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of Transportation

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TRAIN TO WAYSIDE IDENTIFICATION SYSTEM

1998

Federal Transit Administration

Office of Research, Demonstration and Innovation

METRIC / ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

$[(x - 32)(5/9)]$ °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

$[(9/5) y + 32]$ °C = x °F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES	0	1	2	3	4	5	6	7	8	9	10

CENTIMETERS 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 | 25.40

QUICK FAHRENHEIT-CELCIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and/or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10 286.

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16. Abstract

Train to Wayside Communication (TWC) is an optional feature installed on some of the more advanced rail transit system. TWC typically provides two way data communication from moving trains to a central control center. Information such as vehicle numbers, train number, destination, location and vehicle health is transmitted.

TWC is both expensive and usually provided, due to the complexity of the equipment and installation, as an initial feature of a transit system. The search began for an adequate replacement for TWC that would be inexpensive and could be installed on an operating system. This leads to a unique application of an existing automatic identification system. This system transits train operating data from selected wayside gathering points to an operations central control. There, the central computer system displays train identifications as well as assembling a variety of statistical reports . The Mass Transit Administration (MTA) of Maryland demonstrated a TWC system on its rapid rail transit system under an FTA Technology Instruction program grant.

The need for TWC has been adequately fulfilled on an operating rail transit system with automatic identification equipment. From this project, and perhaps future application of this equipment in a similar manner, a suitable replacement for TWC may be provided, which can be done both inexpensively and at any time during the operation of a transit system.

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TABLE OF COMMENTS

EXECUTIVE SUMMARY

The Maryland Department of Transportation, Mass Transit Administration (MTA) has prepared a final report on the Train to Wayside Identification project. The project is hereafter referred to as the AVI (Automatic Vehicle Identification) project. It was funded by the Federal Transportation Administration under the New Technology Introduction Program.

The project was proposed to demonstrate the applicability of automatic identification equipment as a substitution for the traditional TWC (Train to Wayside Communication) systems used on some of the more advanced rail transit systems. TWC is typically a two way communication system utilizing the rail or wayside transponders as the medium. These systems provide for the passing of information and controls between operating trains, wayside signalling and operation control centers. Train consist, destination, identification, condition (commonly called health) and other such information is passed from the train to the wayside. In turn, the wayside equipment and control center passes information and commands as to location, acceleration profiles, train number assignment and destination updates.

This demonstration was designed to use significantly less costly automatic identification equipment. Automatic identification equipment is typically comprised of one way communication devices. The equipment and accompanying software is arranged for use, to the greatest extent possible, as a substitution for TWC. The purpose of this arrangement was to determine the feasibility of using this equipment, configured as a TWC system, for providing real time train identification, automatic routing, generation of statistical reports and automatic maintenance scheduling.

The AVI demonstration included the installation of RF transponder tags on the MTA's 50 married pair METRO railcar fleet. Six wayside reader locations were installed along the line for receiving the data of passing trains. The sites were selected at even intervals and at critical locations such as the midline entrance to the yard and terminal stations. The data is transmitted from the 6 wayside locations to the Operations Control Center via the existing T1 carrier system.

The AVI software package is installed in the central computer system adjacent to the central operating software. Links are provided to the central operating software as required for interface to the scheduling, time and display functions.

Operations personnel can invoke the AVI system at any of the existing workstations. The Operator can view the entire system in real time as the trains pass the wayside locations. The data transmitted from the field includes the location, time, track number, train direction, number of cars in the consist and the identifications of the cars in the order of passing.

The operator can view, and print as required, any of several reports generated from this data. The reports include the system operating data log, specific site operating data log, train (activity), vehicle mileage and vehicle revenue hour operation. The reports can be generated on any number of specific vehicles or sites as selected by the Operator.

A vehicle maintenance scheduling report is also available. It is included as part of the vehicle mileage and vehicle hours report. This report is based on the previous recorded maintenance period and utilizes the AVI mileage and revenue hour data in the generation of the report. For this project one maintenance scheduling report was selected to demonstrate the function. Additional computer memory has been reserved to provide any practical number of additional reports to be added at a later date. These can be based on differing maintenance intervals, accumulated vehicle mileage and accumulated vehicle revenue hour operation.

This is the first known application of this type equipment to a rail transit system. Through this project substantial experience and information was gathered that can be valuable for future projects. It is the MTA's intent to maintain this equipment as a permanent operating system. The long term reliability, maintainability, use and function of the system will be assessed and considered when planning system upgrades and expansions.

Plans for expansion of the AVI system include additional software reports, additional wayside reader sites, upgrading of several of the existing site capabilities, and possibly installation of a vehicle location system for the yard. Future plans may also include the upgrading of the fixed ID RF transponder tags to the newer dynamic RF transponder tags. These new tags allow for the input of dynamic vehicle data, such as failure alarms, during actual operation as they occur.

This project has proven the practical application of a RF transponder tag system on a rapid transit system. A well planned AVI system can substitute for a TWC system, and be installed under operating conditions at a significant cost savings.

PART 1

SYSTEM DESCRIPTION

1.0 SYSTEM DESCRIPTION

This report is the summation of the FTA sponsored Train To Wayside Identification Demonstration project. The project was initiated to demonstrate the applicability of automatic identification equipment as a substitution for the traditional TWC (Train to Wayside Communication) systems used on some of the more advanced rail transit systems. TWC systems are typically two way communication systems utilizing the rail or wayside transponders as the medium. These systems provide for the passing of information and controls between operating trains, wayside signalling and operation control centers. Train consist, destination, identification, health and other such information is passed from the train to the wayside. In turn, the wayside equipment and control center passes information and commands as to location, acceleration profiles, train number assignment and destination updates. Automatic identification equipment is typically, as in this project, comprised of one way communication devices.

This system and accompanying equipment of this demonstration were installed on the Maryland Department of Transportation, Mass Transit Administration's METRO rapid transit line. The METRO is a 18 mile, 29 kilometer rail transit line operating in Baltimore, Maryland on dedicated right of way. The right of way includes elevated, at grade and subway areas. There are 100 heavy rail transit cars operating as 50 permanently coupled married pairs. The married pairs are bi-directional and are operated as two, four and six car consists. The signalling system is automatic train control with cab signals of 10 to 60 mph (16 to 96 kph) with an overall average speed of 40 mph (64 kph). Peak headways are at 6 to 8 minutes with six car consists and off peak headways are at 10 to 12 minutes with two and four car consists. Revenue operation is from 5am to midnight, Monday through Saturday.

1.1 EQUIPMENT AND TECHNICAL DETAILS

The equipment used on this project includes vehicle, wayside and central components. Following is a summary of the equipment.

1.1.1 Vehicle Equipment

The vehicle equipment consists of RF transponder tags manufactured by Amtech Systems Corp. of Dallas, Texas. The tags were supplied by AVI subcontractor CCTC International of Houston, Texas and were programmed prior to installation with each individual car number. They are affixed to the side of each car with double sided, high strength building construction tape by 3M. The tape was selected in lieu of installing mounting brackets or direct fixation, which would have required mounting holes in the car body. Weather and chemical resistance of the tape was reviewed in detail and has thus far proven reliable.

The tags were installed on both sides of the cars to provide reading of the identification regardless of the track or direction that the car may operate. Although the cars operate as permanently coupled married pairs, the tags were installed on every vehicle. This arrangement allows the system to identify a married pair in the instance of a lost or damaged tag by reading the remaining tag on the other vehicle in the pair.

The tags selected do not require any maintenance. They are powered by the RF signal transmitted by the wayside reader units. Missing or inoperative tags can be identified by viewing the system operating data log kept by the central computer. Maintenance personnel can then be sent directly to the vehicle requiring attention.

1.1.2 Wayside Equipment

The wayside equipment consists of six reader units installed at intervals along the double track line, at terminal stations and at the entrance/exit to the yard. Careful consideration was given to remain within the scope of the project while providing an arrangement that would prove to be a suitable demonstration and a building block for the future. Three of the units were arranged as double track units while the remaining three were installed as single track units.

The manufacturer, again CCTC, presented several versions of the same equipment arranged in different enclosures. The choices included:

(1) equipment modules to be installed in owner supplied enclosures

(2) clustered modules preinstalled in mini-enclosures

(3) a complete working system built into a unique cabinet providing full access to all the modules

(4) a bungalow style system usually provided for multi-track installations.

The third choice, a complete working system, was selected. This unit is called the Standalone. It can be configured as a one or a multi-track system. The unit includes a unique double hinged cabinet. The front has a swing open door for servicing the first set of modules. The entire cabinet can then be unlatched from the mounting base plate and swung open for servicing the second set of modules. Optional control and indication panels were installed for local indications of status and activating several self-diagnostic routines. An optional test tag system was included with each unit providing special transponder tags mounted within each antenna assembly. These tags are activated by the Standalone during diagnostics to provide a dynamic test of the readers operation.

The power supply in the Standalone is a complete UPS (uninterruptible power supply) unit capable of accepting two AC power sources. It also contains internal rechargeable batteries. It is an automatic switching unit capable of temporarily running from the internal batteries if both power sources fail. The cabinet is fully sealed with thermostatically controlled heaters and multiple fan coolers including a caged, finned heat exchanger mounted as part of the cabinet. Several serial computer ports are provided for transmission of the data and for either remote or local diagnostic and programming. Programming memory is retained if the unit is shut down or suffers complete power failure.

In considering the structures and close clearances of the transit line the readers were installed as single antenna sites versus the more conventional dual antenna, dual read sites when used on the freight railroads. The single antenna sites also allowed more flexibility in choosing reader locations since free space only had to be on one side of the track for equipment installation.

Dual magnetic wheel sensor assemblies by CCTC were installed at reader locations for each track being monitored. The wheel detectors are used to activate readers in the presence of trains and in determining speed and direction data for the AVI message to be transmitted to central.

An optional "presence" signal feature was not used. This involves connection to existing track circuits or installation of overlay track circuits. When used it can turn on the reader in advance of an oncoming train and provide a more reliable operation. It was determined that considering the lower train speeds in the areas of the reader installations that this feature was not required. If needed it can be added at a later date.

System activation occurs when a train is detected by the wheel sensors. The reader transmits a 900 MHz range RF signal to the train. The transponder tags on the train utilize the transmitted power from the reader to assemble a message containing the coded car identification and transmits the message back to the reader. The reader then uses the information from the wheel detectors and the tag reads to assemble a message to be transmitted to the central computer system. The message includes the time (which is updated periodically by the central system), location, track, direction, speed (not used), and the number of cars in the consist with the identification of each in the order of passing. Additionally the reader runs through a proprietary error correcting and filtering routine in assembling the message since the tags are read multiple times on each passing.

1.1.3 Communication Equipment

Wescom channel unit modules were installed in spare slots on the existing T1 carrier system. Modems were installed at both the wayside and central ends of the system.

The manufacturer normally supplies a 2 wire dial up modem for the reader units. This modem could not be used with the 4 wire channel unit modules. A high quality, extended temperature modem manufactured by Motorola was selected and installed directly in the Standalone units. The central modems are manufactured by Microcom and were provided as six plug in units in a rack mounted card cage.

1.1.4 Central Control Equipment

Connection of the modems to the central computers was made by the addition of an Annex III terminal server on the primary ethernet line. The AVI system is considered non critical and therefore no provisions were made for connection to the secondary ethernet.

A dedicated printer was installed, remotely in the equipment room, to allow both operations and maintenance personnel to print reports as required.

The control and display of the system is accomplished at any of the existing central computer workstations. These are located in the main control room and at several remote sites.

1.2 SOFTWARE

The AVI system software was developed by prime AVI contractor SYSECA Inc. of Marina del Ray, California. It was assembled as a complete operating package. This was done to provide a distinct separation of AVI software functions as compared to the central operating functions. It was installed in the existing central computers with links to the central operating software as required for interface to the scheduling, time and display functions. Record keeping is eternal and a backlog of data is purged only through memory management maintenance of the central computer system. Any of the given reports can be displayed and/or printed as desired. Assembling the reports for specific periods, locations and vehicles is provided. The package provides for the following displays and reports:

1.2.1 AVI System Operation Report

This is the overall AVI system display exhibiting the complete operation. AVI messages are transmitted to central as trains pass the reader sites and assembled on this display in a scrolling fashion. One line of information on the System Operation Display represents a train passing an AVI reader on the wayside. The information contained on each line includes:

Train Number (The AVI software compares the move time to the system schedule currently selected in the central operating system. If the move time falls within a given tolerance of a scheduled train, then the number of the scheduled train is assigned to the AVI record. If the move time is outside of the tolerance for a scheduled train, then the train is identified with a ? symbol in the AVI record.)

Move Time (time that the train passed the reader)

Scheduled Time (Scheduled time of the train as called for in the selected operating schedule)

Deviation (Difference in the scheduled time as compared to the move time of train passage)

Station (name of the closest station to the given reader)

Track (track number)

Direction (East or West for this line)

Length (Length of train consist indicated as number of cars)

Cars (Car identification numbers in order of passing. Note that any cars with defective or missing tags are listed with a "?" symbol.)

1.2.2 AVI Station Report

This report contains the same information as the System Operating Report except it is selected by the operator for any one of the 6 AVI reader locations.

1.2.3 AVI Train Report

This report is invoked to allowing viewing a period of operation for specific trains by train number (train numbers are assigned to operating consists on the line and are used for the tracking and scheduling of the system).

1.2.4 AVI Vehicle Mileage / Hours Report

This report can be generated for each car to assist in vehicle mileage and revenue hour tracking. Developed primarily for vehicle maintenance tracking it can also be used for statistical record keeping and financial operating budget reports. The following information is listed for each car.

Car Number

Daily Hours (Number of revenue operating hours for the given day)

Daily Mileage (Number of operating miles for the given day)

Accumulated Hours Since Last Maintenance (Last maintenance is the date the vehicle was last maintained and is data enterable)

Next Maintenance (This is a data enterable duration in days to the next scheduled maintenance. The system calculates and displays the required date.)

Life Hours (Number of total revenue operating hours on the vehicle. The number is calculated automatically and is based on the cumulative time between reader sites. It is also data enterable to allow periodic updates to correct for slight system drift.)

Life Mileage (Number of travel miles on the vehicle. This number is calculated automatically and is based on the cumulative distance recorded between reader sites. It is also data enterable to allow periodic updates to correct for slight system drift.)

1.2.5 AVI Daily Summary Report

This report is generated daily at the end of revenue service. It displays the mileage traveled on the main line for each train by train number. Included is the daily total for the number of trains passing AVI sites and a summary report of bad tag reads.

1.2.6 AVI Active Trains Report

This report displays a list of current active trains operating on the system. Listed by train number the information includes the number of cars, the car numbers, and the last station/track direction of movement recorded. This report is not generated by the AVI software. Generated and maintained by the central operating software, it is viewable via an alternate command to allow a quick reference to the train list by operations personnel when working with the AVI package.

1.3 Testing

The contract specification for this project required a 30 day demonstration period. This period was to start upon notification from the Contractor that the system was complete. The demonstration was to stop at any time that a problem or failure occurred and resume upon correction.

From May 1997 to September 1997 the testing period was started and canceled two times. Multiple problems with software operation and several changes to operating parameters were identified. It is important to note that this was a lengthy process. System performance was monitored by reviewing the daily reports. The problems that were prevalent tended to mask the minor or less frequently occurring problems. Corrections therefore became a step by step process of identifying a problem, investigation, correction and checkout. This was followed by the next review of the daily reports and a repeat of this process.

During the September 1997 to October 1997 period the 30 day demonstration test was successfully completed. The MTA allowed the test to proceed with two existing problems. The first being a timeout problem at a terminal station where trains are regularly stopped at the reader site. The solution was identified as a change in the timing parameter of the CCTC Standalone reader for that site. The second problem was an occasional error in reading identifications of train consists with tagged and untagged cars. The solution was corrected by tagging the remainder of the railcars. The test period was allowed to proceed since solutions to both problems were identified and additional time was required to proceed with the corrective measures. These corrective actions were later performed with positive results.

PART 2

PROBLEMS

AND

SOLUTIONS

2.0 PROBLEMS AND SOLUTIONS

Following are details of several of the more significant problems encountered and the resolution of each.

2.1 Time Clock Coordination

Problem -
Each reader unit on the wayside contains a clock for the time stamping of train passings in the data. Time stamping at the central location was not practical considering the time delay caused by data processing at the readers before the data packet is transmitted to the central computer system. Synchronized clocks are required to provide coordinated data collection and accuracy in the reports.

Solution -
A method was developed using the main user serial data port to transmit a global clock setting command from the central location. The clocks in the wayside units are now all synchronized through this periodic command.

2.2 Remote Healthcheck

Problem -
The Standalone reader units have both local and remote diagnostic capabilities. The local capabilities are easily accessed through the optional test panels built into the units and through connection of a portable computer for a more detailed diagnostic routine. The same testing was not initially available from the remote (central computer) location. The problem was due to the need for a second communications line from each reader to central for use of the test port on the reader.

Solution -
An alternate method of accessing the diagnostic routine through the main user serial data port was invoked (as was done for the global clock setting command). Additional central software was developed for this function including decoding and display of the large number of failure codes involved. The second communication line was not required for this method of providing the remote diagnostics.

2.3 Communications Delay

Problem -
A delay from the time a train passed the reader until the message was transmitted to the central computer of approximately 180 seconds was occurring. This produced, on a rapid transit system such as this, a somewhat significant difference between the display status of the AVI system and the actual display of train operation in the central control room. The problem was caused by additional timing introduced by CCTC to the reader units. This time was originally intended for freight operations in order to keep the reader in the active mode under slow or intermittent train operation such as encountered in yard areas.

Solution -
The additional timing was removed by changing the software switch associated with that function in the reader units. A remaining time delay of approximately 60 seconds still exists. This delay is caused primarily by the machine speed and large amount of computations involved in the reader with the error detection and filtering functions. Although CCTC indicated that further reduction of the time may be possible, it would require revision of the executive program of the unit and may sacrifice performance. The remaining time was accepted as reasonable and as necessary to retain the accuracy of the data involved.

2.4 Automatic Routing

Problem -
The project called for automatic routing of trains at one interlocking as a demonstration of that feature. The required route was to be selected by the AVI system through comparison of the approaching train, by train number, to the train move called for in the current active schedule at the central control. Although possible, there were several problems as follows:

-The first problem was associated with the aforementioned time delay. The MTA determined and specified the reader locations based on a minimum system resolution required. The locations selected in advance to the interlocking in question were placed to close to allow for advance route alignment with the communication delay.

-The interlocking in question currently has three modes of operation. Those modes being by manual control, automatic control through a PLC (programmable logic controller) logic routine and remote control from the central computer. When in remote control the central computer system is capable of four different modes of operation for requesting routes at that interlocking.

-At the time the original specification was written, the interlocking was in use as a short turnback for alternate mainline trains during off peak periods. Following the start of this project, the short turnback operation was abandoned and full line service resumed.

Solution -
The requirement for automatic interlocking operation was eliminated. With the timing problem it would require using readers significantly farther from the interlocking. This would have proved impractical considering the yard turnout in the section of track involved that could have introduced unidentified trains entering the mainline. These trains would require additional checks to determine the required routing and also the timing problem would be introduced again. The complexity of the existing multiple modes of operation and the cancellation of the short turnback operation were additional considerations.

2.5 Vehicle Identification Errors

Problem -
Vehicle identification errors appeared when operating train consists mixed with tagged and untagged cars. The original scope of the project covered the installation of tags on one half of the rail car fleet as adequate for demonstration purposes. The operation of these mixed consists therefore occurred quite often. The problem appeared to involve the reader executive program. The error correcting process in this program involves comparing the multiple reading of tags to develop some level of confidence. This comparison process was disturbed by the additional wheel counts of the untagged vehicles. CCTC expressed hesitance in addressing any issues with the executive program due to the additional time, expense, and special program status that would be created.

Solution -
It was determined that tagging the remainder of the rail car fleet would solve the problem. Since vehicle tagging is relatively low cost, at approximately $100 total per installed tag, an equitable solution was achieved. It also provided a more realistic demonstration of this type system by eliminating the unidentified vehicles and therefore providing complete operating reports.

2.6 Wire and Cable Installation

Problem -
Through the development of the specification and cost estimation of this project it was found that the wire and cable installation could add considerable cost. The reader installations would require power and communication cabling installed from the wayside locations to the signal and communications rooms of the nearest stations. The cable routes and available wire ways were unknown. At issue was the contingency involved with the labor and materials for installation.

Solution -
The MTA undertook an investigation to identify the routing of these cables including the available wireways, cable troughs and conduits. These details were added to the specification including reference drawings. The local wiring on the wayside for the reader layouts was limited to 50 feet and changed from buried installations to surface mount, hose protected cabling.

2.7 Lightning/Surge Protection

Problem -
When developing the specification, it was determined that four of the reader sites would be located in outdoor locations with the remaining two installed in the underground tunnel portion of the line. The signal system equipment installed throughout the outdoor section had a history of severe, multiple damage failures from electrical storms. The incidence and severity of damage was greatly reduced through applying increasingly higher levels of electrical protection to this equipment.

There was great concern with planning to install the AVI equipment in this area. The nature of the electronic circuits in the AVI equipment is far more sensitive to damage than the signaling equipment.

Solution -

Three level lightning/surge protection was specified as well as the minimum grounding and bonding requirements. The AVI equipment was reviewed and found to be well protected as a standard feature. During installation the grounding requirements were strictly enforced as required to support the operation of the lightning/surge protection equipment. The installation has thus far proven reliable with no incidents of damage to date.

PART 3

CONCLUSIONS

AND

RECOMMENDATIONS

3.0 CONCLUSIONS AND RECOMMENDATIONS

Following are conclusions and recommendations concerning the equipment and any other potential applications involving similar equipment.

3.1 Additional Programming

Additional programming will be required. Regardless of the level of detail applied to the preparation of the specification, there will be more programming needed. The need for additional programming will become evident considering the lack of detail and errors that can occur in a specification, the learning curve, personal preferences and personnel changes, errors and assumptions by contractors, and new requirements as the project progresses.

It is suggested that, assuming a standard construction specification, an additional bid item be added for hourly on-call programming or a software maintenance period to begin at the conclusion of the project. Making this provision in the initial specification will save considerable expense.

3.2 Software Development Plan

A documented software development plan should be specified. Use standard software quality control and development plan specifications that are available. This approach will insure considerable reduction in the amount of errors and misinterpretations. If such a plan is not used, the software will be developed and applied as interpreted by the contractor. Software, once developed, tends to either stay as it is or become modified in lieu of proper redevelopment. A contractor will also contest any changes in the software as unspecified and possible additional work.

3.3 Detailed Display and Reports Specification

Provide detailed specifications for the type of displays and reports required. In-house specification review cycle(s) and follow up meetings will greatly reduce the need for any future changes. Require written response to in-house reviews and document meeting minutes to help settle any future misunderstandings. Alternately, the scope (in particular the quantity) and basic requirements of the displays and reports can be specified and a development cycle with the contractor be required as part of a project.

3.4 License Registration

Specify that the contractor be required to obtain the FCC license in the owners name. (The requirement was included in this project.) The FCC's understanding of this equipment and the current status of it is still somewhat unsettled. Differing statements as to FCC requirements from the equipment manufacturers caused additional confusion. The contractor spent considerable time and effort in settling the issue with the FCC. Part of the problem involved a temporary experimental status assigned to this type equipment. A multiple location radio station license was issued as a final settlement. Note that the contractor also had to expend the effort required to attain the longitude, latitude and elevation for the license.

3.5 Technical Information

The specification for this project required full disclosure of technical information. This was to provide the MTA with the capability of in-house service and shop repairs down to the component level. This is the normal approach for repairs on MTA systems, with fall back agreements to the manufacturers and service shops for repairs as required. The specification had a detailed section for providing this information including component level schematics with all operating data, illustrated part breakdowns with part lists including vendor and generic component part numbers, and circuit operating descriptions.

The manufacturer of the AVI equipment, CCTC, was a subcontractor on this project. Having been paid for progress in providing and installing the equipment, CCTC subsequently refused to provide the shop level information. This problem required an extended period of negotiations, resulting in delivery of the required data.

It is assumed that most other transit agencies have similar arrangements for repairs and require full technical disclosures by manufacturers. Requirements for technical disclosures should be clearly presented during the bid cycle. The technical data can also be connected to a preliminary design submittal, and tied to the initial progress payment, to be transmitted early in a project to insure receipt of the information. Note that, as was the case on this project, CCTC used several units within the assembly that were built by others. CCTC could not supply complete technical information on several of these sub-assemblies. This problem significantly affects the MTA in the repairs of the equipment and will influence decisions when considering future additions or enhancements. In the end, regardless of the effort put forth, some of the information specified may not be acquired.

PART 4

SUMMARY

4.0 SUMMARY

The availability of contractors and manufacturers in this field is the single most significant issue. Additionally, the apparent lack of commitment on the part of the manufacturer of the AVI equipment, to the MTA project, was a continuing difficulty.

The standard railroad industry term for AVI equipment is Automatic Equipment Identification (AEI). The type used on this project was a RF (Radio Frequency) Transponder Tag System. Mandated for use on freight railroads by the Association of American Railroads (AAR) in the early 1990s, the business boomed with the rush for the equipment and installations. The MTA project took place during the rush of freight business, and therefore suffered accordingly.

Only one known manufacturer makes the base equipment meeting the AAR specification for AEI equipment, AMTECH Corporation of Dallas, Texas. In the railroad industry there are several other manufacturers, such as CCTC, that use the base AMTECH equipment and assemble it into entire working systems as was used on this project. The experience of AMTECH and these other manufacturers is almost entirely in the freight railroad field. The impression gained through the course of this project is that both AMTECH and these other manufacturers consider the rail transit industry inconsequential.

The MTA specified AEI equipment meeting the AAR specifications. This was done to insure an industry standard product of known reliability and performance as well as gaining some sense of long term support. There are several other manufacturers of AEI tag type equipment and systems not meeting the AAR specifications. The manufacturers of this other equipment are interested, and may be quite willing to apply their product and attention towards rail transit projects of this type in the future. There will, however, be more trial and error in the successful application of this other equipment to rail transit. The requirement of equipment meeting the AAR specifications is still recommended for the aforementioned reasons.

Another problem in applying this equipment to rail transit involves AMTECH and other manufacturers as well. They customarily provide the AEI data to a customer supplied communication line and are not involved with it's ultimate use. They have no business interests with computer systems, data handling and the software involved. While there is a multitude of system integrators and programming firms available to design this type system, there are fewer with rail transit experience interested in being the prime contractor on this type of project. Retaining a competent prime contractor with responsible subcontractors for the various disciplines involved is a difficult problem to overcome.

The conclusion is the system works reasonably well, is reliable (with only two minor failures in over a year) and has a growing value. A variety of things can be done with the data attained, such as train tracking, automated vehicle maintenance scheduling, life cycle studies, and assembly of statistical reports for various purposes.

This type system is also readily adapted to a personal computer in lieu of the central system used on this project. New advances including dynamic tags and less costly, simplified reader packages have become available and are worth review.

Development of advance relationships with available systems integrators, software developers and AEI equipment manufacturers is highly recommended. Specifying a practical, working system is more likely when a complete understanding of the equipment, configurations and options is understood beforehand.

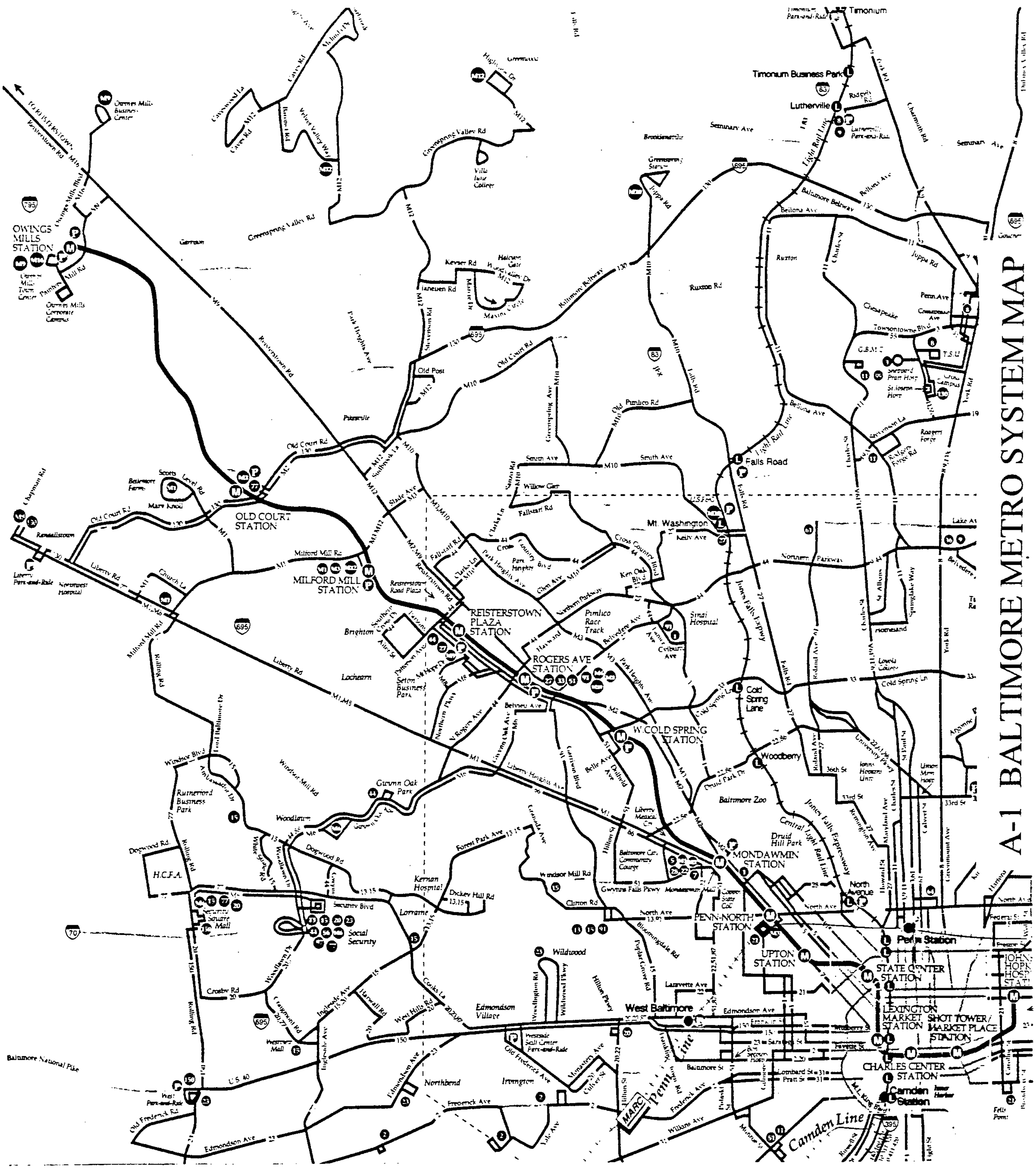
Note that there are multiple configurations of this equipment and it will be great advantage in identifying the required configuration prior to contracting the work. The configurations involve the quantity of readers and antennas versus the number of tracks and frequency of the trains being monitored. Also to be considered is the reading of single tags with a train passage as opposed to reading tags on both sides of the vehicles. The two tag reading method adds a level of reliability by providing the reader a means of additional comparisons in the error checking routine. Options such as tests panels, self-diagnostics and remote access should also be identified and chosen.

Finally, as was demonstrated by this project, application of these products in a similar configuration can be accomplished at significantly lower costs than through TWC or other such custom products

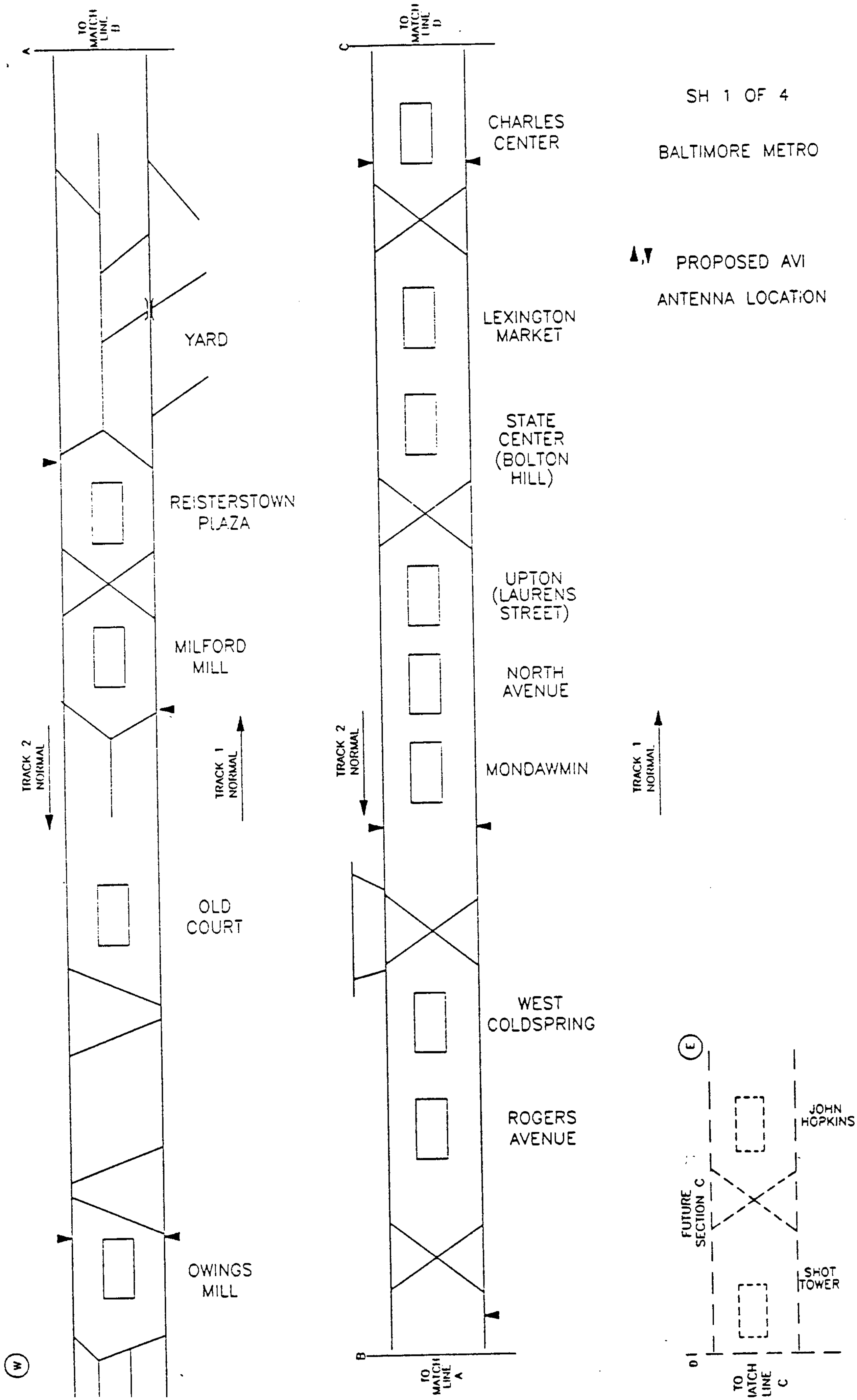
APPENDIX A

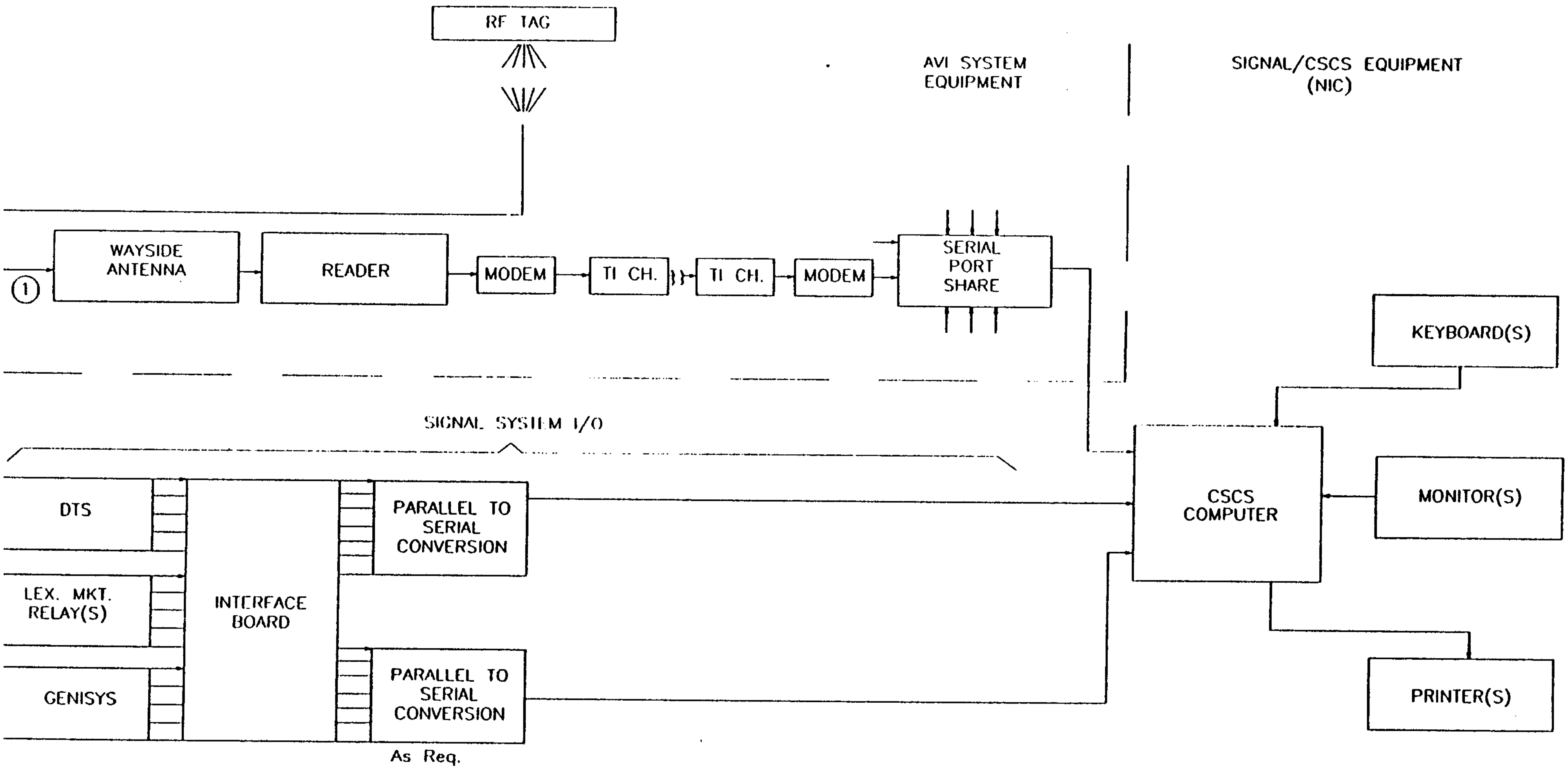
DRAWINGS

Note - Drawings A-2 through A-5 are original contract specification drawings. Although there may be minor differences, the drawings are an appropriate representation of the as-built system.


A-1 BALTIMORE METRO SYSTEM MAP
Timonium
Timonium Business Park
Lutherville
OWINGS MILLS STATION
OLD COURT STATION
MILFORD MILL STATION
REISTERSTOWN PLAZA STATION
ROGERS AVE STATION
W. COLD SPRING STATION
MONDAWMIN STATION
PENN-NORTH STATION
UPTON STATION
STATE CENTER STATION
LEXINGTON MARKET STATION
SHOT TOWER/ MARKET PLACE STATION
CHARLES CENTER STATION
Camden Station
Penn Station
Falls Road
Mt. Washington
Cold Spring Lane
Woodberry
North Avenue
West Baltimore
Camden Line
Penn Line
MARC
Reisterstown Rd
Liberty Rd
Old Court Rd
Baltimore Beltway
Greenspring Valley Rd
Northern Parkway
Cold Spring Ln
Security Blvd
Edmondson Ave
Baltimore Zoo
Druid Hill Park
Sinai Hospital
Pimlico Race Track
Social Security
Security Square Mall
Edmondson Village
Northbend
Irvington
Wildwood
Lochearn
Woodlawn
Randallstown
Brighton
Ruxton
Towsontowne Blvd
Falls Rd
York Rd
Charles St
Jones Falls Expwy
Baltimore National Pike
U.S. 40

A-2 SYSTEM LAYOUT

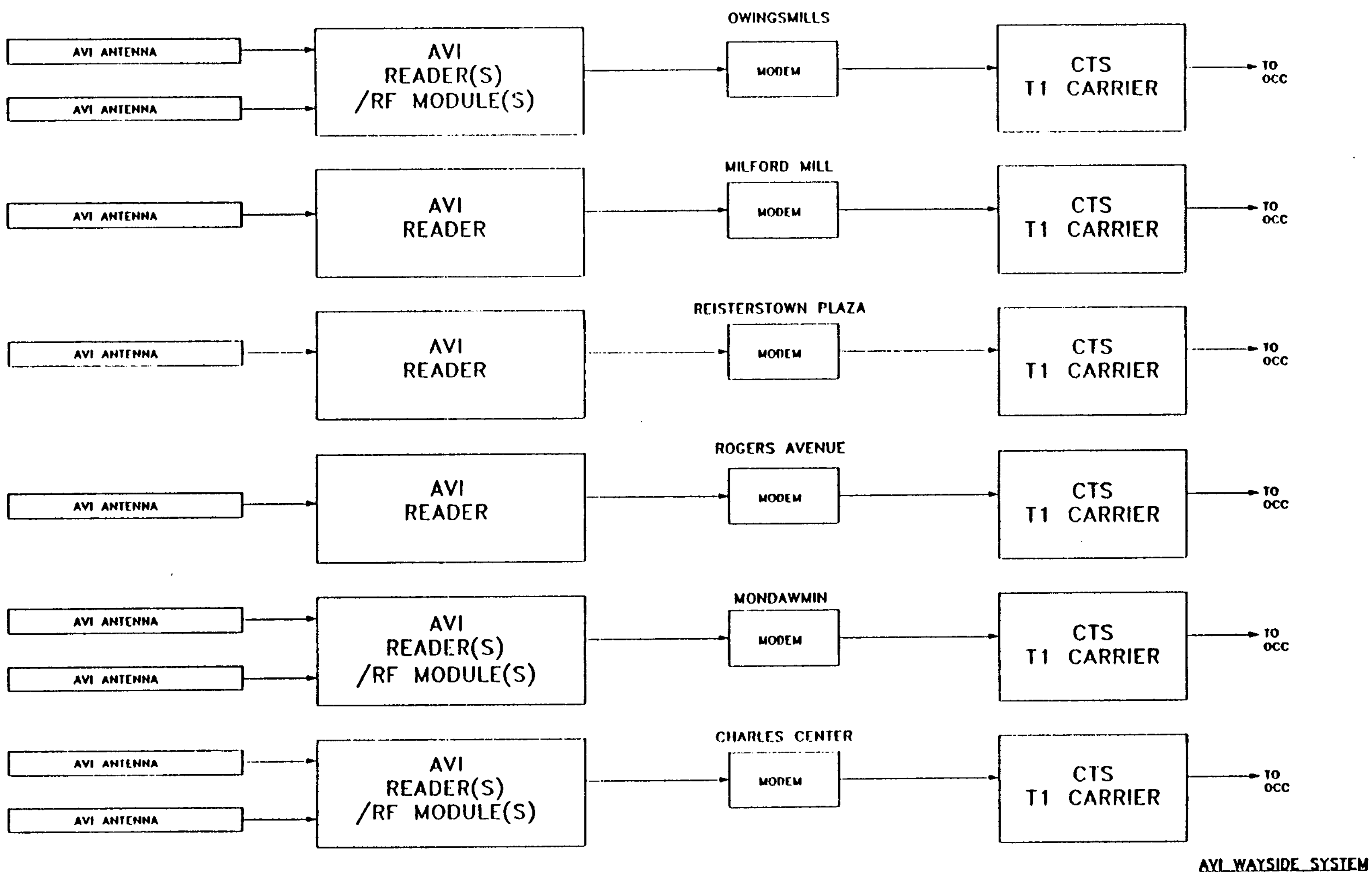




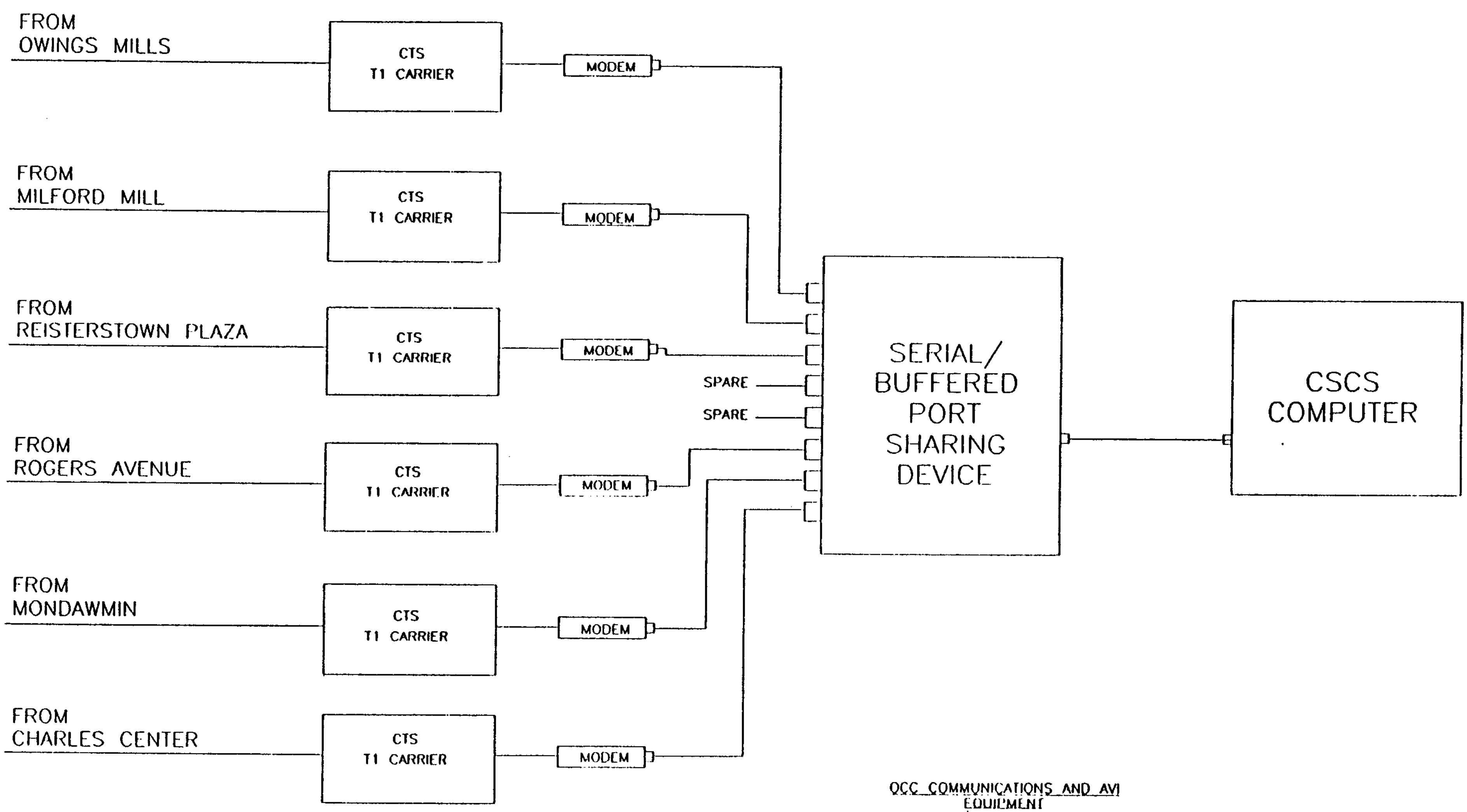
OTES:
. Typical Single Track AVI Reader Site.

SIMPLIFIED AVI SYSTEM BLOCK DIAGRAM

A-3 SYSTEM BLOCK DIAGRAM



A-4 WAYSIDE BLOCK DIAGRAM



OCC COMMUNICATIONS AND AVI EQUIPMENT

A-5 CENTRAL BLOCK DIAGRAM

APPENDIX B

AVI REPORTS

Note - These reports are a sampling of the actual system printouts. Previous to these printouts the system was in a lengthy operate/test/modify period. Specific data such as mileage, hours, etc. may therefore appear somewhat ambiguous pending a resetting of the data to starting values.

Train #	Move Time	Sched Time	Deviation	Station	Track	Direction	Length	CAR 1	CAR 2	CAR 3	CAR 4	CAR 5	CAR 6
03	07:50:44	07:52:00	00:01:16	RP	2	W	6	106	107	158	159	188	N189
06	07:50:53	07:50:40	00:00:13	MM	1	E	6	193	192	161	160	121	120
01	07:50:59	07:50:40	00:00:19	MD	1	E	6	183	182	109	108	163	162
05	07:51:45	07:51:00	00:00:45	OM	1	E	6	101	100	173	172	135	134
02	07:51:54	07:52:30	00:00:36	CC	2	W	6	104	105	150	151	196	197
09	07:53:15	07:52:40	00:00:35	CC	1	E	6	177	176	145	144	125	124
08	07:53:31	07:54:30	00:00:59	MD	2	W	6	180	181	146	147	152	153
07	07:53:59	07:53:00	00:00:59	OM	2	W	6	148	149	138	N139	154	155
06	07:54:51	07:54:40	00:00:11	RA	1	E	6	193	192	161	160	121	120
05	07:58:17	07:58:40	00:00:23	MM	1	E	6	101	100	173	172	135	134
01	07:59:24	08:00:40	00:01:16	CC	1	E	6	183	182	109	108	163	162
08	08:00:23	08:00:00	00:00:23	RP	2	W	6	180	181	146	147	152	153
04	08:00:37	08:00:30	00:00:07	CC	2	W	6	186	187	N132	133	166	167
02	07:59:20	08:02:30	00:03:10	MD	2	W	6	104	105	150	151	196	197
03	08:00:50	08:01:00	00:00:10	OM	1	W	6	106	107	158	159	188	189
06	07:59:31	07:58:40	00:00:51	MD	1	E	6	193	192	161	160	121	120
05	08:02:04	08:02:40	00:00:36	RA	1	E	6	101	100	173	172	135	134
07	08:01:08	07:59:00	00:02:08	OM	2	E	6	155	154	N139	138	149	148
02	08:06:36	08:08:00	00:01:24	RP	2	W	6	104	105	150	151	196	197
03	08:07:05	08:07:00	00:00:05	OM	1	E	6	189	188	159	158	107	106
09	08:07:50	08:08:30	00:00:40	CC	2	W	6	124	125	144	145	N176	177
05	08:06:08	08:06:40	00:00:32	MD	1	E	6	101	100	173	172	135	134
07	08:07:56	08:06:40	00:01:16	MM	1	E	6	155	154	139	138	149	148
04	08:07:49	08:10:30	00:02:41	MD	2	W	6	186	187	132	133	166	N167
06	08:09:15	08:08:40	00:00:35	CC	1	E	6	193	192	161	160	121	120
08	08:10:21	08:09:00	00:01:21	OM	1	W	6	180	181	146	147	152	153
07	08:12:01	08:10:40	00:01:21	RA	1	E	6	155	154	139	138	149	148
03	08:13:30	08:14:4[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	159	158	107	106
04	08:16:08	08:16:0[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	132	133	166	167
08	08:16:24	08:15:0[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

B-1 SYS. OPERATING REPORT (PEAK)

Train #	Move Time	Sched Time	Deviation	Station	Track	Direction	Length	CAR 1	CAR 2	CAR 3	CAR 4	CAR 5	CAR 6
02	12:02:32	12:02:40	00:00:08	MM	1	E	4	181	180	149	148		
07	12:02:48	12:00:40	00:02:08	CC	1	E	4	143	142	127	126		
05	12:03:53	12:04:30	00:00:37	CC	2	W	4	124	125	N120	121		
04	12:05:20	12:05:00	00:00:20	OM	2	E	4	167	166	133	132		
02	12:06:09	12:06:40	00:00:31	RA	1	E	4	181	180	149	148		
06	12:08:22	12:10:00	00:01:38	RP	2	W	4	114	115	168	169		
08	12:09:01	12:10:40	00:01:39	CC	1	E	4	153	152	147	146		
09	12:09:20	12:09:00	00:00:20	OM	1	W	4	144	145	176	177		
02	12:09:58	12:10:40	00:00:42	MD	1	E	4	181	180	149	148		
04	12:11:55	12:12:40	00:00:45	MM	1	E	4	167	166	133	132		
05	12:10:33	12:14:30	00:03:57	MD	2	W	4	124	125	120	121		
07	12:13:37	12:14:30	00:00:53	CC	2	W	4	138	N139	154	155		
04	12:15:34	12:16:40	00:01:06	RA	1	E	4	167	166	133	132		
09	12:15:43	12:15:00	00:00:43	OM	1	E	4	177	176	145	144		
06	12:17:46	12:19:00	00:01:14	OM	2	W	4	114	115	168	169		
05	12:18:39	12:20:00	00:01:21	RP	2	W	4	124	125	120	121		
??	12:20:00			CC	2	W	4	126	127	142	143		
02	12:20:38	12:20:40	00:00:02	CC	1	E	4	181	180	149	148		
09	12:22:07	12:22:40	00:00:33	MM	1	E	4	177	176	145	144		
04	12:19:11	12:20:40	00:01:29	MD	1	E	4	167	166	133	132		
??	12:19:21			MD	2	W	4	138	N139	154	155		
08	12:24:05	12:24:30	00:00:25	CC	2	W	4	146	147	152	153		
06	12:25:38	12:25:00	00:00:38	OM	2	E	4	169	168	115	114		
09	12:25:51	12:26:40	00:00:49	RA	1	E	4	177	176	145	144		
07	12:28:13	12:30:00	00:01:47	RP	2	W	4	138	N139	154	155		
??	12:25:29			MD	2	W	4	126	127	142	143		
05	12:28:29	12:29:00	00:00:31	OM	1	W	4	124	125	120	121		
04	12:29:49	12:3[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]3	132		
09	12:27:53	12:3[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]5	144		

B-2 SYS. OPERATING REPORT (OFF PEAK)

AVI Station Report for CC 08/31/98 14:56:27

TRN	TRACK	DIR	SCHED. TIME	ACTUAL	VARIANCE
03	2	W	07:36:30	07:35:36	00:00:54
02	1	E	07:36:40	07:36:51	00:00:11
04	1	E	07:44:40	07:44:29	00:00:11
08	2	W	07:44:30	07:45:09	00:00:39
02	2	W	07:52:30	07:51:54	00:00:36
09	1	E	07:52:40	07:53:15	00:00:35
01	1	E	08:00:40	07:59:24	00:01:16
04	2	W	08:00:30	08:00:37	00:00:07
09	2	W	08:08:30	08:07:50	00:00:40
06	1	E	08:08:40	08:09:15	00:00:35
05	1	E	08:16:40	08:16:06	00:00:34
01	2	W	08:16:30	08:16:25	00:00:05
06	2	W	08:24:30	08:23:54	00:00:36
03	1	E	08:32:40	08:29:02	00:03:38
??	1	E		08:31:17	
05	2	W	08:32:30	08:32:28	00:00:02
07	2	W	08:40:30	08:39:49	00:00:41
08	1	E	08:40:40	08:43:04	00:02:24
03	2	W	08:48:30	08:48:34	00:00:04
02	1	E	08:48:40	08:49:24	00:00:44
08	2	W	08:56:30	08:56:02	00:00:28
09	1	E	09:05:40	09:01:47	00:03:53
02	2	W	09:04:30	09:04:27	00:00:03
09	1	E	09:05:40	09:04:46	00:00:54
01	1				

B-3 STATION REPORT

AVI Train Report for Ø1 Ø8/31/98 14:56:39

STA	DIR	SCH. TIME	ACT. TIME	VARIANCE	CONSIST
OM	E	Ø7:35:ØØ	Ø7:35:Ø9	ØØ:ØØ:Ø9	183 182 1Ø9 1Ø8 163 162
MM	E	Ø7:42:4Ø	Ø7:41:31	ØØ:Ø1:Ø9	183 182 1Ø9 1Ø8 163 162
RA	E	Ø7:46:4Ø	Ø7:45:Ø2	ØØ:Ø1:38	183 182 1Ø9 1Ø8 163 162
MD	E	Ø7:5Ø:4Ø	Ø7:5Ø:59	ØØ:ØØ:19	183 182 1Ø9 1Ø8 163 162
CC	E	Ø8:ØØ:4Ø	Ø7:59:24	ØØ:Ø1:16	183 182 1Ø9 1Ø8 163 162
CC	W	Ø8:16:3Ø	Ø8:16:25	ØØ:ØØ:Ø5	162 163 1Ø8 1Ø9 182 183
RP	W	Ø8:32:ØØ	Ø8:31:27	ØØ:ØØ:33	162 163 1Ø8 1Ø9 182 183
OM	W	Ø8:41:ØØ	Ø8:42:45	ØØ:Ø1:45	162 163 1Ø8 1Ø9 182 183
OM	E	Ø8:48:ØØ	Ø8:48:22	ØØ:ØØ:22	183 182 1Ø9 1Ø8 163 162
MM	E	Ø8:55:4Ø	Ø8:54:46	ØØ:ØØ:54	183 182 1Ø9 1Ø8 163 162
RA	E	Ø8:59:4Ø	Ø8:58:27	ØØ:Ø1:13	183 182 1Ø9 1Ø8 163 162
MD	E	Ø9:Ø3:4Ø	Ø9:Ø3:5Ø	ØØ:ØØ:1Ø	183 182 1Ø9 1Ø8 163 162
CC	E	Ø9:13:4Ø	Ø9:13:18	ØØ:ØØ:22	183 182 1Ø9 1Ø8 163 162
CC	W	Ø9:28:3Ø	Ø9:27:55	ØØ:ØØ:35	162 163 1Ø8 1Ø9 182 183
RP	W	Ø9:44:ØØ	Ø9:42:47	ØØ:Ø1:13	162 163 1Ø8 1Ø9 182 183
MD	W	Ø9:38:3Ø	Ø9:4Ø:12	ØØ:Ø1:42	16Ø 161 192 193
OM	W	Ø9:53:ØØ	Ø9:52:28	ØØ:ØØ:32	162 163 1Ø8 1Ø9 182 183

B-4 TRAIN REPORT

AVI Vehicle Mileage & Hours Report 08/31/98 14:58:59

Car #	Daily Hours	Daily Miles	Accumulated Hours	Accumulated Miles	Last Maint.	Next Maint.	# Days Between	Life Hours	Life Miles
100	0	0	3	298	01/01/81	01/01/81	0	3	298
101	0	0	3	298	01/01/81	01/01/81	0	3	298
102	0	0	1	387	01/01/81	01/01/81	0	1	387
103	0	0	1	387	01/01/81	01/01/81	0	1	387
104	0	0	2	411	01/01/81	01/01/81	0	2	411
105	0	0	2	411	01/01/81	01/01/81	0	2	411
106	0	3	1	671	01/01/81	01/01/81	0	1	671
107	0	3	1	671	01/01/81	01/01/81	0	1	671
108	0	6	2	461	01/01/81	01/01/81	0	2	461
109	0	6	2	461	01/01/81	01/01/81	0	2	461
110	0	0	0	0	01/01/81	01/01/81	0	0	0
111	0	0	0	0	01/01/81	01/01/81	0	0	0
112	0	0	4	743	01/01/81	01/01/81	0	4	743
113	0	0	4	743	01/01/81	01/01/81	0	4	743
114	0	0	1	692	01/01/81	01/01/81	0	1	692
115	0	0	1	692	01/01/81	01/01/81	0	1	692
116	0	0	3	741	01/01/81	01/01/81	0	3	741
117	0	0	3	741	01/01/81	01/01/81	0	3	741
118	0	0	4	620	01/01/81	01/01/81	0	4	620
119	0	0	4	620	01/01/81	01/01/81	0	4	620
120	0	0	1	410	01/01/81	01/01/81	0	1	410
121	0	0	1	410	01/01/81	01/01/81	0	1	410
122	0	0	1	498	01/01/81	01/01/81	0	1	498
123	0							1	498
124	0							2	715

B-5 VEHICLE MILEAGE & HOURS REPORT

```
AVI Daily Summary Report  08/31/98 15:00:07
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Trains passing AVI units:    456
AVI messages received:       456
AVI messages with errors:      0

Trains & Route Miles     Cars With Bad Tag Reads
  Train #    Miles          Car #     # Bad Reads
------------------------  ---------------------------
```

B-6 DAILY SUMMARY REPORT