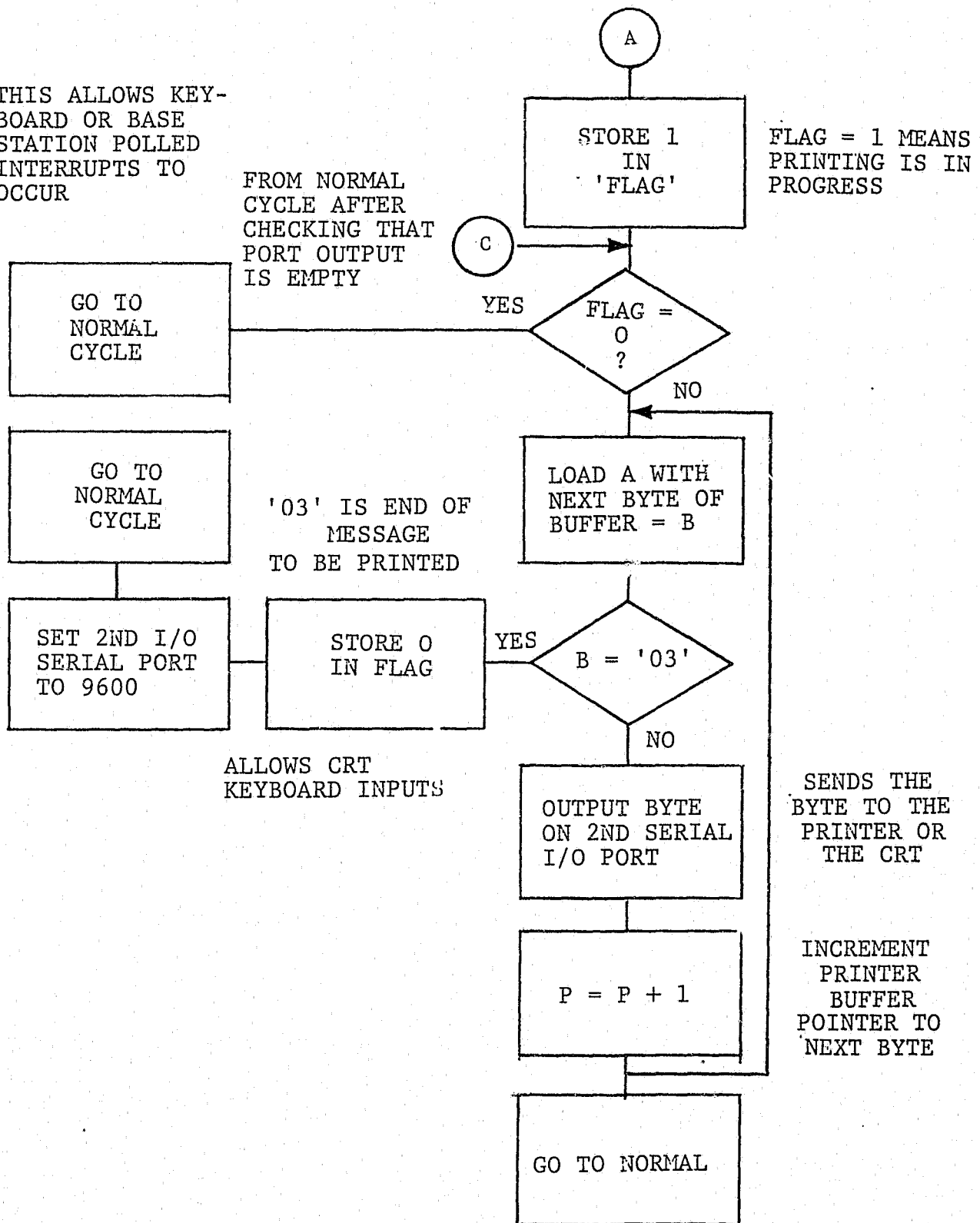


FIG. 2-86 REMOTE ALARM OR PRINTER OUTPUT (CONT.)

This process continues until the terminating character 03 is reached at which time the flag is reset and the baud rate of the second I/O port is set back to 9600 bits per second to allow keyboard input from the remote alarm CRT to be interpreted and sent to the base station. At this time execution is returned to the normal cycle.

Truck File Update Module (Figure 2-419) - This module allows updating of truck information from the base station. The module is entered upon receipt of the GBF60 command. The module picks the first byte of the buffer (which will be the truck number) which defines the subfile which is to be updated. A computation is made incrementing 126 bytes times this truck number so that the correct pointer location can be set in the truck files. The second byte of the buffer is the offset into the subfile to show whether the update information to be location, status, etc. This byte is added to the previous computation to obtain the truck file pointer (after the A100 address defining the start of the file is also added). At this time the third byte is obtained from the buffer to check to see if it is the terminating character for the update information. If it is not, the byte is transferred to the file according to the address pointer. The pointer to the file is updated and the pointer to the buffer is updated and the process is repeated. When the terminating character (ampersand) is reached all the information has been transferred and an exit is done to the normal cycle.

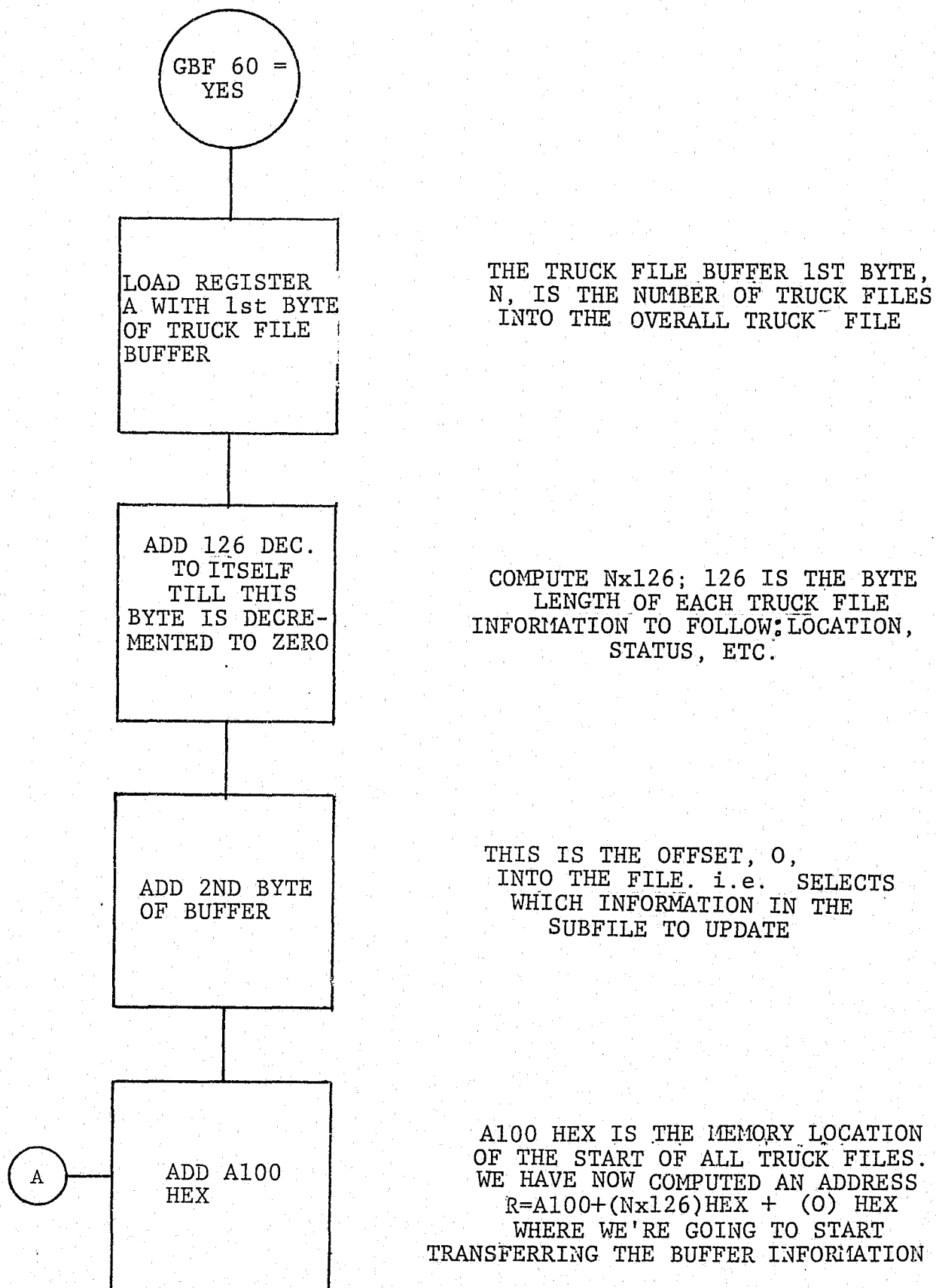


FIG. 2-87 TRUCK FILE UPDATE

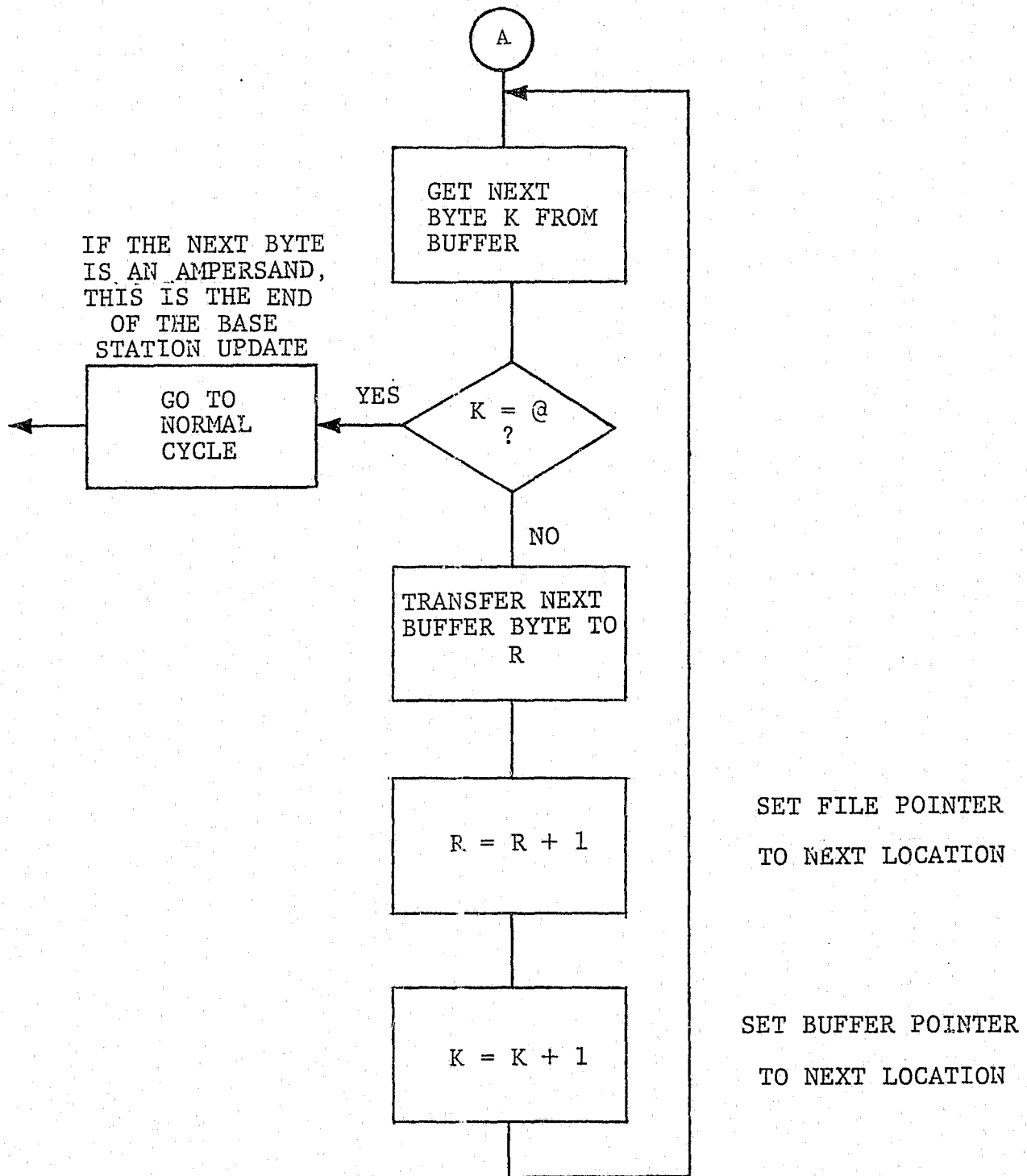


FIG. 2-87 TRUCK FILE UPDATE (CONT.)

CHAPTER III. SYSTEM RESULTS

A. Introduction

From a technical viewpoint, the state-of-the-art of vehicle monitoring has been significantly advanced by the successful development and demonstration of the Cargo Security Field Test System. Implementation of the system resulted in providing an active demonstration of the multi-user, wide area coverage capacity of the system and demonstrated the potential capability of AM Phase-Lock as a vehicle location technology.

The development and subsequent operation of a dedicated, common, mobile radio digital communication link for multiple users was proven viable, useable and operationally acceptable from an end-users standpoint. Furthermore, there were numerous technical firsts achieved with the implementation of the sophisticated, combined data-base-driven and event-driven data processing system which operated in a distributed processing environment.

B. Key Accomplishments

The Cargo Security Field Test Program consisted of outfitting, testing, and evaluating the implemented system which was installed in two distinctly separate pick-up and delivery truck fleets. The system components included 20 vehicles at each trucking operation, a single channel mobile radio communications system, dedicated land lines, a central base station and two remotely located dispatch stations. In addition, a specially designed master phase synchronization unit (rubidium standard) and two slave receiver units were installed at the cooperating AM broadcast radio stations and 256 electronic, pole-mounted signposts were installed to support the

vehicle location system. The system was designed to operate on a 24-hour a day, seven day a week basis.

The results of the test and evaluation of the upgraded system design are summarized in the following paragraphs in terms of the systems developed:

- o Vehicle Location System

- A wide area coverage Automatic Vehicle Location (AVL) system was developed which was operated and provided vehicle location data for a 400 square mile area (the area is greater than the sum of the areas covered by all previous AVL systems).
- A very accurate, repeatable, economical AM Phase signal tracking sensor/receiver was developed.
- A differential navigation system which used two location technologies was developed.
- It was found that the effects of the external environment require that additive augmentation, to solve some very special multipath problems should be incorporated in the system to realize the full potential in terms of location accuracy.

- o Sensor System

- The development and test of the inclusion of combinatorial sensor logic (more than one sensor on required to declare potential alert event) in the vehicle demonstrated that fewer events (alerts and alarms) were declared by the sensor data processor.

- The economical, off-the-shelf sensors used in the system required a reasonableness testing criteria (inclusion of long time constants) to preclude the possibility of declaring false alarms.
 - The environment of the installed sensors was hostile.
 - Effective implementation and use of the cargo compartment motion sensor was marginal and consideration should be given to deletion of the sensor, especially if the system is implemented in tractor-trailer units or if operation in the after hours mode is eliminated.
- o Communication System
- A single channel, multi-user, digital, mobile radio communication system was developed.
 - The developed system operated in a truly non-interference basis with the normal trucking operation.
 - An experimental license is not practical for the system operation, a regular license is required.
 - Numerous instances of malicious mischief were detected with respect to the communications antenna installation. Additive preventive measures and protection are required.
 - Communication coverage in the trucking company yard is unique to the individual trucking company and may require special installation or modification to the system operating philosophy (such as deletion of the after hours mode) to be successfully implemented.
- o Base Station/Dispatch Station System
- An event-driven dispatch display system, which operates five devices using a single low speed

land-line communications link, was developed.

- A simple, comprehensive user-oriented interactive dispatch display and recording/printout system was developed.
- A transaction history and vehicle recent history recording algorithm and recall procedure was developed to provide security personnel with a log of vehicle activity.
- A 100 to 1 input data message filter/editor for vehicle data was successfully developed and evaluated.
- A street data base algorithm, digitizing method, real-time nearest intersection look-up algorithm and vehicle in-route /out-of-route algorithm was developed to provide an alphanumeric display of each vehicle location to the nearest of over 30,000 intersections and vehicle route status for 40 truck routes in the 400 square mile coverage area.

C. Location Subsystem

AM Phase-lock testing was done in two major phases. In the first phase, the raw AM phase data was captured on magnetic tape in a few dispersed regions of the test area. The data was plotted and analyzed to (1) determine the feasibility of implementing the system without mapping the entire 400 square mile area and (2) determine the tracking characteristics of the new AM Phase receiver.

In the second phase, the raw AM phase test data was transferred to the base computer, via the dedicated communications link, where the data was converted first to standard X-Y coordinates and

then to the nearest street intersection. The street intersections, along with the AM Phase and X-Y coordinates were printed out in alphanumeric form. Tests were run in areas in the near vicinity of parallel overhead wires, areas passing through underpasses, and several randomly selected points throughout the area.

The major conclusions of these tests were:

- o The underlying AM Phase measured grid matches the theoretical calculations.
- o The underlying radio frequency (RF) field grid linearity and match to the theoretical grid was exhibited in widely dispersed areas of the test area.
- o The RF fields are stable and reproducible on different days or nights.
- o High rise areas, underpasses, and overhead parallel wires can induce permanent error offsets (cycle slips) in the receiver tracking loops.
- o Short (distance) localized warps cause less than a 600 foot temporary distortion in instantaneous location accuracy.
- o Short warps can be very sharp and exhibit as much as 180° phase shift within a 20-foot distance.
- o Cycle slips due to parallel overhead wires can cause an indefinitely increasing location error.
- o Station over-modulation distorts the carrier causing instantaneous phase noise which translates to no more than a 70 foot instantaneous location error.
- o Digitizing and computer errors translate to less than a 50' error.

- o The randomly located test points results (including over-head wires and underpasses) indicated a 6000 foot, 95% error.
- o Elimination of resetting signpost errors can produce potential tracking accuracy with a worst case error of less than 200 feet.

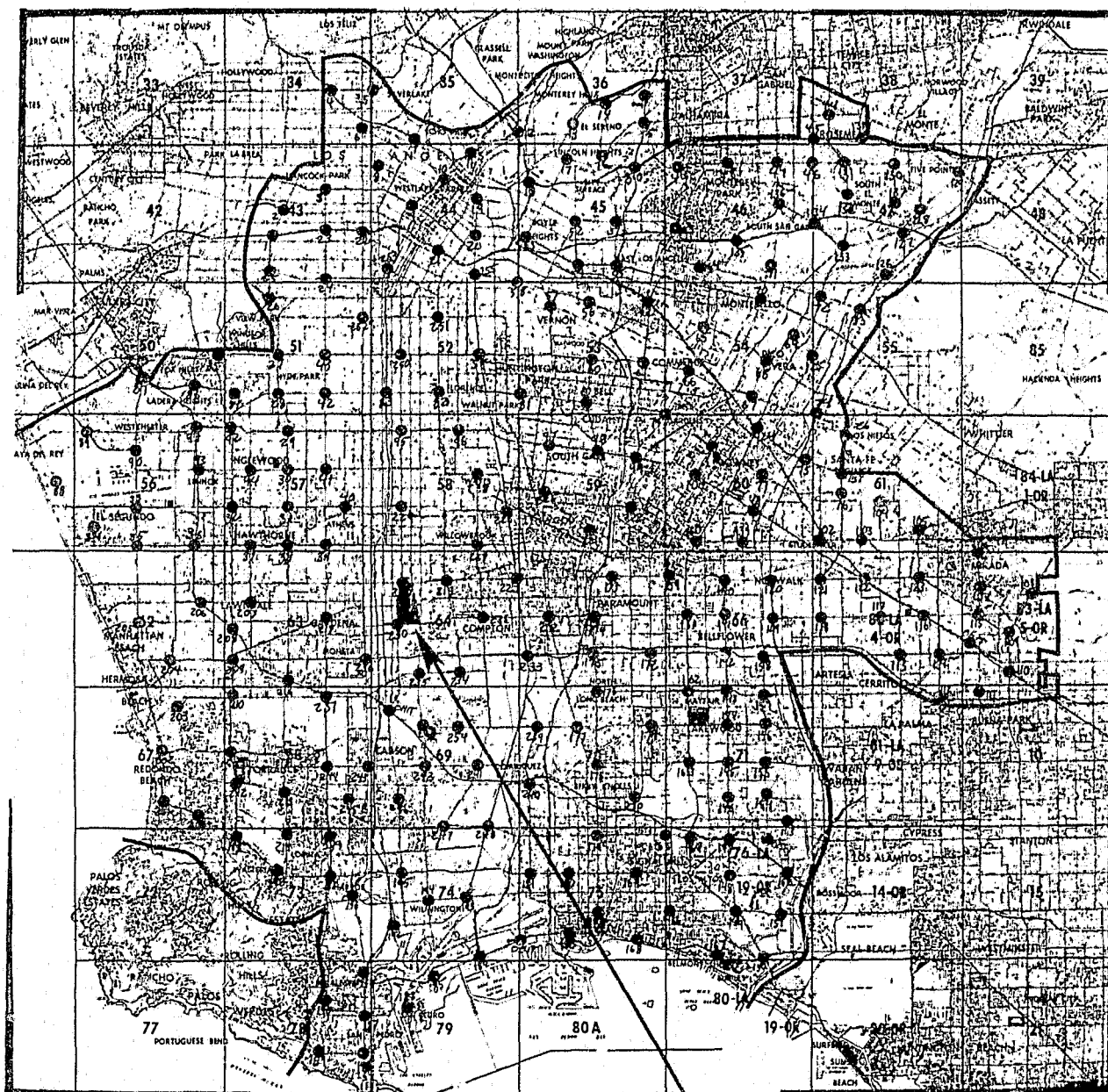
1. Theoretical and Linearity Tests. Tests were run in a few widely dispersed areas of the test area to determine if the actual AM Phase grid matched that predicted by the phase versus distance equations. The theoretical equations of the two phase pairs are:

$$\phi_X = 1/\lambda_B (d_A - d_B) = 1/\lambda_B [[(X_V - X_A)^2 + (Y_V - Y_A)^2]^{1/2} - [(X_V - X_B)^2 + (Y_V - Y_B)^2]^{1/2}]$$

$$\phi_Y = 1/\lambda_C (d_A - d_C) = 1/\lambda_C [[(X_V - X_A)^2 + (Y_V - Y_A)^2]^{1/2} - [(X_V - X_C)^2 + (Y_V - Y_C)^2]^{1/2}]$$

where ϕ_X is the line of position of the frequency pair 1070 KHz - 640 KHz, ϕ_Y is the 1540 - 1070 pair, λ_B is the wave length of the 640 KHz frequency. λ_C is the wave length of 1540 KHz, d_A is the distance from the reference station (1070 KHz) to the position of the vehicle. d_B is the distance to the 640 KHz station and d_C is the distance to the 1540 KHz station and X's and Y's are the orthogonal grid coordinates of the vehicles and stations from which the distances are computed.

Using these equations (where the X,Y data is taken from the U. S. Geological Survey Maps) the theoretical phase counts were determined at various points within the areas. A set of test data acquired in Carson is illustrative of this evaluation. The test route consisted of Main Street, Redondo Beach, San Pedro and Alondra and is shown on the map in Figure 3-1. The calculated AM Phase coordinates for these intersections are shown in Table 3-1.



TEST AREA

FIG. 3-1 TEST ROUTE IN CARSON

The plotted raw AM Phase data, as taken from the test vehicle, is shown in Figures 3-2 and 3-3. A comparison of these plots with the calculations, demonstrates that the measured fields (smoothed by a "least squares" line) deviate from linearity over the distances involved in this test by less than .05%. To exclude the effect of localized warps, the technique for laying in the linear line to the data is to find those data segments which are linear and to connect up these linear segments with one overall straight line. When this is done for all eight tests points for the Carson run and compared to the calculated data, close correspondence is achieved (Table 3-1).

TABLE 3-1

	Main St.	Redondo Beach	San Pedro	Alondra
ϕ_X measured	150	900	8	1040
ϕ_X calculated	<u>140</u>	<u>892</u>	<u>14</u>	<u>1046</u>
Difference	10	8	-6	-6
ϕ_Y measured	1386	1450	1130	1720
ϕ_Y calculated	<u>1382</u>	<u>1460</u>	<u>1130</u>	<u>1712</u>
Difference	4	-10	0	8

The slight discrepancies are caused by odometer error, data fitting, map coordinate error, etc.

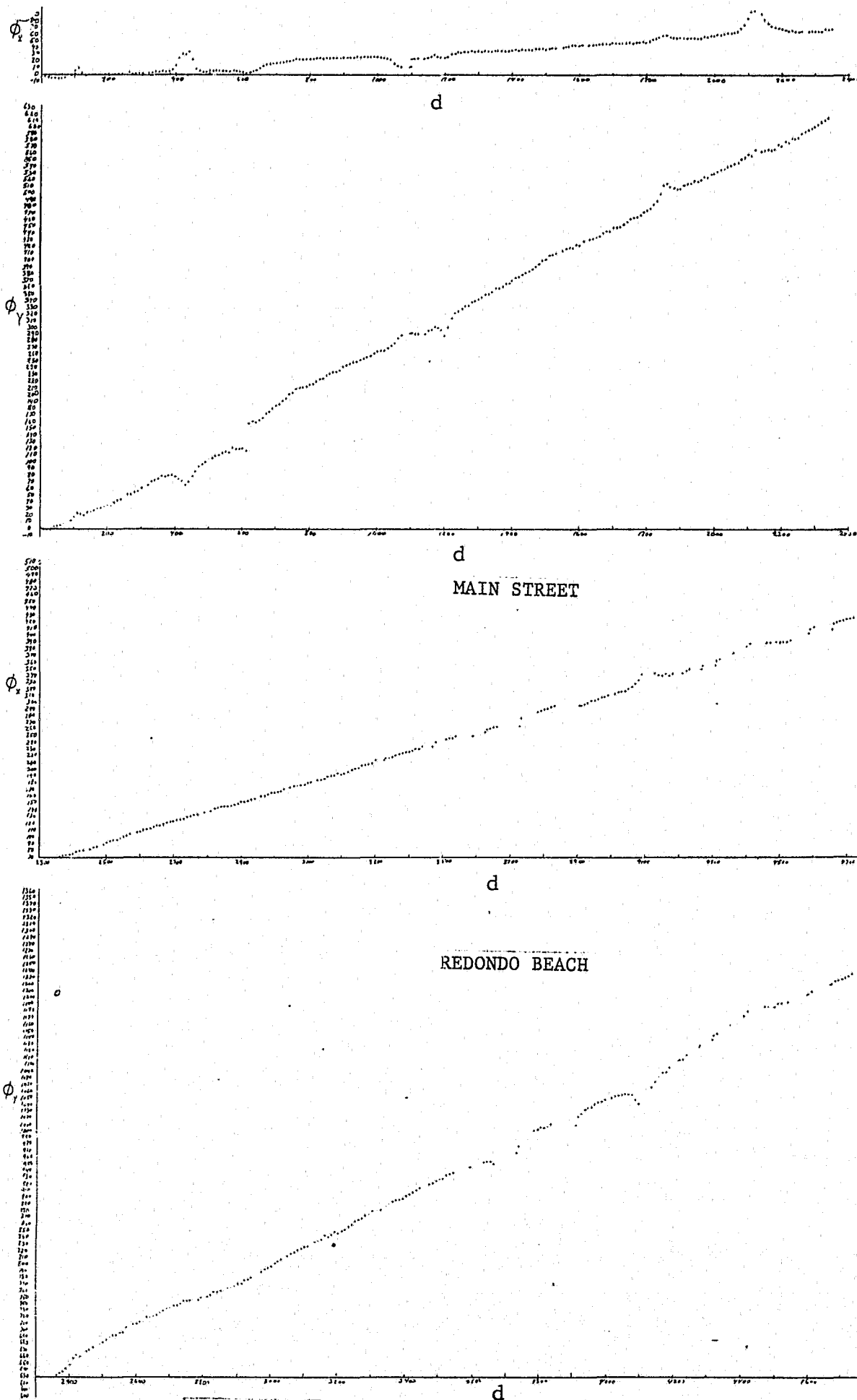


FIG. 3-2 MEASURED AM PHASE DATA IN CARSON

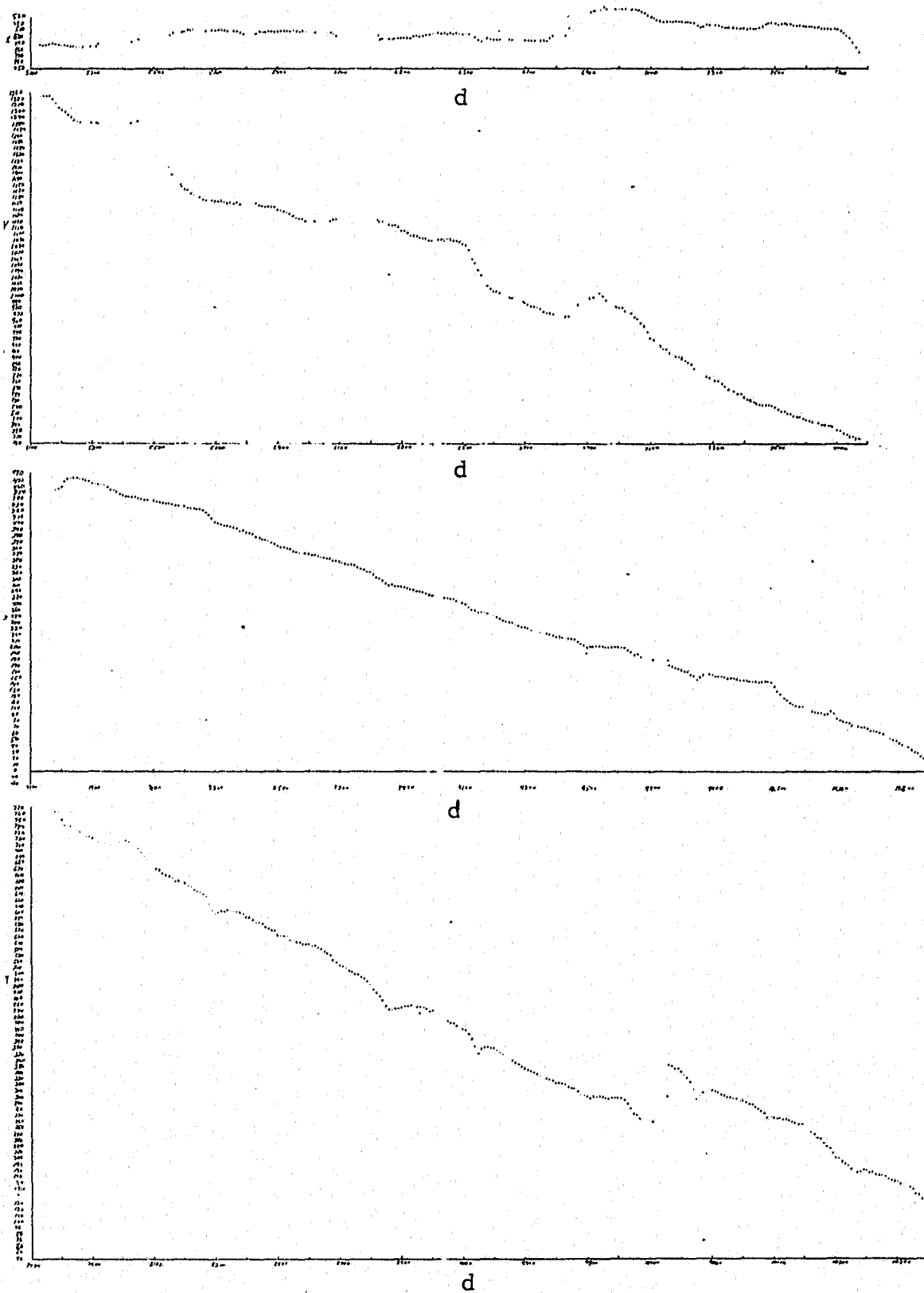


FIG. 2-4b MEASURED AM PHASE DATA IN CARSON (CONTINUED)

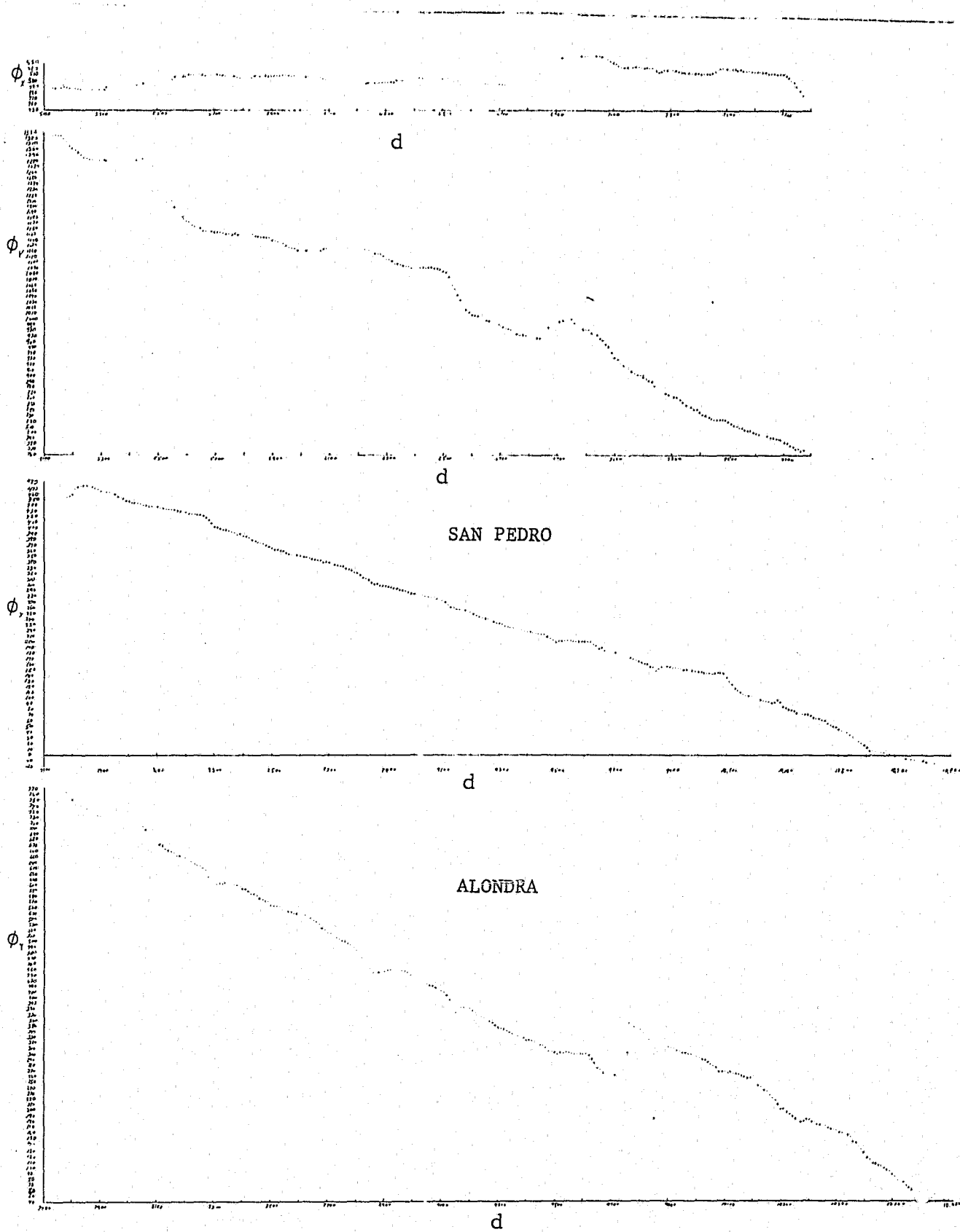


FIG. 3-3 MEASURED AM PHASE DATA IN CARSON

2. Final Phase Testing. Based on the results of the theoretical and linearity tests one would expect the final system output of position to be very good, and this was the case in large portions of the test area. For example, the same test area in Carson discussed previously was run again in the final system configuration, with the results presented in Figure 3-4. The vehicle was run at a constant velocity and polled by the base station at 15 second intervals. The X-Y results were then plotted (small circles) on a map of the area, and shows that the worst case error on this route was less than 200'.

The effect of a proximity unit at Alondra and Main is also shown by the dashed lines along the route. The reset signpost introduces a constant bias offset by the distance the vehicle is away from the signpost when it is reset.

If this offset is removed, the 95th percentile error is reduced to approximately 100'. (This residual error is caused by localized warps at certain locations), and this best demonstrated that the AM Phase unit was precisely tracking the actual carrier phases.

It was demonstrated during the testing that similar accuracies could be achieved in much of the test area. However, in many local areas external environment effects caused the actual phased grid to be severely distorted from the theoretical grid with a result and degradation of accuracy. Although these local areas are small geographically, they can introduce a permanent error offset at the point of occurrence, and since the system is inherently a differential navigation system, all subsequent position reports are in error by this offset until the location system is reset by receiving a proximity unit transmission.

The basic cause of these distortions is R-F multipath. Large structures such as underpasses, high rise canyons, and overhead power

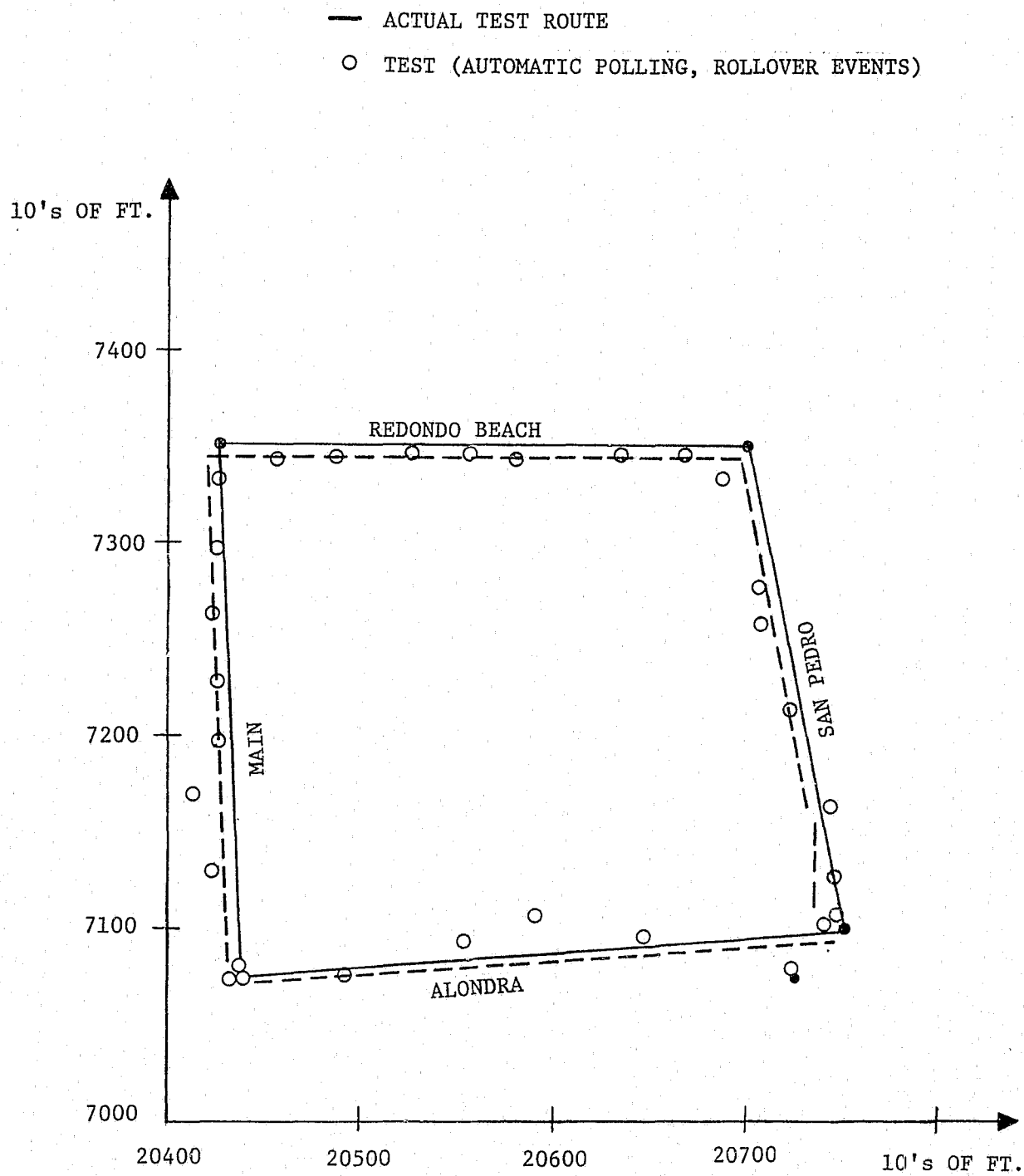


FIG. 3-4 BENIGN AREA

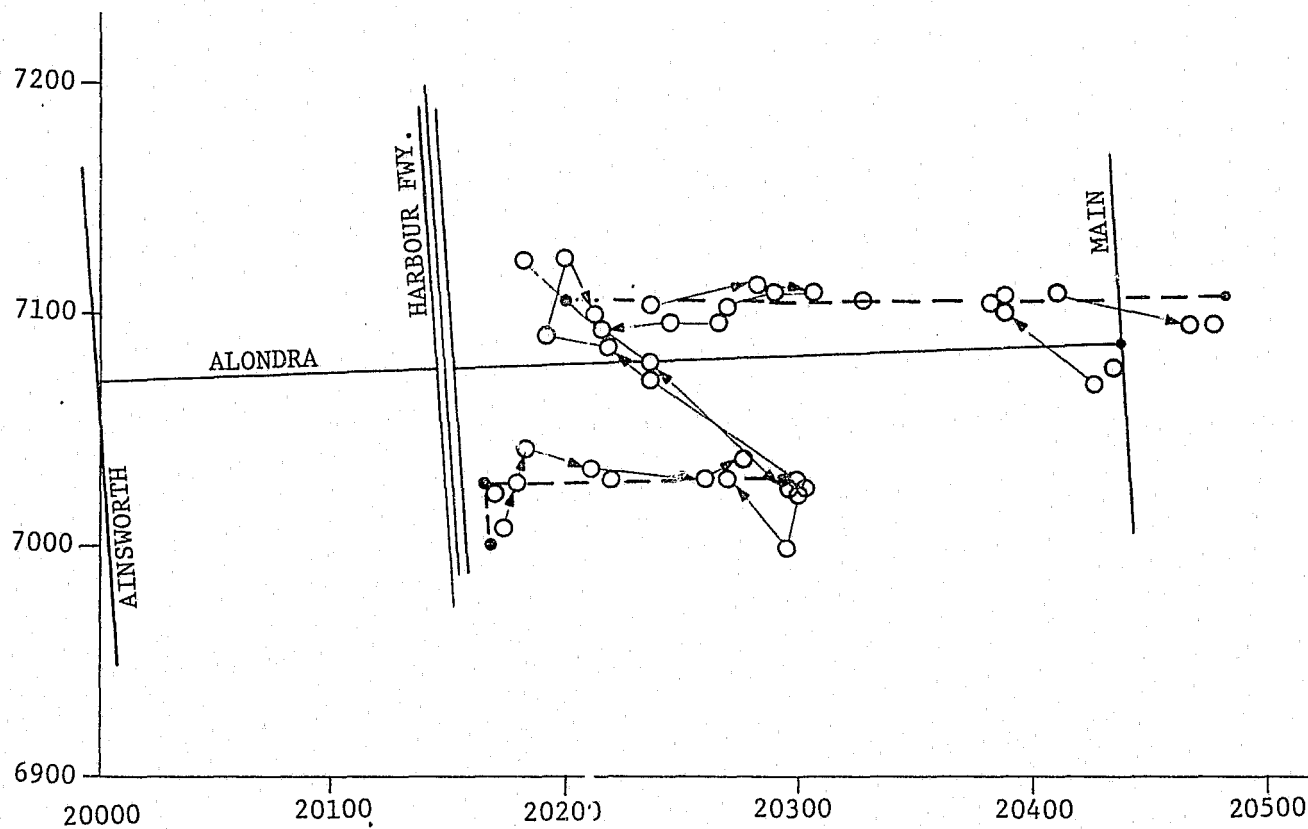


FIG. 3-5 EFFECT OF UNDERPASSES

distribution lines (600 volts or higher) reflect the radiated signal from the radio station. If the vehicle is situated close to such a structures and in such a manner that the main signal is partially blocked, the relatively strong radiated signal from the structure combines with the weak main signal to give a combined, distorted R-F input to the phase receiver. The receiver tracks this combined signal very well, thus distorting the vehicle location data.

In cases where the reflected signal is the strongest of the two, the receiver starts tracking the re-radiating structure. (When the re-radiation is the weaker of the two, it causes the temporary phase warps seen in the AM Phase plots in Carson). During the time that the vehicle is tracking the structure, it is losing the accumulated cycles it should be obtaining from the real radio station. These lost cycles ("cycle slip") are never recovered since AM Phase is a differential navigation system and a permanent bias error offset is introduced into the system.

This offset characteristic is illustrated in Figure 3-5. In this controlled test, the vehicle went straight west on Alondra Street from Main Street. It passed under the Harbor Freeway (underpasses are highly reflecting due to the steel in the concrete), continued to Ainsworth, turned left on Ainsworth, made a U-turn and returned to the start point at Alondra and Main.

For a short period from the start, power distribution lines to the right of the vehicle caused a permanent offset (this effect is discussed below) of approximately 250'. With this offset corrected for, (the dashed line), it is seen the vehicle tracks perfectly until it starts to enter the underpass and begins to track the

strong multipath re-radiation from the structure. The resulting highly distorted phase throws the apparent track of the vehicle to the south-west of the true track. On exiting the underpass the receiver requires the actual broadcast signal and (with the offset) tracks to Ainsworth. Following the U-turn the systems correctly tracks back until it encounters the underpass again going in the opposite direction. The tracked multipath re-radiation causes an offset to the northwest of the true track thus correcting the initial offset. Reacquisition of the actual broadcast signals result in correct tracking until reaching the start point. It should be noted that there is no repeat of the initial power line distribution distortion at the end of the test run. The apparent reason for the effect is that the vehicle returned at a distance from other wires. Because of the high order fall-off of field intensity with distance in the near field, doubling the distance away from the source reduces the received re-radiated signal many orders of magnitude and thus result in minimum error. (This effect precludes the use of field mapping to eliminate warp areas - the offsets are critically lane-of-traffic dependent.

Since the underpass was symmetrical (and the vehicle traveled on the inside lane in both directions) the underpass offset was also relatively symmetrical. However other experiments with this underpass show that wider traffic lane separation causes non-symmetry and results in a net permanent offset in a closed path test.

A test was also made to determine the effect of multipath re-radiation from power lines on the system. Figure 3-6 shows the results of this test and clearly demonstrates the effect of multipath on vehicle location. Portions of the run were repeated,

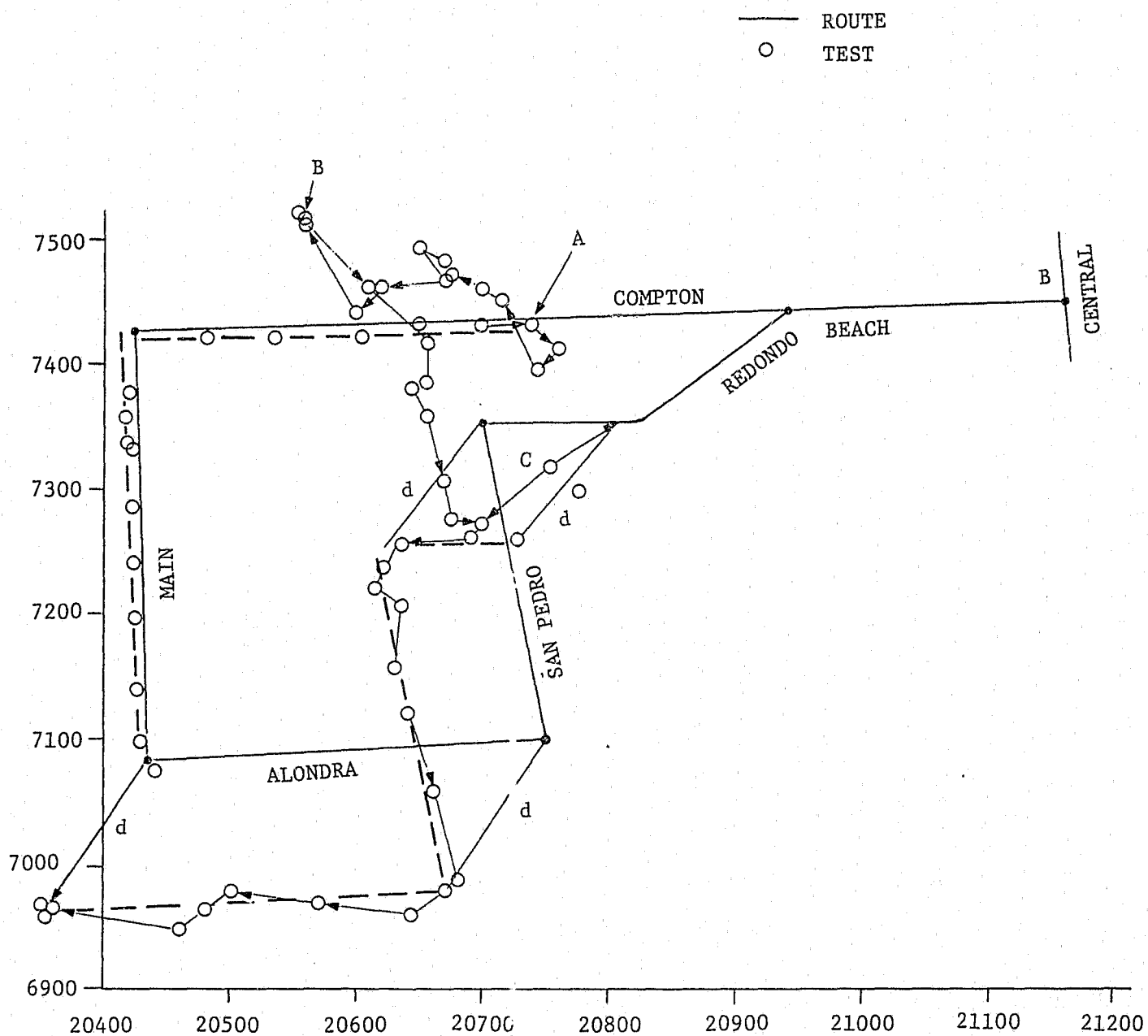


FIG. 3-6 EFFECT OF POWER LINES

and an additional path was added to the upper right of the route, (east on Campton to Central, and returning west on Redondo Beach.)

Starting at Alondra and Main, the first two legs (north on Main, east on Campton) show very close correspondence with the results. At point A (Avalon Blvd.), high voltage power lines are encountered on the south side of Carson and remain until the U-turn at Central (point B). The effect of these power lines differs on the return path (due to different near field effects on opposite sides of the street). The vehicle escapes from the influence of these power lines at point C where Redondo Beach turns slightly to head West. From this point the vehicle tracks correctly back to the start point, (carrying the net power line approximately 1500 feet indicated by the arrows labeled d).

From an overall system standpoint the effect of underpass and high voltage lines is highly deleterious to system accuracy, but in areas free of these influences the AM Phase location system can correctly track the location of the vehicle.

In addition to the controlled tests discussed previously, the system was tested for overall area accuracy (including high lines and underpass effects) at 50 points randomly selected throughout the test area.

The method of the test was to proceed by an assigned route to the location test points in a given order. At each point, the base station manually polled the vehicle for location, and the results were compared to the actual X-Y of the points taken from the geological survey maps. Where reset proximity units were encountered on the route, the effects of detection range offsets were corrected. The resulting accuracy data is thus totally route dependent in going

from one point to the next (depending on any underpasses or power lines present on the route).

The results of the 50 point test are shown in the error scatter plot in Figure 3-7 and Figure 3-8 presents a histogram and cumulative distribution of these errors. An attempt was made during the test to note the presence of wires or underpasses (anomalies) and the data was plotted with and without anomalies. The overall cumulative of the data is also shown.

Analysis was conducted to determine the type of distribution the data displayed. By manipulating the class interval width it was determined that the data was neither a Rayleigh or a Normal distribution. By using a class interval width that varied from $\frac{1}{4}$ mile at the low end and gradually increasing to a mile at the upper end the data fits very loosely to that of exponential distribution. However, due to the lack of points available in each class, no confidence limits were determined.

D. Other Testing

In addition to the accuracy testing described previously, other tests were run to validate the cargo security system's readiness for acceptance testing. These tests are mostly described by the printout obtained from the base station which consists of transactions of an event nature between vehicles the base station as well as the dispatch stations. Communication tests were run and a physical examination of a randomly selected sample of vehicles was conducted by The Aerospace Corporation to validate that all equipment was installed.

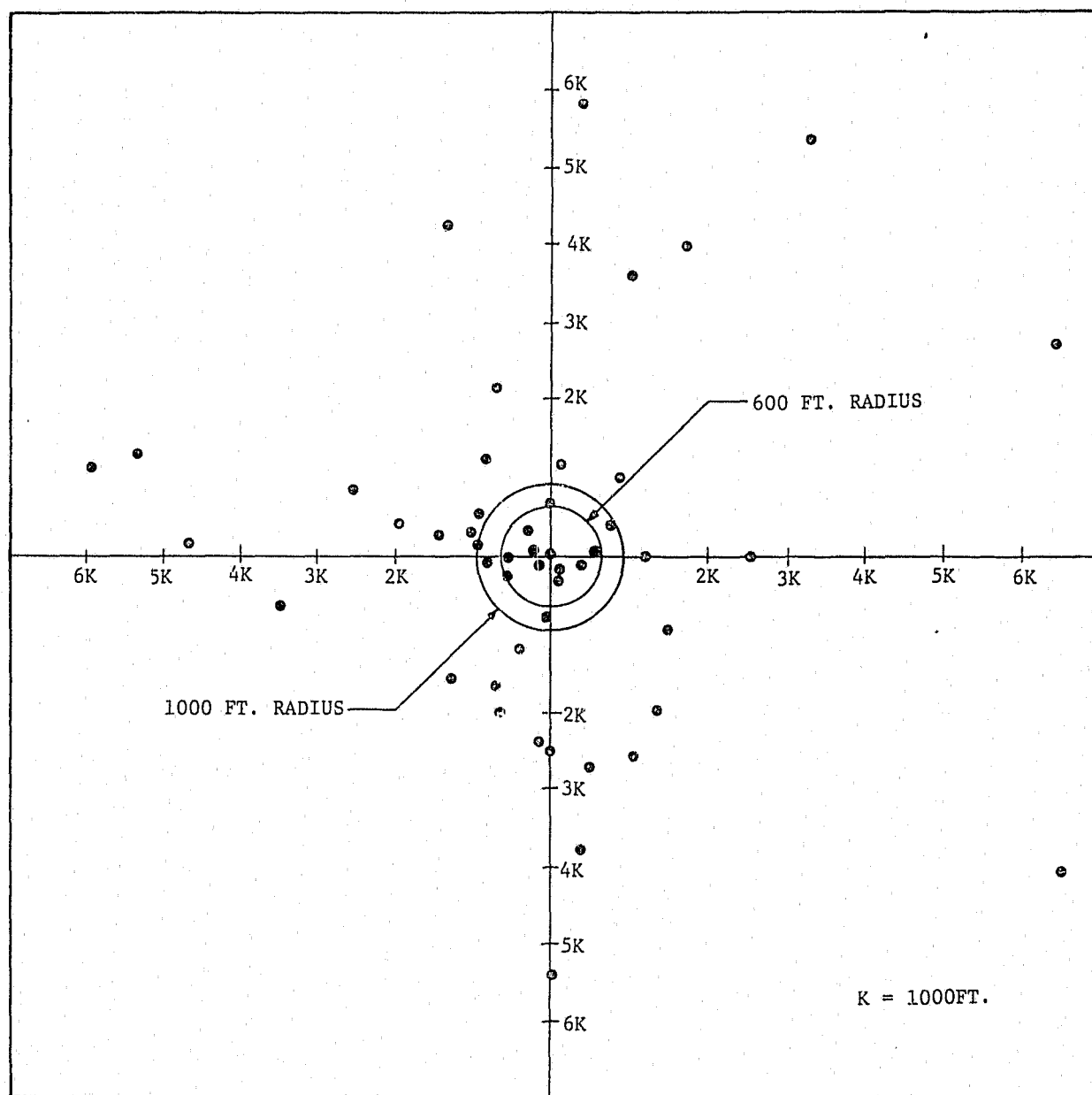


FIG. 3-7 SCATTER PLOT

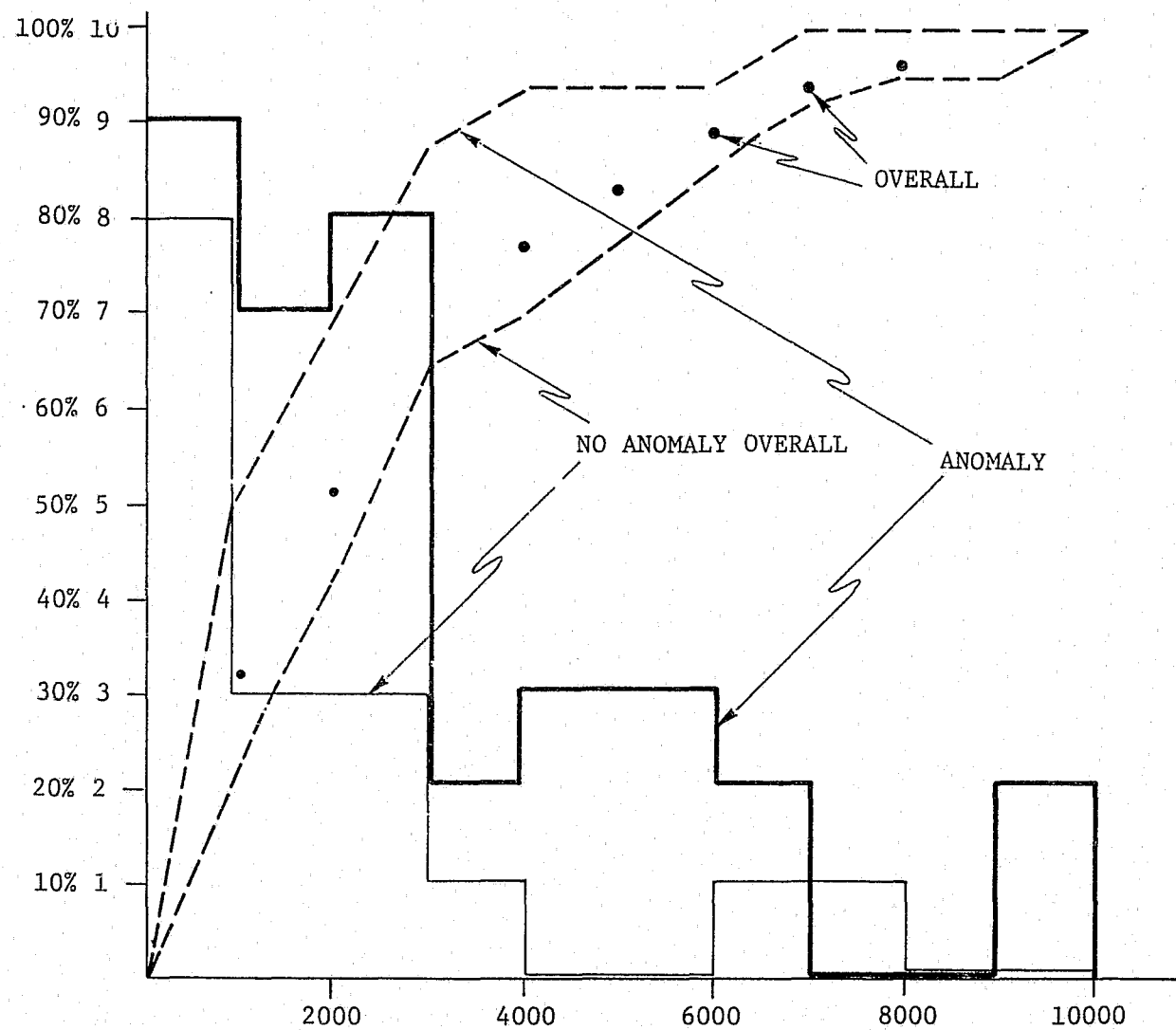


FIG 3-8 50 POINT CUMULATIVE TEST RESULTS

1. Integration Testing. Thirty five vehicles from both Transcon and GI were brought to a state of operational readiness in the final period of integration testing. The system was all enabled including both dispatch stations and the base station, and was to run in the free running mode for one to two day periods. The base station printer printed a log of all transactions during the day, involving any event of an unusual nature occurring on a truck. A typical full day log is shown in the appendix. A page from this log and its interpretation is as follows.

The base station log is in highly compacted format and the codes which describe events are shown in Table 3-2. The April 19th print-out show in Figure 3-9 shows the first transaction to be related to truck number 924, a Transcon vehicle. The next three characters are are not of significance and show an alarm condition. The location of the truck at the start of the alarm condition is at the intersection of Smith and Norwalk Streets in Santa Fe Springs. The time of occurrence of the alarm was at 2:26 P.M. The event causing the alarm was countermeasures. It occurred because of lack of communication with the vehicle for three consecutive polls. (It should be pointed out that this alarm condition occurred fairly frequently because the base station power had at that time been heavily attenuated in an attempt to eliminate interference with co-channel users in the area of Los Angeles, with the consequence that communicative coverage of the area very very marginal.)

The next log event was an alert on Truck 962 located at Santa Ana and two-tenths of a mile east of Indiana Street in Los Angeles at 2:27 P.M. This alert condition was that the seat was empty, yet the vehicle was moving. (The alert condition was caused by the lack of a

TABLE 3-2 BASE STATION LOG EXPLANATIONS

EXECUTIVE PROCESSING ERROR MESSAGES

50	ALERT CONTROL PROCESSOR POINTERS ALIGNED
51	COMMAND WORD 0 IN ALERT CONTROL PROCESSOR
52	NOT VALID COMMAND WORD IN ALCPRC INPUT
53	NO BUFFER IN DRVALM
54	COULD NOT GET VREF FILE - DRVALM
55	COULD NOT FIND BUFR - NORMSN
56	COULT NOT GET VREF FILE - NORMSN
57	COULD NOT FIND BUFR - RLOADR
58	COULD NOT FIND VEHICLE - RLOADR
59	COULD NOT GET VREF FILE - RLOADR
60	RAM LOAD ALREADY IN PROCESS
61	NOT VALID VEHICLE DECLARED - SCRAMB
63	VEHICLE IN REMOTE ALRM MODE - RLOADR
64	COULD NOT LOAD RAM - VEHICLE RAM SENSORS DISABLED
65	COULD NOT FIND BUFFER - SCRAMB
66	ERROR IN GET VREF - SCRAMB
67	NO RAM PROCESSING

VEHICLE COMMUNICATIONS PROCESSING ERROR MESSAGES

0	VC FLAG ERROR - VCMPRC
1	PROCESSOR FLAGS ERROR (VCMPRC)
2	PROCESSOR FLAGS CLEAR (VCMPRC)
10	ALL ZEROES ON INPUT -- WD1 -- (VEHXPT)
11	ALL ONES ON INPUT -- WD1 (VEHXPT)
12	VEHICLE NOT IN QUEUE -- ENABLED (VEHXPT)
13	VEHICLE NOT IN STATUS BUFFER -- VSTAT -- (VEHXPT OR SMUPD)
14	VEHICLE NOT FOUND -- END OF BUFFER (SSPBUF) -- (VEHXPT)
15	VEHICLE NOT NORMAL MODE-LOCATION REQUEST OR RESET SP INPUT -- (VEHXPT)
16	VEHICLE MODE NOT NORMAL - MILEAGE INPUT -- (VEHXPT)
17	VEHICLE ACKNOWLEDGE NOT REQUIRED -- (VEHXPT)
18	VEHICLE NOT REMOTE ALARM MODE, REMOTE ALARM ARM INPUT -- (VEHXPT)
19	VEHICLE NOT ENABLED -- (VEHXPT)
20	SMINPD POINTERS ALIGNED -- (SMUPD)

TABLE 3-2 BASE STATION LOG EXPLANATIONS (CONTINUED)

22	ALERT CONDITIONS EXIST WITHOUT EVENT AFTER SENSOR DEACTIVE TESTED
23	IMPROPER EVENT
24	RAM LOAD IMPROPERLY INDICATES ALERT
25	SENSOR EVENT IMPROPER
26	MILEAGE REPORT - WRONG CODE
27	MODE BIT IMPROPER -- (MIUPDP)
28	VEHICLE NOT IN STATUS BUFFER)
29	IMPROPER MODE FIELD - (SMUPD)
30	SENSOR EVENT DECLARED, EVENT FLAG NOT SET -- (SNEVNT)
31	SENSORS INDICATE NO ALERT WITH EVENT (SNEVNT)
32	TAMPER BIT SET ALL OTHERS CLEAR
33	SENSOR DISABLE PENDING FLAG SET WITHOUT SENSOR LOADED (SNSPT)
34	ACKNOWLEDGE RECEIVED WITHOUT COMMAND -- (SNACKN)
35	NOT VALID ID FOR VREF -- (SNACKN)
36	NOT VALID IN VSTAT -- (RAMPRC)
37	IMPROPER INPUT TO RAMPRC
33	IMPROPER FLAGS SET FOR SLOWPOLL COUNTERMEASURES
39	ERROR RETURN - RTVREF, SNSPOL
40	ERROR RETURN - GTVREF, SNEVNT
41	ERROR RETURN - GTVREF, SCMEVT
42	VEHICLE NOT IN STATUS BUFFER, LOCUPD
43	IMPROPER MODE, LOCATION DATA, LOCUPD
44	NO BUFFER AVAILABLE, LOCUPD
45	ALL ONES FOLLOWED BY ALL ONES
46	COULD NOT FIND SIGNPOST, SPTEST
47	COULD NOT FIND BUFFER, SPTEST
43	COULD NOT FIND FILE, SPTEST
49	COULD NOT FILE, SPTEST
50	ALL ZEROES FOLLOWED BY ALL ZEROES
51	NO DATA IN X,Y FILES
52	CANNOT FIND MINIFILE
53	VALUE NOT IN X,Y FILES
54	POINTERS ALIGNED, LOCUPD
55	BUFFERS FULL, RESNES
56	ERROR IN GATING VSEF, RESENSE
57	NOT VALID VEHICLE - CLNUP (SPVEHD)
58	ERROR IN GETTING VSTAT - CLNUP

TABLE 3-2 BASE STATION LOG EXPLANATIONS (CONTINUED)

59	NO RESPONSE FROM VEHICLE POLL - 3SEC
60	VEHICLE NOT IN QUEUE - RARQST
61	COULD NOT UPDATE VRED - SNACKN
62	MODE = 6 or 7 ON INPUT WORD - (VEHXPT)
63	ROLLOVVR OR REQ BIT SET - MODE 3, -- (VEHXPT)
64	ROLLOVVR OR REQ BIT SET - MODE 4, -- (VEHXPT)
65	ROLLOVVR OR REQ BIT SET - MODE 5, -- (VEHEXPT)
66	VEHICLE NOT IN STATUS 1, 2, 3, OR 4, REMOTE ALARM REQ OR EVENT (VEHXPT)
67	SENSOR ENABLE ACKNOWLEDGE IN NON-NORMAL MODE -- (SNACKN)
68	SENSOR EVENT WITH NO SENSORS SET -MOTION EXCLUDED -- (SNEVNT)
69	IMPROPER FLAGS SET NTEXT
BASE STATION PROCESSING ERROR MESSAGES	
1	'C1' DISABLED
2	'P1' DISABLED
3	(UE/UD) VEHICLE ID EITHER 64 OR 0
4	(UE) VEHICLE ID ALREADY IN VEHQUE
5	(UE) VEHICLE # ALREADY IN VSTAT
6	(UE) VEHICLE # NOT IN VREF
7	(UD) ID NOT ASSIGNED TO VEHICLE #
8	(UE) INVALID TRUCK CO.
9	(UE/UD) INCORRECT DISPLAY MODE
10	(UD) VSTAT ENTRY NOT FOUND
11	(SD/SE) INVALID SENSOR
12	ACKNOWLEDGE ALREADY PENDING
13	SENSOR ALREADY DISABLED
14	SENSOR ALREADY ENABLED
15	BUFFER SPACE NOT AVAILABLE FOR READ OF STFILE
16	ATTEMPT TO READ PAST EOF ON STFILE
17	HARD ERROR OCCURRED ON CHANNEL 7
18	CHANNEL 7 IS NOT OPEN
19	STFILE NOT FOUND
20	VREF FILE NOT FOUND
21	ATTEMPT TO READ PAST END OF VREF
22	HARD ERROR OCCURRED ON CHANNEL 7
23	CHANNEL 7 NOT OPEN
24	INVALID REQUEST

TABLE 3-2 BASE STATION LOG EXPLANATIONS (CONTINUED)

25	DISPLAY CANNOT BE CHANGED
26	BUFFER SPACE NOT AVAILABLE
27	VSTAT EXCEEDED
28	SPVEHD EXCEEDED OR SPVEHE
29	VREF FILE NOT FOUND
30	ATTEMPT TO WRITE PAST EOF
31	HARDWARE ERROR
32	CHANNEL NOT OPEN
33	INDETERMINATE ERROR 1
34	ID NOT ACTIVE IN VEHQUE
35	INVALID COMMAND TO BASE STATION
36	UNIT ENTRY COMPLETE
37	UNIT DELETE COMPLETE
38	SENSOR DISABLE COMPLETE
39	SENSOR ENABLE COMPLETE
40	ZERO AM PHASE COMPLETE, VEHICLE ONLY
41	ZERO AM PHASE COMPLETE, VEHICLE AND PROCESSOR
42	DISABLE ALL SENSORS COMPLETE
43	ENABLE REMOTE ALARM COMPLETE
44	DISPATCH PROCESSOR LOADED - TRANSCON
45	DISPATCH PROCESSOR LOADED - GI
46	SLOW POLL DONE
47	RAM LOAD COMPLETE
48	OUT OF ROUTE ALREADY DISABLED
49	OUT OF ROUTE ALREADY ENABLED
50	INVALID ROUTE(S) ENTERED
51	INVALID DEVICE
52	INVALID TIME
53	INVALID DATE
54	BUFFER SPACE NOT AVAILABLE FOR PRHIST
55	ATTEMPT TO READ PAST EOF RHAVVV
56	HARD ERROR
57	RHAVVV NOT FOUND
58	INVALID DELTA FOR RECENT HISTORY



3-26

1	924	ALARM	SMITH	NORWALK	SNTA F SP	02:26P	CNTR MSR
2	963	ALERT	SANTA ANA	0.2E INDN	L ANGELES	02:27P	ST MTY,MOV
3	963	ALERT	SANTA ANA	0.2E INDN	L ANGELES	02:28P	ST MTY,KON
4	963	ALERT	SANTA ANA	0.2E INDN	L ANGELES	02:30P	ST MTY,MOV
5	963	ALERT	SANTA ANA	0.2E INDN	L ANGELES	02:30P	ST MTY,KON
6	070	ALERT	PIXLEY	ATLANTIC	LA COUNTY	02:31P	ST MTY,KON
7	070	ALERT	PIXLEY	ATLANTIC	LA COUNTY	02:31P	ST MTY,MOV
8	144	ALERT	VIRGINIA	39TH	L ANGELES	02:32P	LDR,KON
9	VC	MSG 020					
10	VC	MSG 031 -	VID 04				
11	963	CSZALARM	7TH	ESPARANZA	L ANGELES	02:34P	STP,OUT OF RT,CD
12	144	ALERT	VIRGINIA	39TH	L ANGELES	02:36P	ST MTY,MOV
13	144	ALERT	VIRGINIA	39TH	L ANGELES	02:36P	ST MTY,KON
14	VC	MSG 031 -	VID 04				
15	963	ALERT	7TH	ESPARANZA	L ANGELES	02:44P	ST MTY,MOV
16	074	ALARM	SLAUSON	GARFIELD	COMMERCE	02:46P	CNTR MSR
17	VC	MSG 031 -	VID 07				
18	963	ALERT	DITMAN	6TH	LA COUNTY	02:51P	ST MTY,KON
19	VC	MSG 031 -	VID 16				
20	070	ALARM	PIXLEY	ATLANTIC	LA COUNTY	02:54P	STP,OUT OF RT,CD
21	144	ALARM	VIRGINIA	39TH	L ANGELES	02:55P	STP,OUT OF RT,CD
22	963	ALERT	WHITTIER	DITMAN	LA COUNTY	02:56P	ST MTY,MOV
23	144	ALERT	VIRGINIA	39TH	L ANGELES	02:56P	LDR,KON
24	VC	MSG 031 -	VID 07				
25	VC	MSG 031 -	VID 04				
26	963	ALERT	WHITTIER	DITMAN	LA COUNTY	02:57P	ST MTY,MOV
27	VC	MSG 053					
28	070	ALERT	PIXLEY	ATLANTIC	LA COUNTY	02:58P	ST MTY,KON
29	070	ALERT	PIXLEY	ATLANTIC	LA COUNTY	02:58P	ST MTY,MOV
30	VC	MSG 053					

FIG. 3-9 ONE DAY OF THE BASE STATION PRINTER LOG

long enough time constant on the seat sensor. When vehicles are traveling on bumpy roads the bouncing of the driver can cause the sensor to become momentarily open indicating that the seat is empty yet the motion sensor indicates that the vehicle is moving).

The third log printout for the same truck occurs one moment later and indicates that the seat is empty with the key on. (The nature of the log is such that when two alert conditions occur, namely seat empty, moving, and seat empty, key on at the same time, the alerts are printed sequentially so in actual fact log item 2 and log item 3 all refer to the same condition).

The fourth item, on truck 963, occurring at 2:30 P.M. also indicates that seat is empty, moving, but in this case it is merely an indication that the alert has been cleared. The same holds for the next transaction indicating the seat empty/key on condition has been cleared. (All of these 4 transactions were a consequence of one bounce on the seat sensor for Truck 963).

The next two events in the log refer to Truck number 70, a GI trucking vehicle, at Pixley and Atlantic in LA county are quite similar to what was discussed above, and occurred at 2:31 P.M., seat empty, key on and seat empty, moving are sequentially printed. The next time in the log for truck number 144, a GI truck, at Virginia and 39th in Los Angeles indicates that the left door is open and the key is on thus giving an alert condition. This is a valid alert which actually occurred in the proper operation of the system. It does, however, indicate that what was believed in the beginning of the program to be a potential theft condition is actually quite normal. The left door open and key on, for example, is a very common occurrence in those trucks which have a power lift on the tail-

gate of the vehicle and require the motor to be running in order for it to operate.

The next item in the log indicates a vehicle communications message 20. This is a software state printout and in no way indicates invalid operation of the system. The log was designed to serve the purposes of program development as well as for the purposes of logging vehicle events.

The next log transaction, vehicle comm message 31, for vehicle 94 indicates that sensor event occurred yet did not cause an alert condition in the software. (The software has built into it the identical filter logic that appeared in the vehicle. Thus, even if an event should trip a sensor combination not detected by the combinatorial vehicle logic, the base station will still filter the message prior to being sent to the dispatch station).

In this case, when this vehicle exited the freight yard, the RAM was not successfully loaded and thus all events were transmitted from vehicle 4. (Vehicle 4 is the code number in the computer for one of the thirty-five vehicles).

The next transaction, Number 11, indicates vehicle number 963 at Seventh and Espera in Los Angeles at 2:34 had an alarm condition caused by the vehicle being stopped, out of route, with the cargo door open. This appears to be a valid event but could have been contaminated by the inaccuracies of the tracking unit (i.e., the vehicle could actually have been in route). No verification of this was possible.

Transaction 12, involving truck 144, and transaction 13 represent another seat bounce problem. These would normally have been cleared with two additional transaction entries but other priority traffic

precluded the transmission of these low priority clearing transaction.

There is a second message 31 from vehicle 04 still indicating its RAM is not loaded. Transaction 15 shows that the truck number 63 had actually started moving and had experienced a seat bounce. The corresponding key-on transaction appears in transaction 18 and both are cleared in transaction 22 and transaction 26.

As the rest of the page is reviewed it is seen that most of the other transactions involve a chattering seat sensor, each chatter causing two alert conditions and two alert clear conditions for the same vehicle.

An item not discussed previously is transaction 30 involving vehicle comm message 053. This particular vehicle comm message indicates that the value of the received AM Phase was not found in the X-Y files (meaning the area digitized for testing). This would suggest that the vehicle has left the test area. It could be caused by the vehicle actually leaving the test area or an incorrect location computation indicating the vehicle had left the test area when it had not.

All the remaining transactions on this page have been discussed previously. In summary, it emphasized that the majority of transactions causing an alert condition were caused by either a chattering sensor, poor communications, or potential inaccuracies of the location system. Recommendations dealing with these three problems will be discussed in a later section.

2. Additional Testing. In addition to the testing of the integrated system described earlier, extensive communication testing of the system was performed in intervals throughout the life of the program. In the first testing that was performed, full power

was used and a survey was conducted throughout the four hundred square mile region. The results fo this testing demonstrated that the round trip data throughput (i.e., a successful completion of the transmission from the vehicle to the base station and back again) exceeded 98.5 percent throughout the whole area. (This result was confirmed later in the course of accuracy testing at the fifty randomly selected points). These tests were conducted under the conditions of daytime and nighttime hours, peak traffic and low traffic, in rain and on clear days, and in different seasons of the year.

However, co-channel interference with other users outside the Low Angeles area was discovered and it became necessary to attenuate the transmitter power from the base station to attempt to reduce this interference to acceptable levels. Two consecutive reductions were made and testing was done following each reduction. After the first it was found that the throughput in almost the whole area still remained above 97 percent but some localized areas showed a drop off to the 50 percent range. These areas were at the extremities of the test area where shadowing due to hills prevented a direct line-of-sight transmission between the base station and the vehicle.

The second reduction reduced the effective radiated power of the transmitter to less than 5 watts. Preliminary tests indicated that the system might still meet the communications throughput specification and showed that the 80 percent requirement for overall round trip communications could not be met in many areas. However, the overall system in this case was not able to operate effectively. At points such as the exit from the yards the RAM was very difficult to load from the base station, and when the vehicles were in shadowed

areas, they were unable to get an acknowledgement from the base station for an alarm or an alert condition. In addition, false communication countermeasures events were declared, thus further loading the system with invalid alarms.

Even at this greatly reduced power it was found that unacceptable interference with San Diego Rapid Transit District still existed due to the relatively high powered mobiles operating in the test area closest to San Diego. For this reason, the program was to be ended prior to 12 month of formal field testing.

In addition to the communication testing a physical examination was made of randomly selected vehicles in the trucking yard. The Aerospace Corporation, with personnel from Gould, inspected each of these trucks and insured that all items of equipment were on the vehicle and properly installed. No discrepancies were found in this system installation inventory.

At the conclusion of this examination, the special accuracy tests described earlier were run. The last dry runs of integration testing before acceptance testing were under way when notification came of the unacceptable communications interference.

E. Installation, Maintenance, and Vandalism

During the course of the field test program, numerous operational conditions were evaluated including the effects and impact of system installation in trucking company vehicles, maintenance of the installed equipment in the vehicles throughout the city, and the relatively hostile environment of the trucking operation relative to the installation and use of sophisticated electronic sensors.

1. Vehicle Equipment Installation. Vehicle equipment installations and operating procedures were discussed and agreed upon by TransCon and GI operational and maintenance personnel prior to the

installation of the Cargo Security AVM vehicle equipment. These discussions and agreements included all sensors and equipment needed to equip a truck with the Cargo Security AVM vehicle equipment. Installation was not normally performed during week days but was primarily done during the night and weekends to ensure operation on a strictly noninterference basis with GI and TransCon Truck Lines.

The equipment installed in the vehicles includes: two antennas, sensors, master control box, cables, power lead, radio, signpost vehicle unit, and AM Phase vehicle unit. See Figure 3-10. The radio AM Phase unit, and signpost vehicle unit were not installed at the initial installation. They were designed with quick disconnects and were installed at different intervals of the program.

The initial vehicle equipment installation included the UHF radio antenna, AM Phase and 27 MHz antenna, all sensor, vehicle control box, and tapping 12V off of the truck's battery. This installation was done on permanent-type basis. This required drilling a number of holes in the trucks for antennas, cables, mounting of the control box, most sensors, and a large, approximately 2" x 3/4" elongated hole for the main harness to enter the cab and master control box. See Figure 3-11.

The majority of the electronic equipment was installed in the vehicle control box bolted to the cab floor on the unused side of the trucks or on the right side of cab, where the passenger seat would normally be located.

All sensor cables and wires were either run under the cab floor, under the cargo floor or with existing truck cables when permissible.

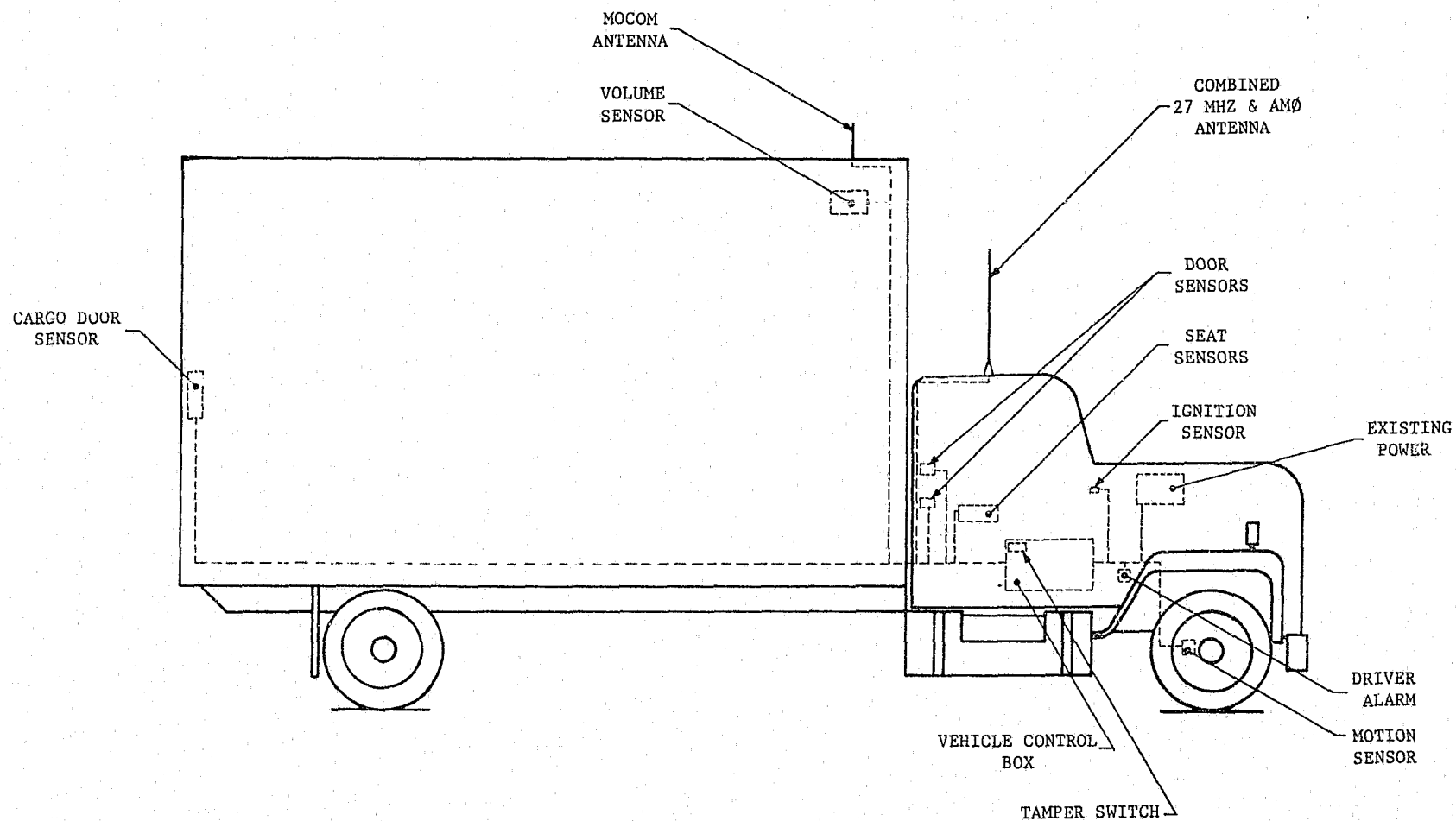


FIG. 3-10 CARGO SECURITY VEHICLE EQUIPMENT



FIG. 3-11 HARNESS HOLES SHOWN PATCHED IN GI TRUCKING VEHICLE AFTER DEINSTALLATION

In most applications the cables and wires were run along the inside of the U-channel of the fram with existing wires and cables. This provided protection and makes it difficult to distinguish between CSS cables and existing truck cables.

All wires and cables were hidden from the view of the driver with the exception of the AM Phase and 27 MHz antenna cable. This cable was visible to the driver in some cases due to the location limitations of the RF antenna.

The Cargo Security sensors, cables, antennas, vehicle control box, and power lead were installed in 20 TransCon and 20 GI trucks during approximately 6 weeks. This installation included a complete and thorough check of sensors by an electronic sensor installation tester designated and built by Gould I³. It was only after numerous sensor activations and correct response indicated on the tester that this phase of the vehicle installation was determined to be complete.

The second phase of the vehicle installation included installation of the electronics equipment located in the master control unit. Inside the master control unit was the AM Phase vehicle unit, signpost vehicle unit, MOCOM 70 radio, and interface terminal boards. The AM Phase vehicle unit and the signpost vehicle unit were mounted on a shelf with quick disconnects to support the system maintenance concept. The MOCOM 70 radio was mounted on the floor of the master control unit and locked into position but could be easily locked into position and slid out for service.

During the final installation and chekcout with the electronics units, each truck sensor was again checked using the radio link to provide and end system check. The equipment was installed and checked out be a specially designed and manufactured system tester. A thorough

communication check was made between the vehicle and base station at the UCB Building. The communication check included such items as correct sensor status and correct vehicle modes. After this procedure was complete, the master control unit was closed and locked. The identified vehicle then became part of the system operation.

2. Signpost Installation. The signpost installation covered a large portion of the Los Angeles area. There were 256 signpost transmitters installed and located within 43 different municipalities at major intersections. The signpost transmitters were operational for a period of approximately 15 month. Each signpost was mounted on a designated utility pole. Each pole required written permission from the city in which the pole was located prior to installation. The transmitters were mounted on a bracket banded to the utility pole with stainless steel adjustable bands. These transmitters were mounted approximately 20 to 24' above the ground with the aid of a cherry picker owned and operated by Gould I³. See Figure 3-12. Each transmitter was checked by a signpost tester during installation for correct code and signal strength. The signposts were periodically checked for failure and possible vandalism.

3. Vehicle Equipment Maintenance: During the final stages of the vehicle equipment installation period following the installation of a majority of the electronics equipment, several design changes were implemented. These changes required modifications to be made to the vehicle equipment printed circuit boards. The changes required additional rework time and maintenance to the vehicle equipment. After modification, three levels of testing were performed on each of the elements of the vehicle equipment.

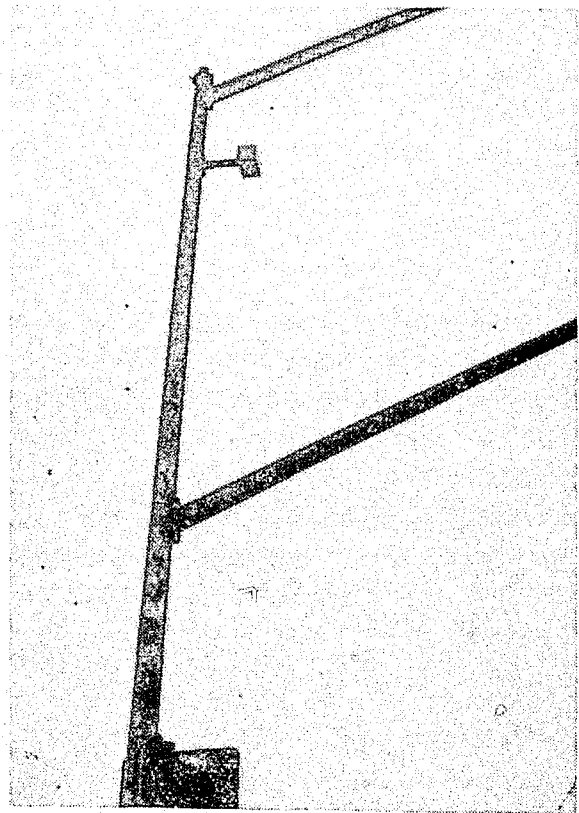
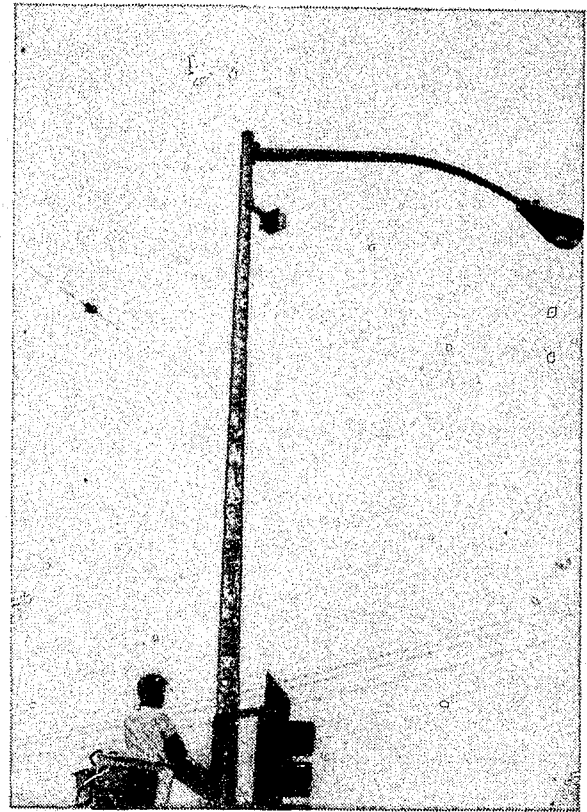
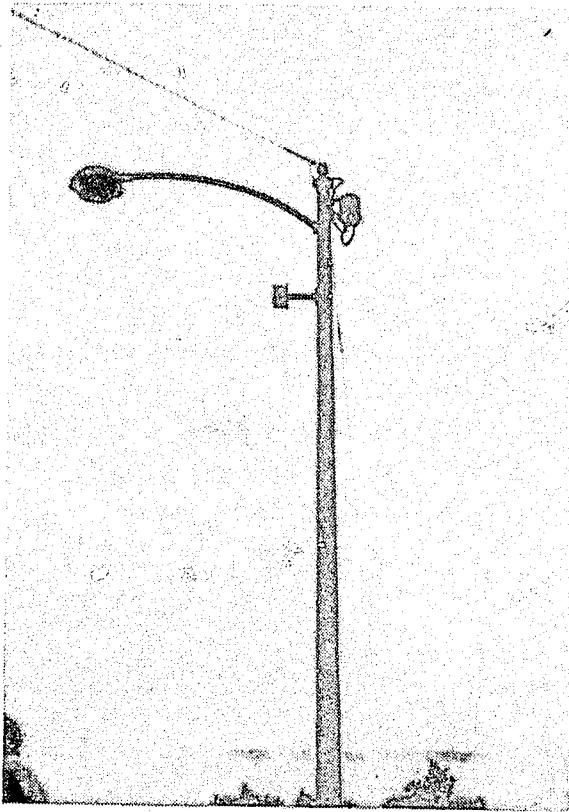


FIG. 3-12 SIGNPOST MOUNTED ON A LIGHTING STANDARD

The first level performed at the Gould I³ facilities was at the module level. It was at this level that the module was thoroughly checked for performance and if a failure occurred it was isolated and corrected. After each module or unit passed this testing it was inspected and made available for the second level of testing.

The second level of testing, also done at Gould I³ facilities was the radio-to-radio closed-loop test. The system level tester was used during this test. It was only after the unit passed both the performance test and a visual inspection was the unit signed off and made available for vehicle installation.

The third level of testing was accomplished after the vehicle equipment was installed in the designated vehicle. This being the most comprehensive test was broken into 5 different areas.

- (1) Visual inspection of antennas, sensors, master control unit and cables on the truck
- (2) Power check with voltmeter
- (3) VSWR check on UHF coax/antenna installation
- (4) Operational check out of all sensors
- (5) System checkout with system tester. This test includes and exercises the following:
 - A. Radio loop
 - B. Operational check of sensor
 - C. Signpost data input
 - D. AM Phase data input
 - E. Countermeasure data
 - F. Base station communication link
 - G. Exercise all operating modes for the signpost unit and AM Phase unit.

Once the vehicle equipment passed all three levels of testing and performed satisfactorily, it was put back into operation.

4. Dispatch Station Maintenance. The only dispatch station failures were in the ISC terminal. Out of the three terminals used, all failed at least once during the program and a total of six failures were recorded. One terminal failed three times. Burn-in of the terminals at an elevated temperature prior to the start of the program would have helped eliminate these infant mortality failures (which were all integrated circuit failures). If the terminal is used on a future program such as burn-in should be implemented.

5. Sensor Maintenance. Most of the sensors were installed and maintained for a period of approximately 14 months. The sensors in general, operated very well during the program and proved adaptable to the rugged trucking environment. In future applications, it is recommended that a re-evaluation of the sensors be conducted to determine if new and improved sensors that could possibly improve the system reliability and incorporate additional processing to reduce the effect of sensor toggling during normal system operations. The sensors were checked periodically for maintenance and evidence of vandalism. Each sensor is listed along with information obtained during this phase of the program.

- a. Door Sensor - The magnetic switches used on the cab doors proved to be reliable. The biggest drawback regarding the magnetic switch was its lack of ability to adapt to the irregularities of the doors and their ability to match up and close properly.
- b. Driver Alarm - The foot operated switch proved to be reliable. This switch was located in such manner it

required little or no maintenance.

- c. Ignition Sensor - Little or no major problem resulted from this sensing devince, it proved to be very reliable.
- d. Cargo Door Sensor - The magnetic switch used in this area was reliable and functioned properly. The only problem with this sensor was the rugged abuse and vandalism that occur in the cargo area.
- e. Seat Sensor - The pressure switch selected for this application did not meet the necessary reliability requirements. The primary reasons this sensor was described as unreliable was the inconsistency of the pressure applied to operate properly due to weak springs, installation restrictions, broken seats, and in a number of cases, driver vandalism. For further application, we recommend a more research in selecting a sensor to detect seat occupancy
- f. Motion Sensor - This sensor was reliable with inherent limitations. The primary limitation is the truck had to be moving over 3 mph for the sensor to indicate movement. Due to tire wear and flats, the wheel with the sensing magnets could be replaced at unscheduled intervals thus introducing additional maintenance.
- g. Volume Sensor - The ultrasonic sensor was not evaluated completely for a number of reasons. The sensor was not physically installed in all trucks because of truck conditions, quantity of freight, and actual system operation because of the high dollar value and susceptibility

to vandalism. Insufficient information is available to rate this sensor for acceptability during actual operations.

h. Countermeasures -

Tamper Switch - The pressure switch encountered little or no problem, it proved to be very reliable.

Countermeasure Circuitry - The countermeasures circuitry associated with the sensors proved to be quite a problem primarily due to the inability to protect this circuitry in the rugged environment. Better selection of components and additional design requirements recommended in future applications.

6. Signpost Maintenance. A number of minor problems were encountered with the signpost and signpost installation. The following list identifies some of the problems that occurred.

- a. Southern California Edison refused to allow use of their poles.
- b. Several cities were slow providing permission to use their poles.
- c. A number of poles with signpost transmitters were knocked down by vehicle accidents.
- d. The lithium cells used to power the signpost transmitters vented and in some cases caused power failure and corrosion to develop on the enclosed printed circuit board.
- e. Traffic at major intersections impeded installation.
- f. The number of power lines at major intersections influenced RF field propagation.

The signposts were checked periodically to determine if the signpost transmitters were functioning properly and for possible vandalism. Checks were made to replace any missing signposts due to poles being replaced by the local authorities following vehicle accidents involving the designated poles.

The signposts were checked periodically with the signpost tester. If for any reason the signpost was determined to be not functioning properly, the signpost was replaced. A number of spares were maintained for this purpose. Once the transmitter was changed, the new code was logged in and changes to the data base implemented. The software system included special routines to allow signpost changes to be made easily to update the system with the new code.

A number of spares were kept to replace any signpost removed due to vandalism or pole replacement. Pole replacement occurred quite frequently where a car or truck would knock down or damage the pole. Local city employees would replace the signpost and frequently notify Gould I³ or The Aerospace Corporation to note the change.

A major problem regarding the signpost transmitters was that the early production models of the lithium batteries used to power the signpost transmitter exhibited a higher failure rate than originally expected. A number of early failures of these batteries occurred due to venting of the cells. This is not only shortened the life of the battery, but the sulfur dioxide gas that vented into the transmitter housing created corrosion that shortened the life of a number of components on the printed circuit board. The battery company (Mallory) has made a number of improvements to overcome these problems. These improvements included the careful selection

of electrolytes, the development of a hermetic seal to prevent leakage of the sulfur dioxide gas, and the incorporation of a safety vent to release the gas prior to occurrence of explosive conditions, in the event of direct short circuit.

7. Vandalism. In this report we will define the word vandalism to describe any intentional damage to any part of the Cargo Security System. In some cases, it is difficult to distinguish between vandalism and failures that might have been attributed to other factors. In this paragraph, only the items that were considered apparent cases of vandalism are presented. These items include several incidents of:

- a. Removing the combined AM Phase and 27 MHz antenna from cab roof of TransCon trucks.
- b. Diking off wires to seat sensor
- c. Diking off power leads to battery, some cases just disconnected
- d. Wires diked off of motion sensor
- e. Antenna disconnected inside cab
- f. Splitter disconnected inside cab.

There were on a few signpost transmitters where possible vandalism occurred. One case was at the intersection of Valley Blvd. and Eastern. The only portion of the signpost remaining was the bracket. The bracket had marks that could have been made by pellets of some kind. Thus giving an indication of possible being shot with a gun of some type. Several similar cases of broken brackets and missing signpost transmitter could have been cases of vandalism but there was insufficient corroborating evidence.

CHAPTER IV AREAS FOR IMPROVEMENT

In this chapter a review of the results presented in chapter three is provided along with recommendations for improvements for future applications of this system. This chapter is divided into two sections: (1) AM Phase-lock recommendations and (2) Other Recommendations. It was felt that the most important subsystem in the Cargo Security Field Test Program was the AM Phase-lock system since it has so much potential as a low-cost wide-area automatic vehicle location system. A lengthy discussion is presented of some proposed improvements to the AM Phase-lock system. An example of the expected system operation with these improvements is also provided. Section B presents other Cargo Security System recommendations dealing with vehicle equipment, communications equipment, base station equipment, and dispatch station equipment.

A final consolidation of system results, areas of improvement and recommendations is presented in Chapter 5.

A. Location Subsystem Recommendations

This section presents the recommendations for improvement of the AM Phase-lock location subsystem. To support these recommendations, a discussion of the environmental problems encountered by the AM Phase-lock system in operation in urban and suburban environment is presented first. This is followed by a discussion of suggested hardware changes and additives necessary to eliminate these environmental, induced problems. This is followed by an example presentation of how the resulting location system would work in practice were it to be implemented.

1. Environmental Findings. Environmentally induced problems encountered by the AM Phase-lock location system discussed earlier in this report are of a general nature and have similar effects on all RF location systems to some degree or other. These problems are:

- a. Low Signal and/or High Noise - When the direct signal path is blocked by large structures, buildings, and dense overhead wires, the direct signal is attenuated, but the ambient noise is not. This results in a low signal-to-noise ratio (S/N) which can cause erratic readings (jitter) or the AM Phase-lock receiver to "freeze" during which time it loses any accumulated phase counts.

The relatively narrow bandwidth of the receiver admits a narrow bandwidth of noise as well as the signal. Noise is made up of receiver noise and normal ambient noise. In addition to the normal high level of urban noise, vehicle ignition noise contains harmonics in this frequency band of the receiver. This noise can result in lowering the signal-to-noise ratio and contributes to the receiver "freeze" condition.

- b. Coherent Interference - High voltage transmission lines have harmonics which can overwhelm the AM Phase-lock receiver in the vicinity of such lines. Low voltage lines also can cause harmonic interference since these lines can be quite close to the vehicle antenna. Underground utilities, railroad tracks, etc., can also cause the same problem and thus render the signals temporarily unusable.
- c. Multipath - Large structures, underpasses, or wires can re-radiate the signal and if the direct signal is blocked

by some structure, the re-radiated signal is then stronger than the primary signal. In these cases, the vehicle will actually track the re-radiation signal and produce an attendant position error caused by an increase in pulse transit time (or phase shift) from the transmitter (cycle slip). In a differential navigation system with periodic resets, the induced cycle slip (location error) remains in the system until reset. An absolute navigation system does not have these problems. Even if the re-radiated signal is not the strongest signal, it still contaminates the direct signal and distorts the phase grid to produce temporary warps.

Overhead wires and transmission lines can also carry signals many miles from the pickup point with less loss and differing time delays than free-space or ground propagation along the same path. This can appear as multipath distortion at various points alongside the wire if the direct signal is attenuated ("standing wave" cycle slips) or the vehicle antenna is very close to the wires (near field effect).

- d. Grid Distortion - Ground anomalies such as large underground concrete structures, rock stratum discontinuities, changes in ground conductivity, etc., can cause the detected grid lines to be distorted from theoretical. Water/earth discontinuities such as ocean beaches can also affect the grid when those discontinuities are between the transmitter and the receiver.

The environmentally generated conditions have varying effects on the AM Phase-lock system, some of which have been compensated for in the present design. There are five major effects of these problems on the AM Phase-lock receiver. These are:

- a. Cycle Slip - A region of poor signal-to-noise, heavy multi-path, or a region of heavy coherent interference can cause the receivers to slip phase counts (or start tracking a reflected signal rather than the direct signal) thus losing or gaining cycles (or causing temporary warps).
- b. Jitter - Poor signal-to-noise or rapid variation in the direct path propagation characteristics of the signal can cause the received phase information to appear to vary causing a jitter in the calculated position. The jitter appears to some degree at all times, but normally causes a relatively small position error ($\sim 50'$) unless the receiver is in a very poor signal-to-noise environment.
- c. Loss of Lock or "Freeze" - When the received signal-to-noise becomes poor or one of the other conditions discussed previously is exhibited, the receiver can completely lose lock. It will then freeze and re-enter the search mode to find and acquire a valid phase signal. Thus, depending on the ambient signal-to-noise as well as the receiver lock-on characteristics, no location information may be available for short periods of time.
- d. Bias Offset - These effects (diurnal variations, weather fronts, etc.) in general can cause a constant offset of the calculated position from the theoretical position over the region of interest. The resulting constant offset assumption

holds in general for regions up to 100 miles in diameter.

- e. Multipath Offset - Offsets in position appear when a strong reflected signal combines with or overwhelms the direct signal.

2. Enhancements to Overcome Environmental Problems. The environment causing the problem mentioned above can be classified into three categories. A discussion of each of these categories and the enhancements proposed to overcome the problems follow:

- a. Hostile Environment - These are the areas such as downtown high rise "canyons", underpasses, or high voltage lines where it was found that AM Phase alone will not work to any reliable degree. Gould I³ recommends overlapping signposts to provide coverage in these areas where the areas are large such as downtown.

At a specified range from a signpost (approximately 150') a vehicle which has been operating in the AM Phase mode will automatically switch to the signpost mode as the signpost signal is received. This range is automatically found from threshold level measurements in the signpost receiver. The unit will look for an adjacent signpost unless the vehicle moves out of the region of any signposts. This is defined by a second threshold level (approximately 300') from the signpost (with no other signpost being received) at which time it starts navigating in the AM Phase or dead reckoning mode (explained later) again. This "boundary" algorithm will allow for location performance in the transition region from all AM Phase to all-signpost operation. When an adjacent signpost is

detected, the navigation proceeds using the signpost receiver and the signpost navigation algorithm built into an on-board microprocessor.

- b. Marginal Environment - These are the relatively small geographical areas (usually less than 1000' radius) in suburban areas where (1) the AM Phase S/N ratio is poor enough so that there is danger of losing lock or extreme jitter or (2) multipath effects would cause large errors (exceeding 600') or (3) the receiver is in danger of slipping cycles. The recommended unit will automatically shift to a temporary "dead reckoning" mode until the signal quality is again usable. This dead reckoning mode, utilizing differential odometers, is practical because of four basic considerations:

- o The AM Phase theoretical grid of phase differences (ϕ_x and ϕ_y) vs. distance is linear over small regions (approximately 1 mile in radius) when the vehicle moves in a straight line.
- o City streets are normally straight line segments between turns.
- o Differential odometer data processing provides turn indication as well as distance. Differential odometers, with microprocessor calibration give quite accurate results¹.
- o Dead reckoning using differential odometers is very accurate over short distances (less than 1 mile).

1. "A Dead Reckoning/Map Correlation System for Automatic Vehicle Tracking," Lezniak, et al, IEEE Transactions on Vehicular Technology, Feb. 1977.

A typical situation is illustrated in Figure 4-1. This is a plot of the theoretical variation in Phase differences vs. distance in a typical marginal environment as the vehicle moves in a straight line (shown dashed) overlaid with the received phase data vs. distance including the effect of jitter or random warps which perturbates the actual received phase data (shown jagged) about the theoretical line.

When the odometer indicates no turn is occurring and the S/N detector (least squares resident) indicates an acceptable quality of signal, the vehicle unit on-board processor calculates a "least squares" fit for the slope, $\Delta \theta / \Delta d$, of the TD vs. distance (shown by the dotted line). Upon detecting a poor S/N condition, illustrated at Point A, the vehicle unit microprocessor extrapolates $\Delta \theta$'s phase lane counts (also shown by the dotted line) by multiplying the odometer Δd by the calculated slope $\Delta \theta / \Delta d$ so that an accurate phase signal can be presented to the base station. When an adequate signal is again present and the receiver/processor has started to track the signals illustrated at Point B, the vehicle unit again starts conventional AM Phase processing.

If a turn occurs during normal processing, the microprocessor starts calculating a new slope. If a turn occurs during "dead reckoning" the vehicle unit microprocessor uses its extrapolated distance at the turn, the delta angle of the

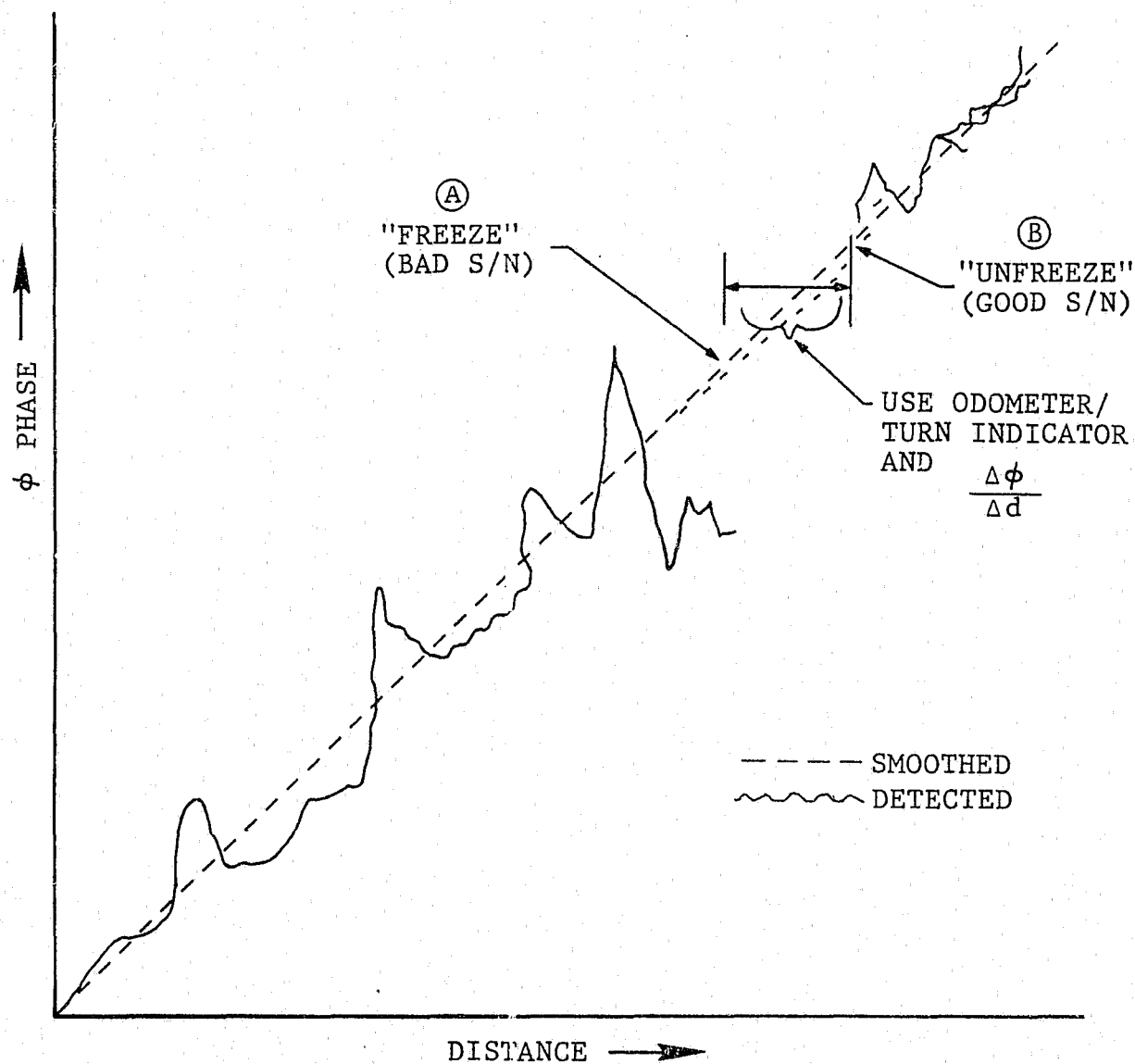


FIG. 4-1 TYPICAL PHASE ϕ VS. DISTANCE

turn and the $\Delta\phi/\Delta d$ prior to the turn, to compute a new $\Delta\phi/\Delta d$ for further extrapolation of phase lane counts.

- c. Benign Environment - When the S/N detector is above the acceptable level, the vehicle unit operates as a conventional AM Phase receiver (except for the enhancement of continuously computing $\Delta\phi/\Delta d$ slopes via the "least squares" method and extrapolation of ϕ 's via these calculated slopes and the distance traveled).

A constant grid bias offset is obtained from a prior calibration of the grid using a test vehicle or the use of a monitor station. This offset is known at the base station so that corrections can be made for it.

- d. Enhancements for Remaining Problems - The use of a signal quality calculation will allow excessive jitter conditions to be detected and eliminated by transferring temporarily to the "dead reckoning" mode. The use of the continuously extrapolated ϕ 's will allow any measurement to be tested for "reasonableness." Thus, cycle slips will be instantly detected and corrected for by the microprocessor.

3. Location Subsystem Hardware. The two independent odometers mounted on the front wheels will provide distance traveled to the on-board microprocessor. Inside the microprocessor, the data from the two odometers are converted to "differential" data for turn measuring since a turn can be calculated quite accurately by the microprocessor. We recommend an algorithm which measures the difference in distance (after the raw inputs are smoothed) traveled by the two odometers and converts this difference into a turn indication. During

periods of good signals the "least squares" processing algorithm will yield an accurate measure of the distance traveled along straight line segments. This accurate measure will be compared with the measure derived from the odometers and used to calibrate the odometer against the effects of varying tire radius, velocity, air pressure, outside temperature, etc.²

These odometers, in conjunction with the microprocessor, allow the dead reckoning mode to be easily and inexpensively implemented.

The microprocessor will also do the decoding, error checking, etc. which would normally be a part of the logic of a Gould I³ overlapping signpost-only location system.

After the location signals have been properly received and formatted by the vehicle microprocessor, they will be sent to the base station computer. There they will be converted by the existing algorithm to X,Y coordinates suitable for street matching. This X,Y algorithm is fully developed, and was used by Gould I³ very successfully on this program.

A complete file of the names and coordinates of all streets and highways in an area will be stored in the base station computer. All of the digitizing algorithms, software, and hardware have been developed and proven, and allow all streets and highways to be digitized for storage accurately and inexpensively.

The map matching algorithm in the base computer will take the computed X,Y and locate the nearest street so that the street location

2. Evaluating a Police-Implemented AVM System: The St. Louis Experience (Phase I) Larson, et al, IEEE Transactions on Vehicular Technology, Feb. 1977.

of the vehicle can be determined. This matching algorithm has also been developed and used successfully on this program. By interrogating the vehicle for the distance traveled since its last turn, a further map matching can be incorporated to improve the overall system accuracy.

4. Projected Accuracy. The AM Phase-lock location system with the enhancements discussed earlier would be an ideal candidate to meet an accuracy requirement of 600', 95% of the time. The dominant error sources are:

1. Jitter (low S/N)
2. Multipath (temporary warps)
3. Coherent interface
4. Cycle slips (permanent multipath)

Through use of signposts, odometers, turn indicators, and a least square fit algorithm these errors will be minimized.

When in the downtown high rise areas, the system navigates using "signposts." Signposts are the technology used by Gould I³ in Philadelphia in winning the Multi-User Automatic Vehicle Monitoring (AVM) runoff and were proven to meet 300' 95% of the time. Thus, one is assured of meeting 300' in downtown high rise areas where the signal is unusable for AM Phase-lock processing.

In areas of severe multipath or bad signal-to-noise, the receiver is enhanced by "local" dead reckoning. Dead reckoning is known to be extremely accurate over short runs. Since the areas of poor signal outside the high rise area are very localized, the local dead reckoning enhancement is ideal for maintaining system accuracy within the requirements.

In order to better envision the use of the system in an operational deployment, an example will be discussed showing how the enhancements are utilized to insure that the accuracy will be met. This example is first illustrated in Figure 4-2.

A theoretical grid of constant Phase X and Phase Y is illustrated by the diagonal lines. The path followed by the vehicle in the example starts at the start, S, makes a right turn at A and crosses through the downtown area to B. The signposts deployed downtown are shown by small circles (signposts are deployed throughout the downtown high rise area, but only those on the route example are illustrated). At point B, the vehicle turns left and soon enters a region of severe multipath caused by reflection of the signal from an adjacent structure. After traversing this region, the vehicle encounters a region where the signal-to-noise is so poor that extreme jitter occurs. While still in this region the vehicle makes a 45° turn to the left at G. After passing through this area, the vehicle passes beneath a high voltage power line before arriving at the end E.

An analysis of each of these legs will now be shown along with an illustration of the operation of the enhancements. The theoretical Phase X and Phase Y encountered on the leg will be shown (by a solid line) along with the hypothesized signal available from a conventional receiver (shown as a solid jagged line). The computed track of the vehicle by the on-board microprocessor using the enhancements will also be shown (as dotted lines).

The first leg from the start, S, to the turn at A is shown in Figure 4-3. Both phase lane counts are theoretically decreasing as we move toward point A, and the actual phase lane counts are also

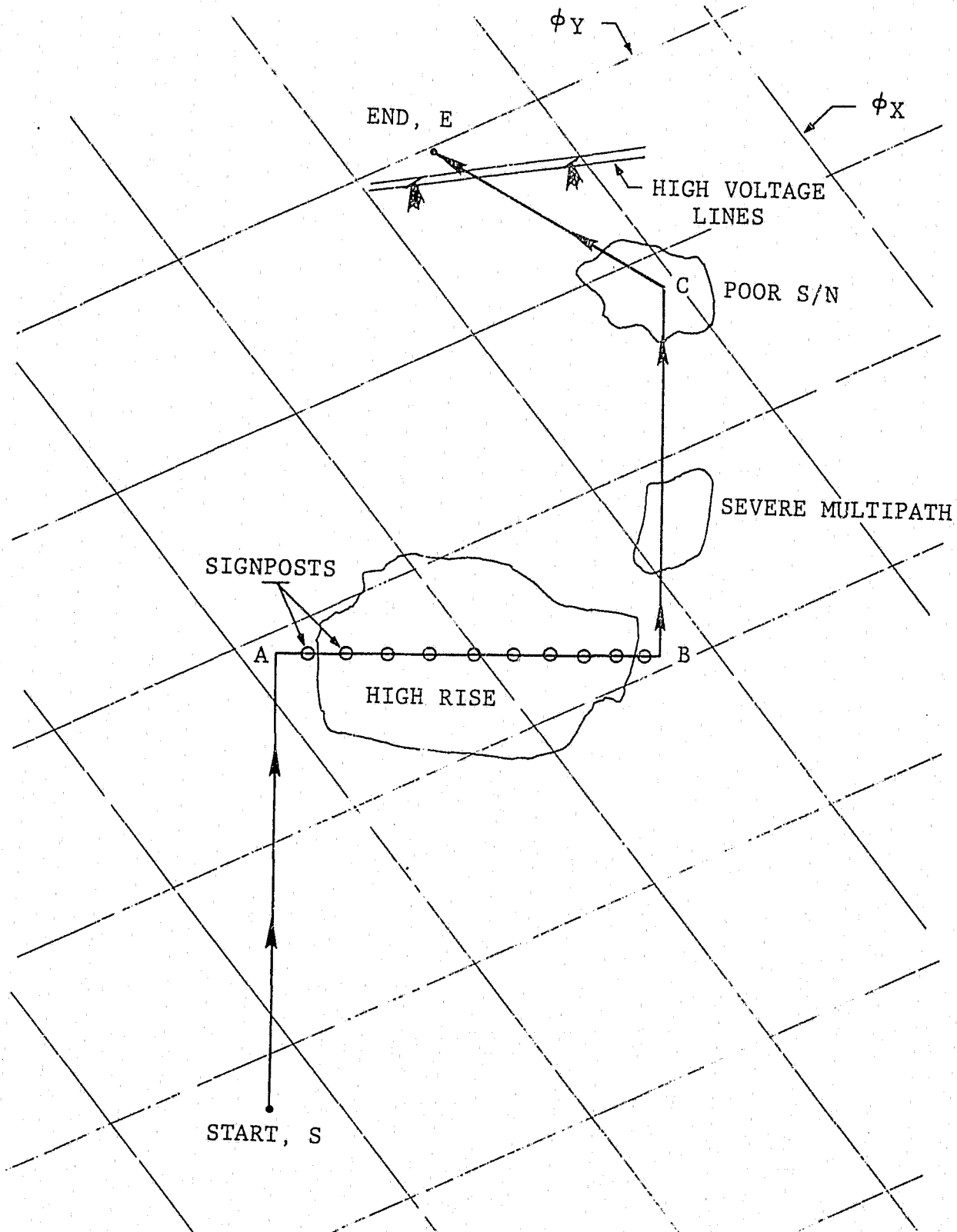


FIG. 4-2 LOCATION ACCURACY EXAMPLE

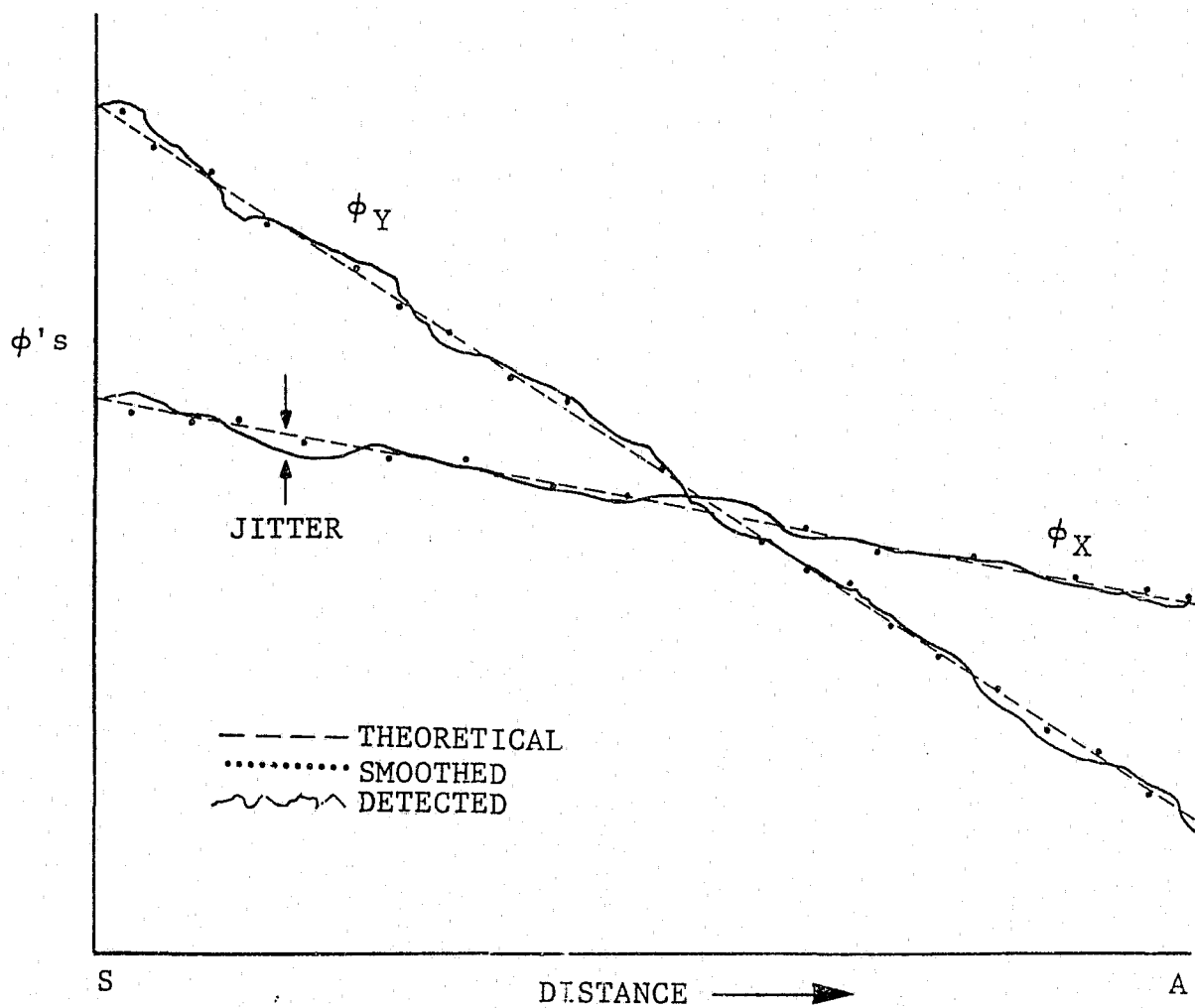


FIG. 4-3 LEG S-A OF THE EXAMPLE

decreasing with only a relatively small amount of jitter. The error equivalent of this jitter in clean areas such as this almost never exceeds 50' when an adequate signal is available (as we are assuming). However, the on-board processor is doing a continuous, linear least squares fit of the received data to further reduce this error. This output is shown as the dotted lines. The residual jitter is expected to be reduced to less than 10' maximum. This output is further used to do continuous calibrations of local dead reckoning sensors.

Upon turning right at A, the vehicle almost immediately encounters the signposts covering downtown and continues with signposts to point B. This leg is shown in Figure 4-4. As can be seen, the signal becomes quite erratic compared with the theoretical as the vehicle enters the downtown high rise area. However, at this point the vehicle starts encountering signposts. The dotted lines show the equivalent $\emptyset$'s computed from the microprocessor as it navigates using signposts only. Since the signposts can be installed so that no more than 300' is traversed before a new signpost region is encountered, a 300' 95th percentile accuracy would be assured.

The local dead reckoning system is used only in an auxiliary mode when navigating via signposts. As may be seen, the accuracy is excellent even though the AM signal is totally erratic.

At point B, the vehicle turns left exiting the high rise area and the signposts. This next leg is shown in Figure 4-5. As may be seen, after traveling a short distance, the least squares calculations (dots) become much more accurate than the jitter in the raw received data. When the vehicle starts entering the multipath area, the AM Phase raw data indicates that the vehicle has made a turn. However, the turn indication from the local dead reckoning sensor disproves

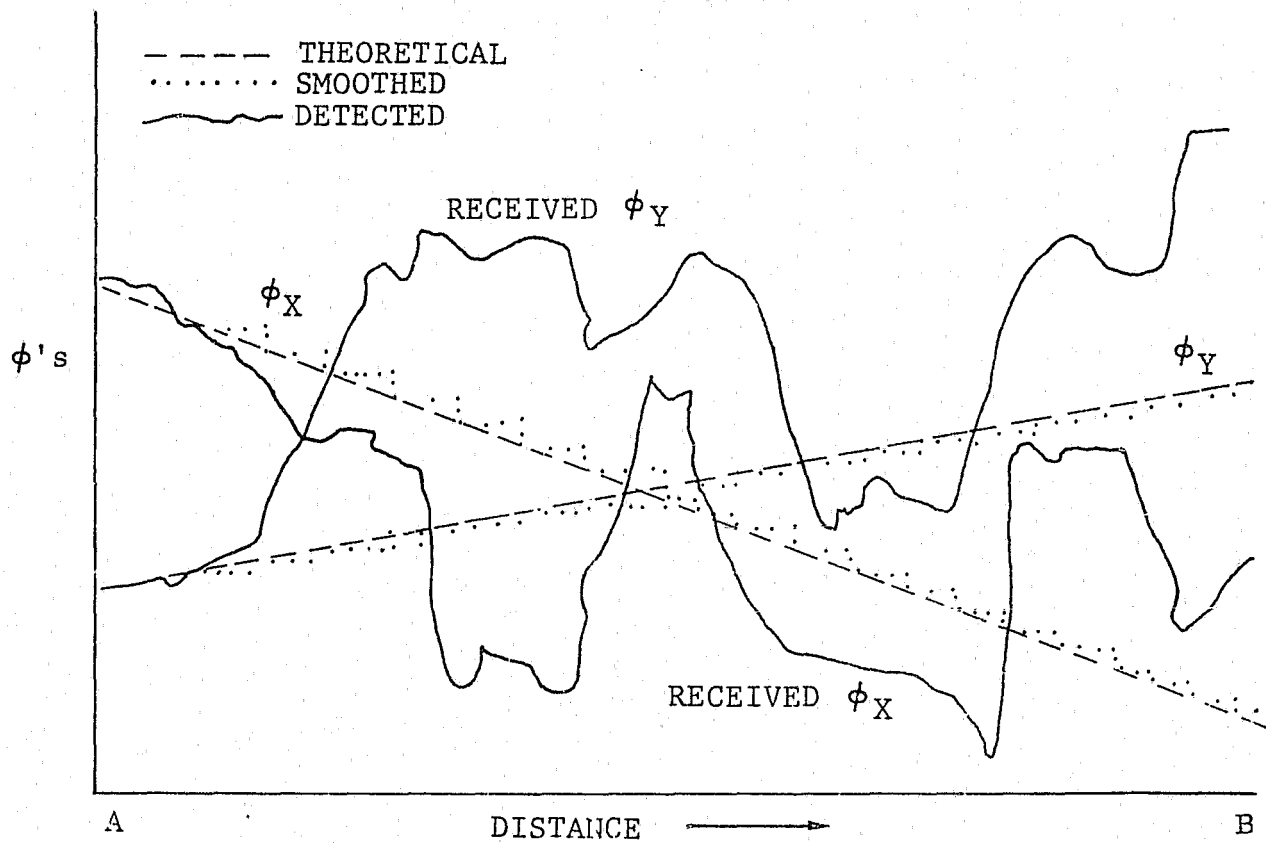


FIG. 4-4 LEG A-B OF THE EXAMPLE

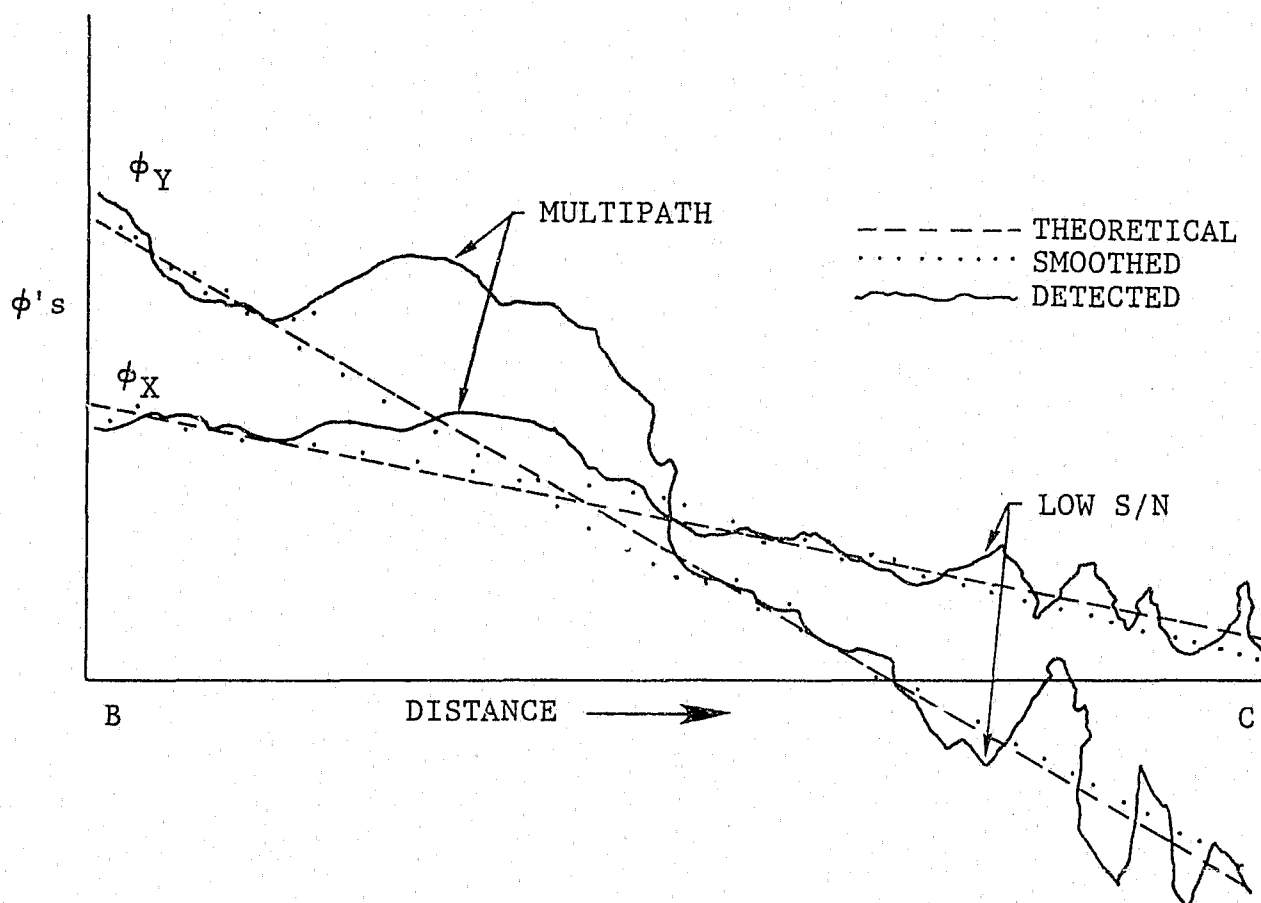


FIG. 4-5 LEG B-C OF THE EXAMPLE

this, thus indicating the received data is contaminated with multipath. The calculated slopes of θ 's versus distance obtained previously are now used instead of the received data and extrapolated forward using odometer inputs. The slight error in slope induced by residual jitter just prior to entering the multipath region as well as the slight error in the odometer data in measuring true distance traveled causes the extrapolation to differ slightly from the true theoretical, but the induced error is still within a specification.

As the vehicle exits the multipath region, the AM data starts to agree with the extrapolated data and the calculated AM data slopes come in agreement with the previously calculated slopes. At this point, system control reverts to basic AM computations augmented by the least squares calculations. This condition applies until the vehicle enters the region of poor signal-to-noise. This is indicated by the residuals (calculated jitter) in the AM data after subtracting out the least squares linear fit. At this point, the vehicle again reverts to extrapolating the θ 's using the calculated slopes and the odometer distance data.

At point C, the vehicle turns to the left by 45° while it is still within the poor S/N area. This leg is shown in Figure 4-6 and as may be seen, the S/N is still poor. The vehicle unit microprocessor takes the turn indicator information (45°) and calculates new TD's versus distance slopes using the turn data which are used for further extrapolation of the odometer. There is a slight additional error introduced at this point due to the error in the indicated turn ($\pm 1^\circ$), but the error is still within specification.

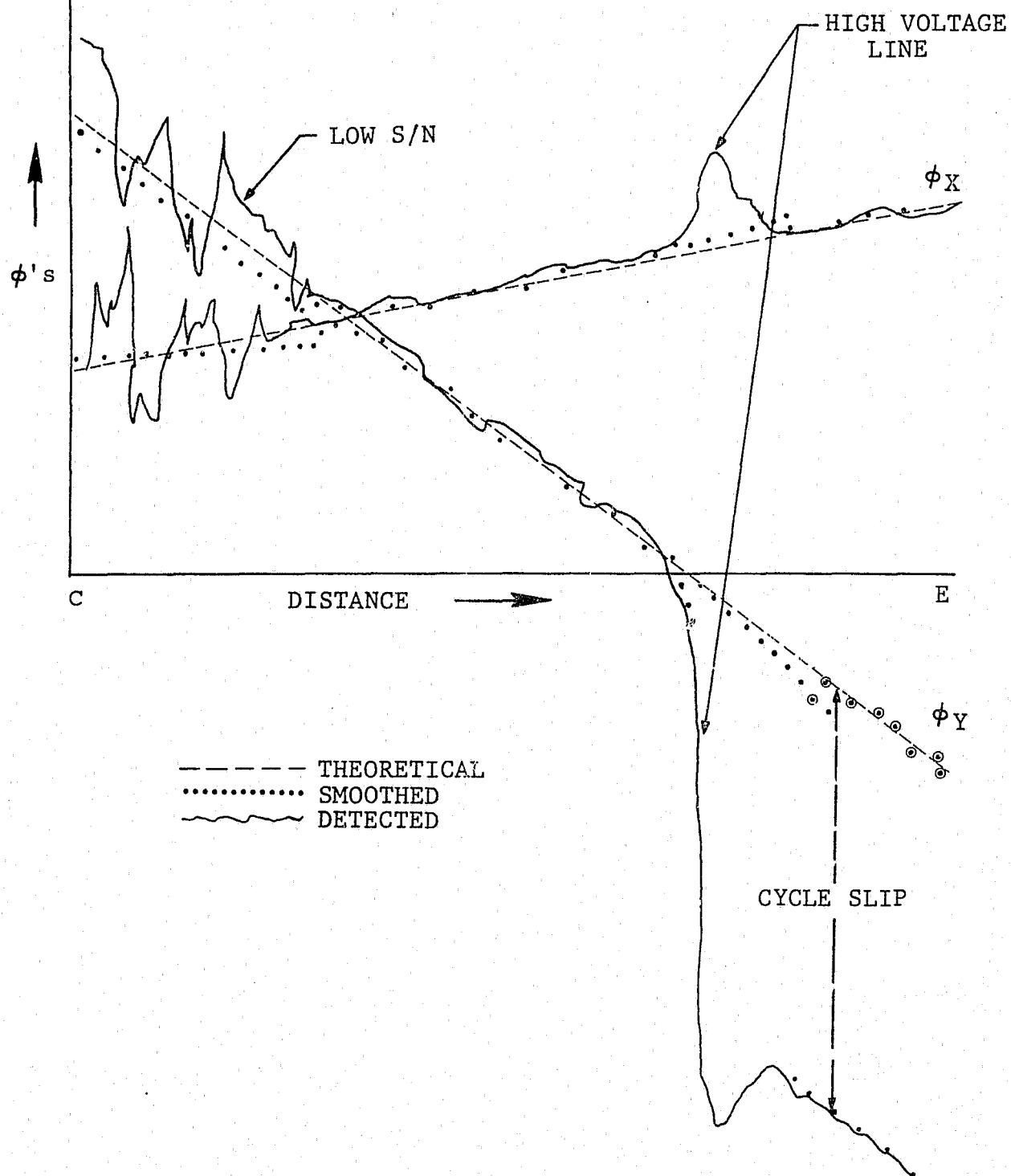


FIG. 4-6 LEG C-E OF THE EXAMPLE

After the poor S/N indication goes away, the unit again reverts to the basic AM data with the least squares fit as was done previously. This continues on leg C-E as shown by the dotted lines until the high voltage power lines are encountered.

At this point, one of the $\emptyset$'s ($\emptyset x$) exhibits a multipath anomaly which is handled in exactly the same manner as the previously described multipath example. However, the second $\emptyset$ ($\emptyset y$) encounters a severe problem in that the induced multipath is so severe the tracking mechanism of the receiver becomes confused and instead of tracking the direct signal, it starts tracking the reflected signal. This induces a large and increasing offset in the data, and this gross inaccuracy will persist forever unless it is corrected.

The vehicle unit microprocessor algorithm corrects this situation, however, since it is continuously monitoring for cycle slips. After the vehicle leaves the region of the high voltage line, the least squares is implemented on the cycle slipped data, and the distance (indicated by the dashed line) between the previous extrapolation and the current least squares is compared for equality. When this condition is not found (as indicated) the unit corrects the received data by the calculated amount (shown by dots inside circles) and proceeds.

This severe but representative example shows the real world conditions that AM receivers encounter. The recommended enhancements correct for these anomalies and would allow accurate AM navigation (600') everywhere.

5. Absolute Solutions for the AM Phase Subsystem. The current implementation of AM Phase is as a differential navigation system. No time marks are transmitted from the station to allow time of transit calculations to obtain the distance from the station to the

vehicle. The receiver continuously monitors phase and as phase goes through a cycle, distance of the cycle is calculated. That distance is added on to the previous sum of cycle distances encountered by the vehicle. If for any reason the vehicle should not properly calculate a cycle, this sum or integral retains the error forever.

It would be highly desirable to be able to obtain absolute position locations via AM Phase. It might be possible to put a small amount of modulation on the carrier and this could be the technique which would allow absolute solutions to be obtained.

For example, the FCC allows 20 cycle variations of the carrier. Were the carrier to be frequency modulated deliberately by a sine wave signal of 20 samples per second, the AM Phase receiver could be designed to track this modulation signal (which mounts to a sub-carrier on the carrier). 20 cycle per second signals give a wave length many miles long, more than sufficient to cover the region of interest for one cycle of this phase. Thus, solutions could be obtained within the region of interest by tracking the carrier modulation. It is recommended that this approach be pursued.

B. Other Recommendations

Evaluation of the operation of other elements of the system has also been conducted with a view toward improving performance. In the following subsystems, improvements in the operation of each subsystem are identified.

1. Vehicle Equipment. Trucking company vehicles, in general, do not have properly noise-suppressed ignition systems. As a result, ignition noise is generated (in some cases in quite significant amounts). The harmonics are particularly bad in the band associated

with the signpost receiver and can cause so much signal-to-noise interference that signpost signals are actually missed.

Since the system, in effect, has a signpost interlock entering and leaving the yard, these specially coded signposts must be detected for the base station to know if the truck is in the yard or out. The system cannot function properly because of electrical noise interfering with the signpost receiver at those locations and the overall system thinks the truck has not actually entered or left the yard.

The recommendation for improvement of this situation in any future system is to install ignition suppression on all vehicles that are to be used on the test.

As mentioned, when a truck enters the yard it enters the remote alarm mode. However, every trucking company is unique as to its radio coverage. As a result, if a truck is parked inside a shed, then no communication is possible with the base station and it is possible for various undesirable things to happen including running the batteries down. For this reason, i.e., that no common solution is available to insure communication with trucks in the yard, it is further recommended that remote alarm not be implemented in a future system. This would insure that undesirable things such as running down the batteries could not occur. The experience with both Transcon and GI led us to believe that the remote alarm function would be of highly marginal use in any case. It is further recommended (if remote alarm is removed) that the dispatch station be transferred to security.

In spite of intense efforts to protect the system as much as possible against accidental or deliberate damage it was found in the various maintenance pulled, that vandalism had been done to the installations, probably by the drivers. There is no possible way that an absolute guarantee can be made that any system cannot be vandalized. If nothing else they could take a sledge hammer to the vehicle box. Our only goal in the whole program was to insure that if vandalism did occur we could ascertain whether it was deliberate or accidental. This we were successful at doing.

However, the deliberate vandalism caused a number of the vehicles to be inoperative until they were repaired. It is recommended in any future program that an intensive training effort be done at the start of the program to attempt to reduce these incidents of vandalism.

It was found also that various truck batteries were quite weak. It is trucking company policy to run a battery until it will not hold a charge for starting again. In some cases this means that batteries are old and very weak. For example, we found on one truck that one 25 watt transmission from the mobile radio would pull enough charge off the battery to drop the steady state voltage from 12 volts to 8 volts. It is recommended that on a future program that new batteries be installed in all trucks that are to be used.

2. Communications Equipment. Although the program was stopped because of co-channel interference, the common communications link concept worked extremely well. The drivers and dispatchers were not aware of any transmissions going to and from the base station. The common communications link is therefore recommended as the communications approach to be used on any future program. However, it must be accompanied by a permanent user license to insure that there will be no co-channel interference. Therefore, well in advance of any

program, provisions must be made to obtain such a permanent license.

3. Base Station/Dispatch Station. It was found in the course of the program that the arithmetic computations involved in determining position were extensive enough to require the speed of a higher speed computer and an 11/34 was temporarily added to the system. It is recommended in a future program that nothing less than an 11/34 be used.

From a convenience standpoint it was found that, due to freeway traffic, it was impractical to get rapid access to the base station if it crashed or needed any modifications. Therefore, in any future operational use of the system it is recommended that a remote access terminal, over leased lines, be attached to the base station so that normal base station operation commands can be done from this terminal at a convenient site. The base station site on this program was chosen for coverage reasons and not for convenience access reasons.

It is further recommended that any software that is used on a future program have automated crash recovery procedures built in so that it won't be necessary to go to the base station to restart the system.

The dispatch concept was to use an intelligent terminal at the dispatch station which would, in turn, route data from one single modem port to the printer and to the remote alarm and also collect data from the remote alarm CRT keyboard and the dispatcher keyboard for transmission over that same port back to the base station. Using only one port minimizes leased line costs and using an intelligent terminal allows this to be done. In addition, a low speed modem was used, thus minimizing all communications costs.

However, it was found that the intelligent terminal chosen (although it had many desirable characteristics such as extremely bright, flicker-free, color displays) had a very primitive operating system from a host computer communication standpoint. It is recommended that in any future program, a custom operating system for the intelligent terminal be written first. This would dramatically increase the speed or reduce the time delay between an actual event being detected at the base station and showing itself to the dispatcher. It would also prevent any queueing problems at the base station. The extra operating system need not be complicated at all, but should just be merely a communications handler.

CHAPTER V SUMMARY OF RESULTS AND RECOMMENDATIONS

When viewed from a development standpoint, a Program (1) demonstrated the multi-user wide area coverage capacity and potential capability of AM Phase as a vehicle location technology, (2) established that a dedicated common mobile radio digital communication link for multiple users can be implemented, and (3) achieved numerous technical firsts in the implementation of a combined data base driven and event driven data processing system in a distributed processing environment. However, these features and capabilities were not allowed to be fully tested and evaluated in an operational environment because of the unavailability of a clear mobile radio channel in the Los Angeles area.

A summary of the technical achievements is presented in Table 5-1. The technical achievements have been categorized into three areas: location system, communication system and data processing and control system. Some of these achievements have been accomplished by other systems, but none have been done in such an economical manner (e.g., host computer-to-remote computer interface - the remote dispatch station consisted of three, separately supplied, off-the-shelf components which were linked to the host computer using a single low speed data modem and required no added special interfacing or signal conditioning hardware. Other achievements, such as the development and test of a terrestrial AVL system which operated anywhere within a 400 square mile area have never been accomplished before.

A summary of the Program results identified in previous chapters, describing the system results which lead to the set of recommendations

TABLE 5-1 SUMMARY OF TECHNICAL ACHIEVEMENTS

LOCATION SYSTEM	- o The AM Phase-Lock grid, generated by three AM Broadcast stations has been tested and demonstrated that it matches theoretical calculations and produces fields which are invariant, stable, and repeatable. - o A precise AM Phase-lock sensor/receiver/processor has been developed which compensates for anomalies in the transmittal field, such as overmodulation, etc., and allowed the environmentally generated grid warpage phenomena to be qualitatively and quantitatively defined. - o A preliminary assessment has been completed to determine a method whereby the true potential vehicle location accuracy using the AM Phase-lock technique could be achieved. - o A hybrid differential navigation system has been developed which determines absolute vehicle location using relative phase data from the AM Broadcast stations and resetting signposts.
COMMUNICATION SYSTEM	- o A single channel, multiple user, mobile radio communications link was implemented. The communications link demonstrated its capability to transmit and receive digital information from vehicles located anywhere within a 400 square mile area of the Los Angeles basin. - o Digital data thruput for the implemented communications link was evaluated and demonstrated error-free transfer in excess of 98% of the time at a 1500 bps data rate. - o A base station computer-to-remote computer communications link which operated at 1200 bps over conditioned telephone lines was developed, tested, and operated free of undetected errors.
DATA PROCESSING AND CONTROL	o A variable alarm system was developed whereby various alert and alarm conditions could be assigned to specific vehicles. An in-vehicle RAM was loaded to specify the types of alert and alarm conditions which would be applicable to a specific vehicle.

TABLE 5-1 SUMMARY OF TECHNICAL ACHIEVEMENTS (CONTD)

DATA PROCESSING AND CONTROL (CONTD)	- o An automatic vehicle "mode shifter" was developed whereby individual vehicles would automatically change operating modes upon entry or exit from trucking company yards. The automatic mode shifter could be disabled via keyboard entry at the base station terminal. - o Development was completed for a unique, two-part software package to allow the remote microprocessor to give full information on twenty trucks and also drive a printer, another CRT, and two keyboards -- five devices in all -- using a single 1200 bps telephone link. - o A highly accurate "inverse" algorithm (AM phase to X-Y), and closest street intersection algorithm were developed and used. - o The development of a street data base algorithm, digitizing method, and nearest segment look-up algorithm which produced an alphanumeric display of over 30,000 nearest intersections in the 400 square mile area was completed. - o The development of a data base and event-driven, asynchronous control system servicing 56 separate devices, 54 of which were remote was completed. - o An applications package program of over 36,000 words was developed which made use of over 350,000 words of user data base detected, processed, managed, time tagged, and recorded in volatile memory over 37 different types of messages from enabled remote vehicle units and on-line recording of all transactions to and from each remote vehicle unit and dispatch station.

to be considered for any future implementation of the Cargo Security System is summarized in the following paragraphs. The information is formatted into areas which describe the salient results and specific recommendations. The areas addressed are: overall system operation results, communications results, AM Phase results, vehicle equipment results, dispatch station results, and base station results.

1. Overall Results. The overall system worked well including the base station, the dispatch stations, the vehicles, the AM Phase unit, etc.

Recommendations: There should be a follow-on program for the Cargo Security System which would consist of (1) a special development phase to implement and test the AM Phase recommendations provided below, (2) an active deployment of the improved system and (3) an evaluation of system operation with a dedicated, clear channel communication link.

2. Communications Results. The common communication link worked extremely well. When the radios were operating at full power the throughput approached 100% and in all cases was at least 98%. However, the total evaluation program was not completed due to the non-technical problem of co-channel interference of the common communications link.

Recommendations: In the follow-on program, the common communications link concept (CCL) should be used. When the common communications link is used, a permanent user license for the selected frequency must be obtained.

3. AM Phase Results. The AM Phase hardware worked extremely well. The AM Phase receiver provided a means of determining the actual RF phase characteristics and nuances of the AM Phase data

which was received at the antenna. As a result of having the developed AM Phase receiver, it was discovered that the external environment produced contaminated AM Phase signals (due to multipath) which were impossible to eliminate with the current unaugmented receiver RF processing system.

Recommendations: Use the AM Phase system (in a hybrid with overlapping signposts) as the vehicle monitoring technique in the follow-on program. In the follow-on program, a special development phase should precede implementation of the overall system. This development phase is to combine "local" dead reckoning with the accurate AM Phase data. The local dead reckoning should consist of dual odometers (which are quite inexpensive), or a similar device(s) for providing heading and distance information, an on-board microprocessor in the vehicle unit (to process the odometers and make the dead reckoning calculations).

4. Vehicle Equipment Results. Due to metal building interference, communication with the vehicles once they are parked in the yard was sometimes very spotty. In some cases, because of the bad communication, the vehicle batteries ran down causing inconvenience to the trucking companies (and in addition, the base station did not have accurate knowledge of the vehicle status, only that communications was not possible).

Recommendations:

(1) Eliminate necessity for communication with vehicles once they are in the yard. This approach could be implemented by deletion or redefinition of the remote alarm mode.

(2) Switch the system into a very low power, stand-by state, using yard entry signposts, to switch the system to low power or off

when a truck goes into the yard and switch the system to normal when a truck exits the yard.

(3) As part of the installation procedures, all vehicles should be tuned (to reduce truck noise) and new batteries installed to preclude trucking company operation inconvenience.

5. Dispatch Station Results. The dispatch station distributed processing concept of using intelligent terminals to reduce cost was proven and worked well. However, the terminals chosen exhibited poor reliability. Additionally, updates of vehicle status from the host computer to the dispatch station were delayed in time due to the high overhead communications format required by the operating system of the ISC.

Recommendations:

(1) Use the distributed processing concept in the follow on program.

(2) In the follow-on program choose a different terminal or conduct a reliability improvement program for the ISC terminals.

(3) Develop a special communications adjunct to the operating system so that the format problem can be reduced to manageable portions, thus improving the delay time and the queueing situation at the base station.

6. Base Station Results. The base station worked very well. The software was reliable and computational results were very accurate. However, system testing identified that a faster computer than originally envisioned was required. Additionally, because of the few system crashes which did occur, it was necessary to have an attended base station to provide system recovery in the event of failure.

Recommendations:

(1) In the future program, use at least an equivalent of a DEC 11/34 or modify the distributed processing concept.

(2) In future systems. complete the implementation for the remote access terminal which was used as the system console. Have the terminal located at a site which is convenient and implement, to the maximum extent possible, automated crash recovery procedures.

END