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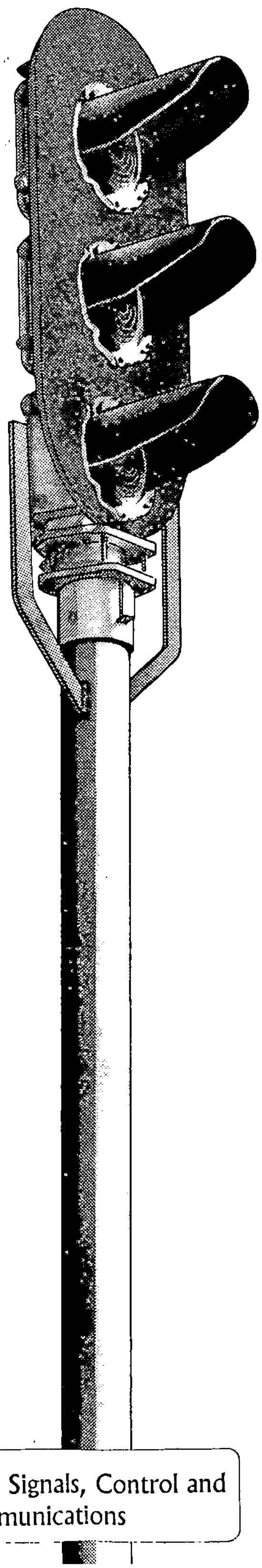

TASK 6
Specification Development

JANUARY 1981

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16. Abstract

Development of a signal/control system for high speed 255 Km/h (160 MPH) train operation must proceed in a logical sequence. One step is a comparison of alternative candidate systems representing state-of-the-art technology. This report presents a functional specification with which to measure the utility of selected candidates. Requirements are organized to permit growth from basic cab signaling to total monitoring and control from a single point. A functional path has been taken in order to provide the widest latitude in hardware design.

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PREFACE

This report results from research supported by the Department of Transportation, Federal Railroad Administration, Office of Research and Development, under Contract DOT-FR-773-4236; "Evaluation and Assessment of Signal/Control System Equipment and Technology."

The contract covers the first phase of a multi-phase program directed at the upgrading of signal and control systems on Amtrak intercity rail routes for high speed 255 Km/h (160 MPH) passenger trains.

The study includes the following seven separate but interrelated Tasks:

Task 1 - "Assessment of Signal/Control Technology and Literature Review"

Survey and assessment of the technologies incorporated in current signal and control practice; literature review and reference.

Task 2 - "Status of Present Signal/Control Equipment"

Review and analysis by major domestic and foreign railroads of the signaling system in use; discussion of candidate systems for adaptation by Amtrak; recommendations for further activity.

Task 3 - "Standardization, Signal Types, Signal Titles"

Analysis with emphasis on standardization of domestic operating rules and equipment, including signal types, aspects, titles and standards; analysis of impact of FRA Rules, Standards and Instructions (RS&I) on development of improved systems; recommendations for standardization.

Task 4 - "Electrical Noise Disturbance"

Study of causes of electrical noise disturbance or EMI (Electromagnetic Interference) as it relates to signaling; recommendations on both rolling stock and wayside signaling equipment to reduce and limit the effect of EMI radiation to acceptable levels.

Task 5 - "Economic Studies"

Economic aspects of potential improved signaling systems including capital and operational costs, reliability and maintainability, effects of standards, cost savings and benefits.

Task 6 - "Specification Development"

Functional specification for an improved signal/control system to be used by Amtrak in intercity passenger rail operation at speeds up to 255 Km/h (160 MPH).

Task 7 - "Final Report"

Final report incorporating findings of Task 1 through 6 of this study and including recommendations for further work that may be pursued in support of improved signaling systems, their application and utilization.

This document reports the findings of Task 6 - "Specification Development."

The authors wish to acknowledge with appreciation the efforts and cooperation given by the many individuals in Government, railroads and elsewhere who contributed so greatly to the overall effort. To single out individuals who were especially helpful would risk overlooking others who also provided valuable assistance. Therefore, our sincere gratitude is extended to all who were contacted and assisted on the project.

The contents of this report represent the views of the authors who are responsible for the facts and the accuracy of the data presented herein.

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SECTION 1.0

INTRODUCTION

This report presents the results of Task 6, DOT Contract DOT-FR- 773-4236, entitled "Specification Development." It is the last of a progressive series of in-depth reports covering all aspects of improved signal systems. The report of Task 1 assessed the specific technologies available for use in the design of signal and command/control systems. Task 2 determined the status of present signal/control systems. Task 3 recommended the standardization of signal types and titles. Task 4 evaluated electromagnetic interference (EMI) in the railroad environment. Task 5 evaluated the economic aspects of improvements to signal/control systems. This report presents the functional requirements for the development of advanced signaling and command/control systems.

The purpose of this report is to characterize the functional specification requirements for an improved signal/control system to be used by Amtrak in intercity passenger rail operations at speeds up to 255 Km/h (160 MPH). The requirements are organized and segmented in a manner which will allow step-by-step improvements with each modification adding capabilities which build toward the final goal of total passenger train monitoring and control.

SECTION 2.0

PROCEDURE

During previous tasks 1, 2, 3, 4 and 5 initial activity was concentrated on a review of existing literature. The Railroad Research Information Service (RRIS) bulletins were utilized to identify applicable documents in the time period from 1973 to 1979. Other sources of data were also identified and utilized, such as the National Technical Information Service (NTIS), various public, private and university libraries, but the majority of the information was identified by RRIS. Over 400 documents were accumulated and reviewed. One hundred and six documents are related to EMI and operational environments.

The primary source of document copies was the Transportation Center Library at Northwestern University in Evanston, Illinois. Several documents were identified which were available only through the International Union of Railways Office for Research and Experiments (UIC/ORE). These documents were obtained for the program by the FRA Technology Planning Office (RRD-1). Documents in foreign languages were translated. The translation from Russian and German was accomplished by the International Translation Center, Inc., in Washington, D.C. Additionally, the program library subscribed to 14 periodicals which were continuously reviewed for applicable articles.

The documents obtained were each screened upon receipt and identified in a cross-reference index to denote their applicability to each of the program tasks. This index is presented as Appendix B to this report.

While the literature search was being accomplished, a series of questionnaire forms were prepared to obtain additional data from the railroads, transit properties and suppliers of equipment. These questionnaires were sent to the 17 railroads over which Amtrak operates, 6 foreign railroads, 2 domestic transit properties, 7 domestic suppliers and 11 foreign equipment suppliers.

The data obtained via the literature search and the questionnaire were screened to establish a group of suppliers, transit properties and railroads to which field survey trips were made to obtain further data. The U.S. suppliers surveyed were: General Railway Signal Co. (GRS), Union Switch and Signal (US&S) Division of Westinghouse Airbrake Co. (WABCO), Westinghouse Electric Co. (WELCO), Harmon Electronics, Transcontrol Corp., Safetran Systems Corporation, and Thompson-Ramo-Woldridge (TRW).

The foreign suppliers surveyed were General Signal Company (GSC) Division of General Electric Company (GEC), and Westinghouse Brake and Signal in England, Seimens Corporation and Standard Electric Lorenz (SEL) in Germany, and WABCO in Italy.

The domestic railroads that were visited included the Chessie System, Southern Pacific and Union Pacific, while the transit properties included Chicago Transit Authority and the Bay Area Rapid Transit System. The European properties visited included: British Rail (BR), London Transport, French National Railroads (SNCF), German Federal Railroad (DB), Munich S-Bahn and U-Bahn systems, and the Italian State Railways (FS).

Engineering studies and analyses were performed on literature, questionnaire and field survey data to define the functional specification for the signal/control system that meets the following most significant technical requirements:

(a) High speed 255 Km/h (160 MPH) operation mixed with other slower trains which are not equipped with the overlay system components.

(b) Fail-safe design according to current U.S. signaling standards and providing safe stopping distance (with full service brake) to a preceding train.

(c) Modular design compatible with existing signaling systems and allowing for system expansion in terms of both coverage and functional capability.

(d) Compatible with electrification.

Previous tasks under this study have defined three candidate system types and have also postulated three levels of system capability categorized as follows:

- Category "A" - Cab Signaling Only
- Category "B" - Cab Signaling with Central Monitoring
- Category "C" - Cab Signaling with Central Monitoring and Control

The three candidate system types defined are:

- Intermittent Systems
- Coded AC Systems
- Continuous Automatic Train Control (CATC)

Additional studies under Task 6 have resulted in the definition of a concept using the coded ac system in combination with passive wayside markers. The passive markers are used to modify the train speed limit downward if the train is on an approach and to forestall enforced braking if the train is within the proper speed limit when the marker is detected. In some situations this concept might be used in lieu of adding more track circuits and cab signal codes (more aspects).

The selected candidate system is a coded ac system with capability to accommodate five aspects using the standard code rates of 0, 75, 120, 180 and 270 ppm. The level of implementation specified herein provides for a Category "C" system capability. The requirements for Category "A" and Category "B" level systems are easily derived by deleting the output control functions (from central) to arrive at a Category "B" level and by deleting all central control area requirements to define a Category "A" system.

SECTION 3.0

BACKGROUND

Present day signal/control systems vary in complexity from fixed signs and written train orders to the more sophisticated computer aided traffic control systems (TCS). In all of these systems the design philosophy of control circuitry and technology employed in the application of the design vary considerably.

There are major differences between signaling and control systems implemented in the U.S. and Europe. This is due, in large part, to the design philosophy involved. It is therefore important that the reader have knowledge of historic developments on both sides of the Atlantic.

In the United States, railroad signal and control systems began to evolve in the last decade of the 19th century. At the turn of the century, railroad signal engineers were well organized in the development of safe and efficient movement of trains by signal indication. While safety, as a primary objective, prevailed during evolution of signal systems, different operating philosophies and requirements resulted in a variety of aspects and rules. As early as 1906, Congress authorized a study of signal systems, and the first regulation appeared following enactment of the Transportation Act in 1920. This Act gave the Interstate Commerce Commission (ICC) authority to establish and enforce specifications for signaling equipment and to establish requirements for operation and maintenance of this equipment.

The Congressional study was confined to development and application of train stop and/or train control devices. Based on this study the Federal government, in cooperation with the signal section of the American Railway Association, developed specifications and requirements for train stop, train control, and cab signaling systems. In 1922 the ICC, after conducting hearings on the subject, ordered 49 railroads to install automatic train stops or train control devices on at least one of their passenger service divisions. A revision to this order was issued in 1924 to expand the total number of railroads to 91 and permitted use of controlling devices on locomotives. Given this impetus, suppliers and railroads developed both continuous and intermittent cab signaling systems. Prior to World War II the most common cab signal system applied code-rated ac energy superimposed, within the rails, on the basic dc track circuit. In most cases this track circuit continues to be dc.

The Signal Inspection Act of 1937 gave the ICC additional authority to control signal systems through regulation. After World War II the character of railroad operations changed dramatically. The impact of the increased availability of automobiles and the massive federal highway improvement program resulted in a decreased demand for passenger railroad service. This trend was accelerated by the rapid, government assisted development of air transportation and the growth of intercity bus systems. Meanwhile the railroads, which were faced with ever mounting maintenance costs, concentrated on freight traffic with fewer but longer and heavier tonnage trains. In 1947, ICC Order No. 29543 mandated train stop, train control or cab signals for trains exceeding 80 MPH. One result of this activity was a decrease in train speeds, and since automatic train stop, train control or cab signal systems were not required below 130 Km/h (80 MPH) most automatic train control equipment was removed after formal hearings before the ICC. The end result is that the residual wayside portion of cab signaling equipment in use on U.S. railroads is largely based on 30-to-40 year old technology. Except for the newer composite, on-board cab signal packages developed to enable Amtrak locomotives to operate with various types of wayside cab signaling, no notable advances have been made in on-board cab signal equipment employed on U.S. railroads.

On the other hand, the need to move freight efficiently and economically has led to a rapid development of sophisticated centralized traffic control systems. These systems came into being in the early 1930's using synchronous coded carrier systems. The recent availability of minicomputers and microprocessors have expanded the functional capabilities of traffic control systems (TCS). TCS implementation has eliminated many manned signal control points and provided information in real time to the operating center for traffic management and maintenance operations, and utilization of TCS has eliminated the need for train orders to govern train movement. The efficiency provided by TCS has permitted a reduction in main line trackage with a negligible loss of train capacity.

In Europe and Japan the development pattern of railroads was somewhat similar to that in the U.S. prior to World War II. The principal difference was that priority was placed on passenger train operation, and the traffic density in these countries was somewhat higher than in the U.S. After World War II development patterns markedly diverged. Because of wartime devastation in Europe and Japan an important element in the reconstruction of these societies was the upgrading of the rail transportation systems. This rebuilding resulted in a continued passenger train market and the need for much higher train densities (shorter headways) than were developed prior to World War II. These requirements forced a rapid growth in cab signaling and ultimately a high degree of automatic train control.

The UIC, through ORE, developed standards for new signaling systems for the European countries, and a similar effort took place in Japan. Since the purpose of such systems is to provide increased safety, the development program was appropriately directed, and the design standards were rewritten to reflect new technologies as they were proven safe and reliable for revenue operation. In both Europe and Japan the use of redundancy to achieve fail-safe operation is common, and implementation of redundant voting computers and microprocessors is becoming a standard means of achieving fail-safe, fail-operational system capability.

The first use of a fully computerized train control system took place in Japan on the Shinkansen line which became operational in 1964. This high speed system operates up to 220 Km/h (135 MPH) on seven-minute headways and has proven to be so successful that the Japanese National Railways (JNR) have implemented the basic design of the signal/control and communication system as the standard for all passenger train service. In Europe the intermittent cab signaling system which was standard prior to World War II has been upgraded to reflect current technology and is widely used for medium density operation. High density operation, which requires continuous cab signaling, is achieved most commonly by the use of ac coded systems with the running rails as the transmitting media or by use of digitally modulated audio frequency carriers using inductive loops as the transmitting elements. The latter of these is standard for the German Federal railways on those lines carrying their high speed passenger trains.

The development of transit systems in the U.S. and Europe has followed patterns similar to those of the railroads. The European transit systems utilize essentially the same signaling design as the railroads except that fully automatic train operation is standard. Older U.S. transit properties utilize standard railroad signaling equipment with automatic train stops or cab signaling. Automatic train operation employing code-rated frequency track circuits can be found on newer or upgraded systems. A few U.S. transit systems also utilize computer technology in their automatic train operations.

SECTION 4.0

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of tasks 1, 2, 3, 4 and 5, a system configuration has been selected which best meets the overall requirements and objectives of the study. The approach has been to analyze the candidate systems and techniques recommended and selected in tasks 2 and 5 by postulating different control concepts and evaluating them against the technical requirements. In evaluating the degree to which various system concepts meet the requirements, two separate steps were taken: first, the configuration was established to provide the basic functions of signaling, control, and communications necessary to satisfy the system constraints, and secondly, the configuration was evaluated to determine if the safety requirements would be satisfied. One conclusion reached is that although the intermittent overlay control systems are attractive from a cost standpoint, system safety is dependent on one or more of the following factors or conditions:

(1) Ultimate safety is dependent upon the base signal system and the action of the engineman.

(2) All trains in the system must be equipped with the overlay system components.

(3) Separate vital systems must be provided for safe train separation and overspeed protection.

(4) Data communications channels must be vital (fail-safe).

(5) Unless all of the above factors or conditions are present the system is unsafe.

For the purposes of this report the contract statement of work requires that the system mandate, at the least, an audible or visible warning to the train crew if a dangerous situation exists or could exist, and further that safety must be improved by enforced braking to safe speed if such unsafe conditions are present. Any future evolution in automatic train control would depend upon the basic information and safety elements acquired for continuous cab signaling and brake-throttle controls. Cab signaling systems based upon inductive loops and wiggle wire concepts meet, to some extent, the train-to-wayside communications requirement. However, for large geographic areas such as the Amtrak network, additional systems would have to be developed. The cost and vulnerability to vandalism of inductive loop or wiggle wire systems tend to rule out systems of this type for mainline rail applications. The ac coded system is the only generic type of system used in the U.S. that will satisfy all the system requirements. Even so, there are several drawbacks and problems associated with this type of system that have heretofore not been resolved satisfactorily. For example, the heavy expense involved in installing and maintaining insulated joints and Z-bonds and the length limitations imposed by the required shunting sensitivity should still be considered areas where improvement is needed. On the other hand, the relative cost of track circuits as compared to other location systems can be misleading since hidden costs are sometimes overlooked when only direct hardware and installation estimates are used. For example, if the system requirements are to include all the functions which can be provided by the track circuit, then additional sensors and functions must be added to the intermittent system in order to arrive at a meaningful comparison. The added functions and features should include at least the following: (a) axle counters and/or train lines and other ancillary equipment necessary to provide parted train protection, (b) broken rail protection, (c) data reporting methods equivalent to track relay contacts, and (d) track switch point protection. The track circuit is particularly attractive for cab signaling systems because it can be overlayed to provide continuous and variable speed command codes in specific and limited sections of rail.

The requirement for a cab signal overlay system for various types of control systems has been basic to the overall study. It appears that the most feasible and acceptable approach is to provide, first, an automatic block signal system with several aspects and overlay the cab signals; then second, acquire the communications and central data processing facilities. Because of limited growth potential and safety considerations it is recommended that intermittent cab signaling not be used for the Amtrak network.

There are a number of other investigative areas which are not a part of this contract but which should be considered in conjunction with the recommendations for improving signal/control technology contained in this report. Among these are:

- Braking performance analysis should be made for all types of trains including locomotives and cars to establish acceptable standards so that uniform safety margins may be incorporated into all signaling systems used on Amtrak lines.

- Develop methods and materials for insulating rail joints to reduce maintenance and improve reliability of track circuits requiring such insulators.

- Continue the policy of separating safety-related vital functions from control functions. Solid-state circuits and microprocessors should be used for non-vital control functions, while the critical governor function of controlling the application of service brakes in enforced braking applications must continue to be a vital function.

- Develop hardware and software for onboard equipment and trackside markers which will provide for the use of the train velocity and elapsed time or develop a vital distance measuring subsystem in conjunction with the vital count of a pulsed tachometer generator.

- Continue the development, testing, and evaluation of the system concepts specified in Appendix A, in order to bring about the generation of detailed design and hardware specifications in Phase II.

- Development of communications between trains and a central control point, such as those proposed in this report, requires that application be made with the FCC for the proper channels to conduct the necessary exchange of data. The FRA should pursue this very important aspect and assure that the proper allocation of radio frequencies is made to the railroad industry. Allocations in the microwave band would be appropriate for digital communications from train to wayside and from wayside to the central control area.

- A standardization of software documentation should also be pursued for use with the signal/control system suggested here as well as for applications elsewhere. This standardization should include a portability requirement which will allow the software to function with computers of different manufacture and architecture.

- A study should be made to determine how to best meet the problem of high speed trains and highway grade crossings. This study should evaluate the safety of signaling devices versus the total elimination of grade crossings where high speed trains are in operation.

APPENDIX A

SIGNAL/CONTROL SYSTEM FUNCTIONAL SPECIFICATION

APPENDIX A

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SECTION 1.0

SCOPE

1.1 Introduction

This specification establishes the functional requirements for a railroad signal/control system for intercity, high-speed passenger trains. The objective is to define system functional characteristics and, insofar as possible, not to constrain the hardware implementations that evolve to meet these functional requirements. However, the system must be implemented so that the environmental and physical parameters can be met through the use of solid-state technologies.

1.2 Purpose

The signal/control system defined herein shall be suitable for use in consonance with a variety of existing signaling systems. It shall be possible to overlay elements of the system and to operate with an existing ABS system of block controls and centralized control (TCS), and in addition the system shall form the basis of a complete control and supervisory system in areas where no other automatic controls currently exist.

1.3 Definitions

For the purpose of this report, the following definitions of words, terms and phrases used in railway signal and train control systems apply. These definitions are intended only as an aid to the material contained herein. Many are drawn from regulatory documents, while others were developed by the authors for this report.

Aspect, Signal - The appearance of a roadway signal conveying an indication as viewed from the direction of an approaching train; the appearance of a cab signal conveying an indication as viewed by an observer in the cab.

Automatic Block Signal System (ABS) - A block signal system wherein the use of each block is governed by an automatic block signal, cab signal, or both.

Automatic Train Control (ATC) - The system for automatically controlling train movement, enforcing train safety and directing train operations. ATC includes subsystems for Automatic Train Protection, Automatic Train Supervision, and Automatic Train Operation.

Automatic Train Operation (ATO) - The subsystem within Automatic Train Control which performs the on-train functions of speed regulation, program stopping and performance adjustment.

Automatic Train Protection (ATP) - The subsystem within Automatic Train Control which maintains safe train operation. ATP subsystems include train detection, train separation, interlocking, and speed-limit enforcement.

Automatic Train Supervision (ATS) - The subsystem within Automatic Train Control which monitors and provides controls necessary to direct the operation of a system of trains in order to maintain intended traffic patterns and minimize the effects of train delays on the operating schedule.

Back Check - A checking function to verify both states of a two-state element such as logic elements or relays.

Block - A length of track of defined limits, which may consist of one or more track circuits.

Block, Absolute - A block in which no train is permitted to enter while it is occupied by another train.

Cab - The compartment of a locomotive from which the propelling power and brakes of the train are manually controlled.

Cab Signal - A signal located in the engineman's compartment or cab indicating a condition affecting the movement of a train or locomotive and used in conjunction with interlocking signals and in conjunction with or in lieu of block signals.

Cab Signal System - A signal system so arranged that wayside conditions are indicated in the cab or compartment of a locomotive.

Central Processing Unit (CPU) - A major computer subsystem which performs arithmetic functions, program control, manipulation of data and controls the sequence of instructions in accord with a stored program.

Circuit, Acknowledgement - A circuit consisting of wire or other conducting material installed between the track rails at each signal in territory where an automatic train stop system or two-indication cab signal of the continuous inductive type is in service to enforce acknowledgement by the engineman at each signal displaying an aspect requiring a stop.

Circuit, Control - An electrical circuit between a source of electric energy and a device which it operates.

Circuit, Non-vital - Any circuit whose function does not affect the safety of train operation.

Circuit, Track - An electrical circuit of which the rails of the track form a part.

Circuit, Track; Coded - A track circuit in which the energy is varied or interrupted periodically.

Circuit, Track; High Level AC/DC - A track circuit which employs relatively high alternating circuit voltage on rails, low impedance energy source, and transformer-rectifier unit between rails and direct current track relay.

Circuit, Track; Impulse - A track circuit into which high voltage, high current pulses of extremely short duration are fed to a receiver with a differential track relay which can distinguish working pulses from interference.

Circuit, Track; Phase Selective - An ac track circuit consisting of a discrete ac signal frequency code transmitter code following relays and a phase selective detector unit. Local and operating energy applied to the phase selective relay must be in proper phase relationship in order that the code-following track relay will respond to the track circuit command codes.

Circuit, Vital - Any circuit the function of which affects the safety of train operation.

Code, Transmitter - A device to periodically vary an electrical circuit at a definite, predetermined code frequency.

Contact, Open - A current-carrying member which is open when the operating unit is in the normal position.

Contact, Polar - A part of a relay against which the current-carrying portion of the movable polar member is held so as to form a continuous path for current.

Contact, Reverse - A term used to designate a current-carrying member when the operated unit is in the reverse position.

Continuous Control - A type of control in which the locomotive apparatus is constantly in operative relation with the track elements and is immediately responsive to a change of conditions in the controlling section which affects train movement.

Cryptographic Technique - Enciphering and deciphering of messages.

Cut-section - A location other than signal location where two adjoining track circuits end within a block.

Device, Acknowledging - A manually operated electric switch or pneumatic valve by means of which, on a locomotive equipped with an automatic train stop or train control device, an automatic brake application can be forestalled, or by means of which, on a locomotive equipped with an automatic cab signal device, the sounding of the cab indicator can be silenced.

Disk - A computer bulk storage memory element.

Distance, Stopping - The maximum distance on any portion of any railroad which any train operating on such portion of railroad at its maximum authorized speed, will travel during a full service application of the brakes between the point where such application is initiated and the point where the train comes to a stop.

Equipped - Amtrak locomotives which are equipped with the overlay system components.

Encoding Techniques - Conversion of messages into digital data.

Enforced Cab Signaling - A signaling system so arranged that its operation will automatically result in the application of the brakes to bring the train to an allowable speed or to a stop.

Fail-Safe - A term used to designate a railway signaling design principle, the object of which is to eliminate the hazardous effects of a failure of a component or system.

Fail-Operational - A system which will continue to provide all functions required for manual operation in the event of a single point failure.

Forestall - As applied to an automatic train stop or train control device, to prevent an automatic brake application by operation of an acknowledging device or by manual control of the speed of the train.

Governor - A functional element which monitors and restricts locomotive speed below an established set of values.

Handshake - A continual checking technique between the two system elements requiring interrogation by the first element followed by the proper response from the second element and interrogation by the second element followed by the proper response from the first element.

Headway - The elapsed time between the passing of the locomotive of a train and the locomotive of a following train.

Indicator, Cab; Audible - A device (usually air whistle) located in a cab equipped with cab signals designed to sound when the cab signal changes aspects and continues to sound until acknowledged.

Input/Output (I/O) Device - A device which allows bidirectional data flow between a computer and external element.

Insulated Rail Joint - A joint in which electrical insulation is provided between adjoining rails.

Interlocking - An arrangement of signals and signal appliances operated from an interlocking machine and so interconnected by means of electrical locking that their movements must succeed each other in proper sequence, train movements over all routes being governed by signal indication.

Interlocking, Automatic - An arrangement of signals, with or without other signal appliances, which functions in response to relay operation and circuit logic as distinguished from those whose functions are controlled manually, and which are so interconnected by means of electric circuits that their movements must succeed each other in proper sequence, train movements over all routes being governed by signal indication.

Interlocking Limits - The track between the opposing home signals of an interlocking.

Interlocking, Manual - An arrangement of signals and signal appliances operated from an interlocking machine and so interconnected by means of mechanical and/or electrical locking that their movements must succeed each other in proper sequence, train movements over all routes being governed by signal indication.

Interlocking, Relay Type - An arrangement of signals, with or without other signal appliances, operated either from a control machine or automatically, and interconnected by means of electric circuits employing relays so that their movements must succeed each other in proper sequence, train movements over all routes being governed by signal indication.

Intermittent Control - A type of control in which the locomotive apparatus is affected only at certain designated points, usually at signal locations.

Majority Voting - A logical process which compares the output of three or more devices and detects a failed device which is in disagreement with the other two.

Meet - A pre-programmed or pre-determined point where one train meets another as prescribed by train orders, timetable or signal indications.

Microprocessor - A microcomputer composed of large scale integrated (LSI) circuits.

Operating Rules - A set of regulations which direct the response of enginemen to signal indications and other prescribed conditions.

Relay - A device that is operative by a variation in the conditions of one electric circuit to affect the operation of other devices in the same or another electric circuit.

Relay, Code Following - A relay which will follow or reproduce a code without distortion within practical limits.

Relay, Magnetic Stick - A relay the armature of which remains at full stroke in its last energized position when its control circuit is opened.

Relay, Two-Element - A relay, usually alternating current, having two separate windings, both of which must be properly energized to cause the relay to operate.

Relay, Vane Type - A type of alternating current relay in which a light metal disc or vane moves in response to a change of the current in the controlling circuit.

Signal - An appliance which conveys information governing train movements.

Signal, Approach - A fixed signal used in connection with one or more signals to govern the approach thereto.

Software - The complete set of instructions provided to a computer to allow the execution of a program or process.

System, Absolute Permissive Block - A block signal system under which the block is usually from siding to siding for opposing movements, and the fixed signals governing entrance into the block display an aspect indicating Stop when the block is occupied by an opposing train. For following movements the section between sidings is divided into two or more blocks, and train movements into these blocks--except the first one--are governed by intermediate fixed signals, cab signals or both. The intermediate fixed signals usually display an aspect indicating Stop; then Proceed at Restricted Speed, and the cab signal displays an aspect indicating Proceed at Restricted Speed as its most restrictive indication.

System, Automatic Block Signal - A series of consecutive blocks governed by block signals, cab signals, or both, which is actuated by a train, engine or certain conditions affecting the use of a block.

System Automatic Cab Signal - A system which provides for the automatic operation of cab signals.

System, Command/Control - A continuous or hybrid cab signaling system with an integrated command center capable of directing and supervising all trains properly equipped.

System, Enforced Cab Signal - A signaling system so arranged that its operation will automatically result in the application of the brakes to bring the train to an allowable speed or to a stop.

System, Block Signal - A method of governing the movement of trains into or within one or more blocks by wayside or cab signals.

System, Universal Code - A signal system employing continuously coded track circuits, code following relays and decoding units.

Time Table & Train Order Operation - An operating system in which train movement is determined by a time table which may be modified by train orders.

Traffic Control System (TCS) - A block signal system under which train movements are authorized by block signals whose indications supersede the superiority of trains for both opposing and following movements on the same track.

Train-to-Wayside Communication System (TWC) - A non-vital, bidirectional, digital data communications system for communication, at fixed points, between trains and wayside.

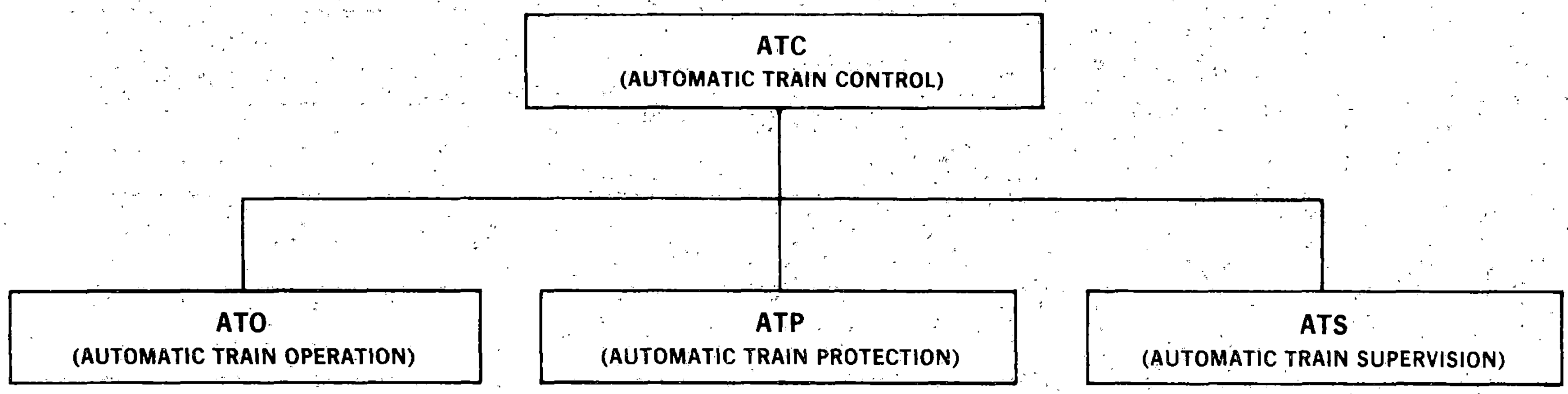
Transponder (Wayside) - An active or passive tuned wayside device which, when electro-magnetically coupled to a receiving unit on a locomotive, conveys speed control, location or other information to the train. When the locomotive-mounted unit is active it is called an interrogator.

1.3.1 Major Systems and Functional Subsystems

Within the signal industry there exists a considerable difference in interpretation or meaning of technical system terms. These variances in interpretation and or meaning that have developed in domestic and foreign technical literature have often caused confusion to U.S. railroad and transit signal engineers. Four terms which are important to an understanding of this report but have received varying interpretations are the following: (1) Automatic Train Control, (2) Automatic Train Operation, (3) Automatic Train Protection, and (4) Automatic Train Supervision.

Although each of the technical terms has already been defined, above, the relationship of these major signal/control systems and component subsystems is further illustrated in Figure A-1, so that the reader may identify the contemporary context of this specification.

RELATIONSHIP OF MAJOR SIGNAL SYSTEMS & AVAILABLE FUNCTIONAL SUBSYSTEMS



ATO

- TARGET SPEED DISPLAY
- TARGET DISTANCE DISPLAY
- QUANTITATIVE SPEED DISPLAY
- SPEED REGULATION
- BRAKING REGULATION
- PROGRAM STOPS
- DOOR & DWELL OPERATION
- TWC (TRAIN TO WAYSIDE COMMUNICATION)
- ONBOARD ROUTE CONTROL

ATP

- TRACK CIRCUITS (TRAIN DETECTION)
- WAYSIDE SIGNALS
- ROUTE SECURITY (LOCKING)
- WAYSIDE SPEED LIMIT COMMANDS
- CAB INDICATION
- OVERSPEED ALARM
- OVERSPEED CONTROL
- INTERLOCKING CONTROL

ATS

- TRAFFIC CONTROL SYSTEMS
- BLOCK OCCUPANCY (TRAIN TRACKING)
- DTS (DATA TRANSMISSION SYSTEM)
- TRAIN IDENTIFICATION
- LOCOMOTIVE IDENTITY
- TWI (TRAIN TO WAYSIDE INFO)
- AUTOMATIC DISPATCHING
- TRAFFIC REGULATION
- MANAGEMENT INFORMATION SYSTEM
- CORRECTIVE STRATEGIES
- SCHEDULE CONTROL
- VOICE COMMUNICATIONS
- STATION GRAPHICS CONTROL
- HOT BOX, FLOOD, SLIDE, ABNORMAL LOAD, BROKEN FLANGE, ETC. DETECTORS

FIGURE A-1

SECTION 2.0

APPLICABLE DOCUMENTS

2.1 Military

2.1.1 Military Standard

The following documents are a part of this specification only to the extent noted.

MIL-STD-461A	Electromagnetic Interference Characteristics Requirements for Equipment
MIL-STD-470	Maintainability Program Requirements (For Systems and Equipment)
MIL-STD-785A	Reliability Program for Systems and Equipment Development and Production
MIL-STD-810C	Environmental Test Methods
MIL-STD-883B	Test Methods and Procedures for Microelectronics
MIL-STD-1553B	Aircraft Internal Time Division Multiplex Data Bus

2.1.2 Military Handbooks

The following handbook is a part of this specification to the extent noted.

MIL-HDBK-217B	Reliability Prediction of Electronic Equipment

2.2 Industry

2.2.1 Industry Standards

The provisions in the following documents shall be adhered to where applicable.

American Railway Signaling Principals and Practices Published by the Association of American Railroads.

NFPA-70 National Electric Code

2.3 Government

2.3.1 Government Regulations

All applicable provisions in the following documents shall be adhered to.

Code of Federal Regulations 49 Transportation:

Parts 231 through 236

49CFR Part 213, Track Safety Standards, particularly 213.9(c)

49CFR Part 218, Railroad Operating Rules

49CFR Part 220, Radio Standards and Procedures

49CFR Part 90, FCC Requirement for Land Transportation Radio and Microwave

ICC Orders No. 13413 and No. 29543

Where modification to an existing system or installation of a new system which may affect the safety of train is contemplated, an application to the FRA Safety Board and possibly the FCC will be required. This will include a request for relief from any of the standards now in compliance with FRA Rules, Standards & Instructions.

The application must state whether the request meets RS&I requirements or how it otherwise provides adequate safety. It must also present an adequate justification for relief.

2.3.2 Government Studies

The following FRA studies shall be used as applicable as background information:

Evaluation of Signal/Control System Equipment and Technology. Task 1 - Assessment of Signal Control Technology and Literature Review.

Evaluation of Signal/Control System Equipment and Technology. Task 2 - Status of Present Signal/Control Equipment.

Evaluation of Signal/Control System Equipment and Technology. Task 3 - Standardization, Signal Types, Titles.

Evaluation of Signal/Control System Equipment and Technology. Task 4 - Electrical Noise Disturbance.

Evaluation of Signal/Control System Equipment and Technology. Task 5 - Economic Studies.

SECTION 3.0

REQUIREMENTS

3.1 System Definitions

The following paragraphs delineate the requirements for the wayside and trainborne features and functions required to configure the subject system. Some of the basic features specified are intentionally vague regarding certain site specific or design specific details and areas that are not critical to the functional operation of the system. In other cases the requirements are quite detailed and are called out to allow for orderly system expansion and provide means for the incorporation of future technologies as they become available. This specification is based on the results of the earlier tasks performed under Contract DOT-FR-773-4236 "Evaluation and Assessment of Signal/Control System Equipment and Technology". The overall objective of the study has been to select the most promising system technologies for use by high-speed, intercity Amtrak passenger trains. An overlay system has been defined which incorporates extensive capability and flexibility and is based on sound economics. The most significant technical requirements for the system can be summarized as follows:

(a) High speed 255 Km/h (160 MPH) operation mixed with slower trains which are not equipped with overlay system components.

(b) Fail-safe design according to current U.S. signaling standards and providing safe stopping distance (with full service brake) to a preceding train or hazardous condition such as a broken rail or switch not properly aligned.

(c) Modular design which is compatible with existing signaling systems and allows for system expansion both in terms of coverage and in terms of functional capability.

(d) Compatible with electrification.

Previous tasks under this study have defined three candidate system types and also have postulated three levels of system capability categorized as follows:

- Category "A" - Cab Signaling Only
- Category "B" - Cab Signaling with Central Monitoring
- Category "C" - Cab Signaling with Central Monitoring and Control

The three candidate system types defined are:

- Intermittent Systems
- Coded AC systems
- Continuous Automatic Train Control (CATC)

Additional studies under Task 6 have resulted in the definition of a concept using the coded ac system in combination with passive wayside markers. The passive markers are used to modify the Amtrak train speed limit downward if the train is on an approach and to forestall enforced braking if the train is within the proper speed limit when the marker is detected. In some situations this concept might be used in lieu of adding more track circuits and cab signal codes (more aspects).

The selected candidate system is the coded ac system with capability to accommodate five aspects using the standard code rates of 0, 75, 120, 180 and 270 ppm. The level of implementation specified herein provides for a Category "C" system capability. The requirements for Category "A" and Category "B" level systems are easily derived by deleting the output control functions (from central) to arrive at a Category "B" level and by deleting all central control area requirements to define a Category "A" system.

The functional requirements for the signal/control system are described in paragraphs 3.1.1 through 3.1.9 together with the associated diagrams. Some of the requirements are pertinent to both Category A and Category B candidate systems, and all are required for Category C candidates. The applicability of requirements to each category is shown in tables A-1 through A-3.

3.1.1 General Description

The signal/control system described in this report can be characterized as a continuous cab signaling system with an integrated command center capable of directing and supervising all equipped trains from a central location. Data processing and sensors shall be required both on-board each train and at the central control area. The basic system concept shall be one in which a central control point will acquire knowledge of the position and velocity of each train and supply virtually continuous speed-modifier commands to all equipped trains in the system. A secure and reliable data communications link to and from all equipped trains shall be a prime requisite of the system.

The central control point shall process all data from the trains, diverging route or controlled interlockings, and wayside sensors in order to monitor train routing and separation and to derive supervisory velocity commands Figure A-2).

TABLE A-1. LOCOMOTIVE FUNCTIONAL REQUIREMENTS

FUNCTIONAL REQUIREMENT	CATEGORY A	CATEGORY B	CATEGORY C
VITAL SPEED GOVERNING	YES	YES	YES
VITAL SPEED DETECTION	YES	YES	YES
INDICATED POSITION (Pi)	YES	YES	YES
ABSOLUTE POSITION DETERMINATION (Pa)	YES	YES	YES
INDICATED VELOCITY (Vi)	YES	YES	YES
TRACK BLOCK BOUNDARY, TRACK MARKER, OR TRACK TRANSPONDER DETECTION	YES	YES	YES
OVERSPEED DETERMINATION AND DISPLAY	YES	YES	YES
BRAKE ENFORCEMENT	YES	YES	YES
DATA PROCESSING	YES	YES	YES
CAB SIGNAL DISPLAY	YES	YES	YES
DATA ENCODING	NO	YES	YES
UHF (VHF) TRANSMISSION	NO	YES	YES
EXTERNAL DATA VERIFICATION	NO	NO	YES
DATA DECODING	NO	NO	YES
UHF (VHF) RECEPTION	NO	NO	YES

TABLE A-2. WAYSIDE FUNCTIONAL REQUIREMENTS

FUNCTIONAL REQUIREMENT	CATEGORY A	CATEGORY B	CATEGORY C
TRACK CIRCUITS	YES*	YES*	YES*
FIVE ASPECT CODE IN TRACK BLOCKS	YES*	YES*	YES*
TRACK RELAY INTERFACING	YES**	YES	YES
TRACK SWITCH INTERFACING	YES**	YES	YES
TRACK SENSOR INTERFACING (BROKEN WHEEL, DRAGGING EQPT., ETC.)	NO	YES	YES
RF, COMMON CARRIER, OR MICROWAVE (SATELITE OR RELAY) DATA TRANSMISSION	NO	YES	YES
DATA ENCODING	NO	YES	YES
UHF (VHF) TRANSMISSION	NO	YES	YES
RF, COMMONCARRIER, OR MICROWAVE (SATELITE OR RELAY) DATA RECEPTION	NO	NO	YES
UHF (VHF) RECEPTION	NO	NO	YES

* OR EQUIVALENT
** AS REQUIRED

TABLE A-3. CENTRAL CONTROL AREA FUNCTIONAL REQUIREMENTS

FUNCTIONAL REQUIREMENT	CATEGORY A	CATEGORY B	CATEGORY C
REDUNDANT CENTRAL PROCESSING	NO	YES	YES
RF, COMMON CARRIER, OR MICROWAVE (SATELITE OR RELAY) DATA RECEPTION	NO	YES	YES
DATA ENCODING	NO	YES	YES
DISPLAY OF TRACK DATA	NO	YES	YES
PRINTOUT CAPABILITY OF DATA	NO	YES	YES
DATA RECORDING	NO	YES	YES
RF, COMMON CARRIER, OR MICROWAVE (SATELITE OR RELAY) DATA TRANSMISSION	NO	NO	YES
DATA ENCODING	NO	NO	YES
TRAIN SUPERVISION CONTROLS	NO	NO	YES

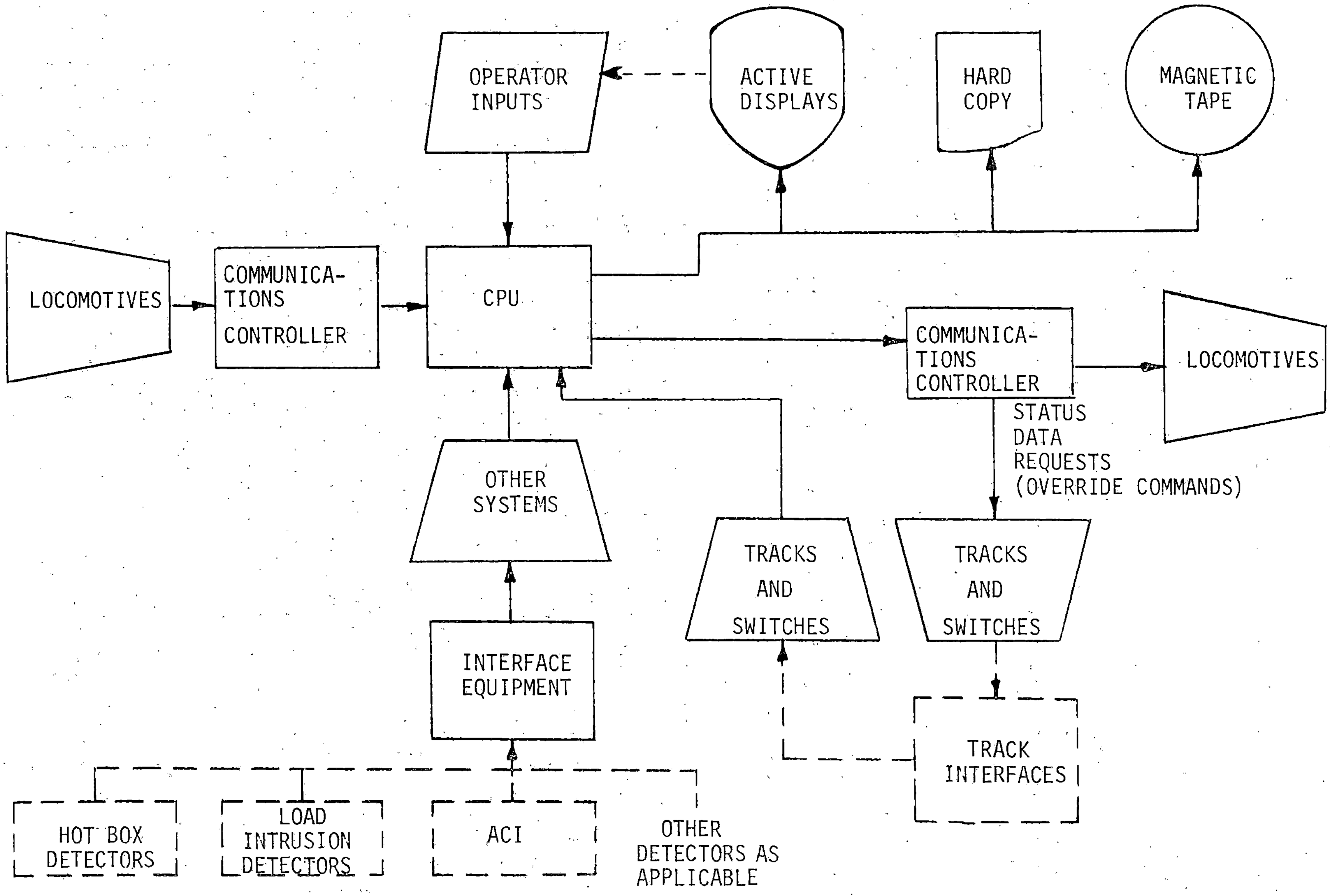


FIGURE A-2 WAYSIDE AND CENTRAL CONTROL FUNCTIONS

The absolute position of each train shall be periodically verified and the velocity continuously measured on board. The on-board data processor shall monitor positional checkpoints and integrate the measured velocity data to maintain a continuous estimate of train position. These data shall always be available for transmittal to the central control point. Additional operational train identification and status data, including any malfunction indications, shall be reported to central over the communications data channel. Data processing at the control center shall require train status data, switch position information, civil speed restrictions, track conditions and desired train headways. The primary data outputs shall be speed commands and cab signal data for the trains, system status display signals and management information. In operating territories not using centralized control growth provisions shall be required for other supervisory functions such as route control commands.

3.1.2 Position Determination

Train position shall be established and maintained at all times during automatic operation. A unique coordinate system shall be established and encoded such that the exact location of each train shall be known in terms of the transportation zone, rail line, section and mile post data. A unique identifier shall be used to differentiate between tracks in areas of multiple trackage and sidings. In regions using block controls, the block or track circuit shall be identified as part of the location data. In other regions, supplemental wayside markers, transponders and/or other unique wayside monuments shall be additionally used to establish absolute train position (Pa). The absolute positional data shall be automatically derived from the unique wayside monuments and shall also be capable of being entered manually by the engineman. Positional information shall be preprogrammed along the planned route so that upcoming checkpoints are anticipated by the on-board data processor. These preprogrammed data shall have sufficient resolution to indicate whenever a checkpoint is missed or not recorded. The continuous position of the train in terms of the unique coordinate system shall be computed using the discrete inputs of absolute position and the integral of the vital speed measurement (Vi). The sequence of absolute positional data shall be used for comparison with the indicated continuous position (Pi), and scale factor and bias corrections shall be generated to refine the velocity measurements and the indicated continuous position. (See Figure A-3). Data from track circuits indicating occupancy shall be sent to the central control area for direct correlation with the positional data derived on board the train. The block occupancy data shall be provided for safety and is necessary to the operation of mixed traffic where some of the trains are not equipped with the proposed system. Pertinent data concerning each block, such as identification, length and grade, shall be stored at central.

3.1.3 Velocity Measurements

Train velocity shall be measured in a vital function by the use of one or more passive vital speed probe(s). A "back check" technique and/or a toggled "Exclusive OR" circuit test shall be used to assure the integrity of the tachometer probes and associated wiring.

The dynamic range of the probe output shall be compatible with a maximum train speed of a least 255 Km/h (160 MPH). A scale factor shall be selected which is compatible with the positional resolution requirement and a train speed of at least 255 Km/h (160 MPH). Reasonable data rates shall be used throughout the system design. Speed probe outputs shall be detectable and of usable magnitude down to a lowest speed of 1.6 Km/h (1.0 MPH).

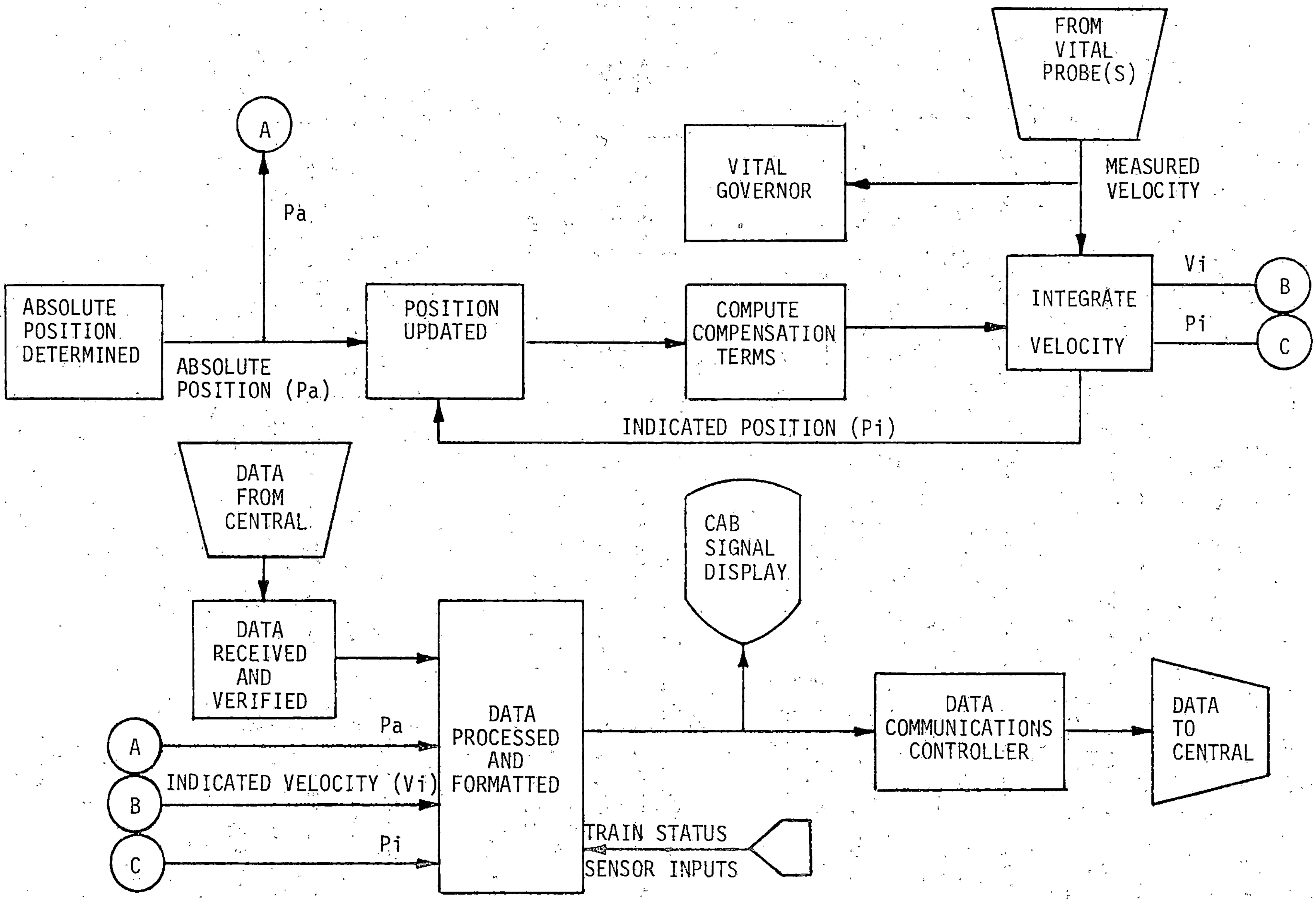


FIGURE A-3. TRAIN FUNCTIONS

Parallel redundant devices shall be used to detect malfunctions in the speed measurement subsystems. Alternatively, a triple redundant system with majority voting and a fail-operational capability shall be used, depending upon the reliability of the hardware components selected. In either case, failure reports shall be generated for input to the on-board data processor. A fail-operational technique shall be employed where appropriate, and where it is applied consideration must be given to the requirement for reporting and repairing the failed unit within a time frame consistent with the basic MTBF of the components. A specific time limit shall be established within which the system shall be allowed to operate in a fail-operational mode and when the system must be repaired and restored to normal operation.

3.1.4 Communications to the Central Control Point

A data communications link shall be established from each equipped train to the central control point. Handshake and cryptographic techniques shall be used to uniquely identify and define the data transmission from each train to central control. These techniques shall ensure the validity of the train identification and the transmitted data. Train data reports shall consist of the following:

(a) Train Identification

(b) Retained Last Command from the Central Control Point

(c) Last Absolute Position

(d) Present Indicated Position

(e) Present Velocity

(f) Train Status Data.

A separate wayside data communication link to the central control point shall be established for reporting block occupancy and switch position status. Other sensor reports such as "dragging equipment," "broken wheel," and "hot box" shall be reported on another data communications link.

3.1.5 Communications to Trains

The central control point shall have the capability of establishing secure and reliable communication links to all trains equipped with the signal/control system equipment. A suitable protocol along with handshake and encoding techniques shall be used to ensure the integrity of the messages directed to each train. It is essential that the speed command data transmitted to each train be considered a secure function. Therefore, it is crucial that the message be uniquely coded and deciphered so that only one specific train can respond to the command from central.

The polling cycle time and/or the elapsed time between speed command messages to a train shall be a design parameter which limits headway and maximum allowable speed. The message cycle rate shall be variable as required depending upon the operational situation. However, the design maximum rate shall be specified and be consistent with design headway and permissible operating speeds.

3.1.6 Central Control Point Data Processing

Central control data processing shall be accomplished using a redundant triplex configuration (or a suitable alternative) with parallel and serially redundant switchover apparatus. No single switchover failure shall inhibit proper operation of the fail-operational mode using the two remaining processors. Majority voting shall be used to determine the failure of one of the three processors and initiate the automatic exclusion of the failed element. It shall be possible for the operator to take any one of the three processors off-line at any time during normal operations without disrupting any of the system functions.

Figure A-4 shows an alternative fail-operational computer configuration which shall be used as appropriate. With this arrangement any unit may fail without affecting system operation. The high-speed data bus shall be completely redundant, and dual port I/O shall be used for the device controllers. The software operating system shall keep one of the functional paths on a standby basis and automatically switch over when a malfunction occurs. Units shall be capable of removal during operations for maintenance or replacement without disturbing the system. When replaced, the replaced unit shall become the standby unit since the system shall have already automatically switched over to the alternate device. With this type of configuration as many as sixteen central processing units (CPU's) may be used and arranged in such a way that they may share the data processing tasks, solve the same programs simultaneously, or serve as standby units.

It shall be a requirement that any of the CPU's (including the power supplies, blowers, etc. associated with it) can be removed and replaced without affecting system operations.

The basic central control data processing equipment shall be capable of dynamic analyses of track configuration and train movement related to the generation of speed commands, performance of supervisory and display functions necessary to the system interface with the central supervisor, and the management and control of the communications subsystems. Ancillary functions shall also be provided such as self-diagnostic features and the majority voting controls mentioned above, as well as hard copy outputs for system malfunction reports and other management data documents. All significant events and operator actions along with management data shall be recorded on tape for permanent files.

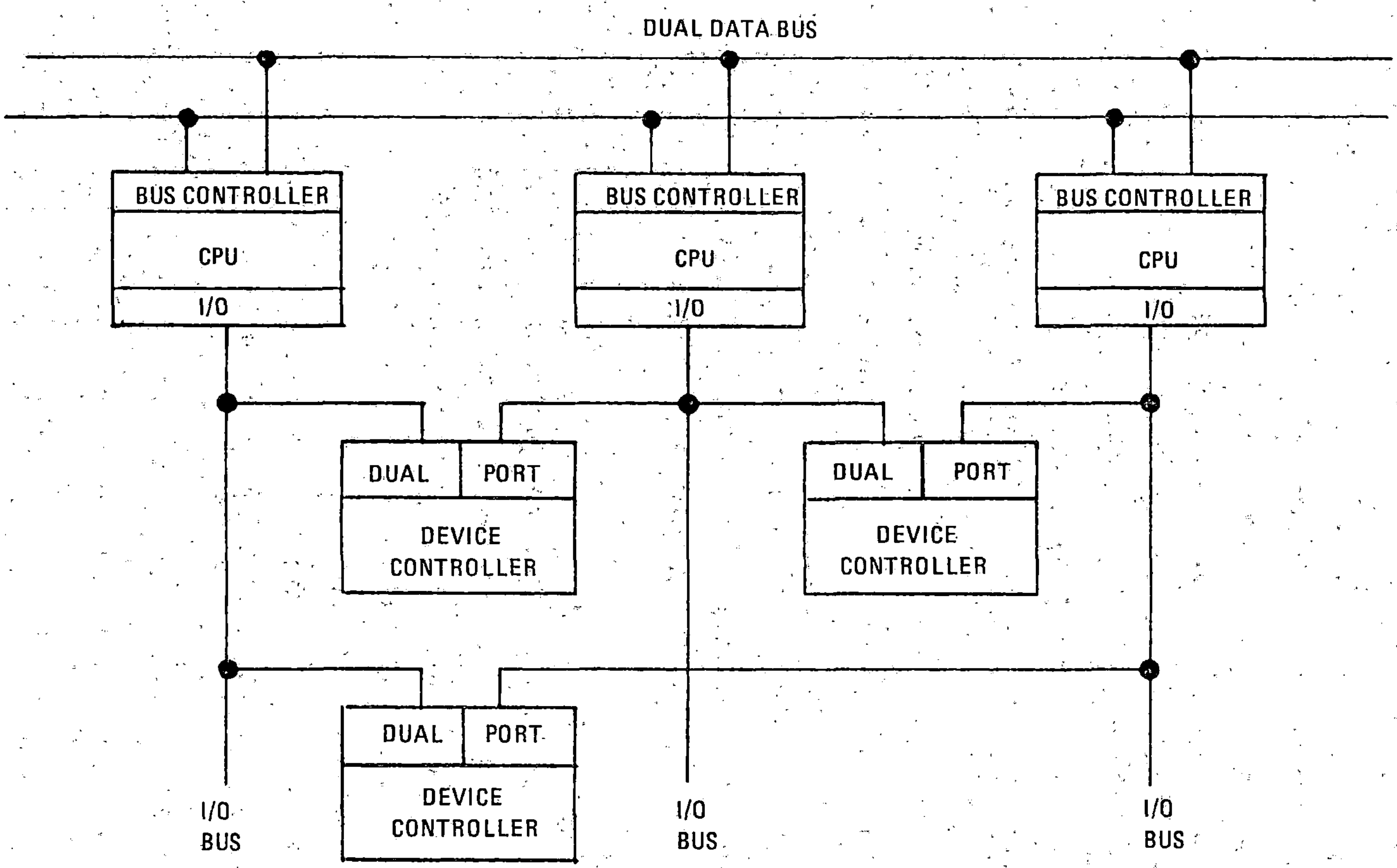


FIGURE A-4. FAIL-OPERATIONAL CONFIGURATION PARALLEL BUS ARCHITECTURE

Central control data processor input/output functional requirements are summarized below (refer to Figure A-3).

Inputs	Data communications from each train under system control: Means shall be provided for receiving, decoding and inputting digital data communications from each train.
Supervisor Inputs	Supervisor controls for computer management, system operational inputs and supervisory overrides.
Other System Data	Interface data from any other train control or switch control system.

Interfacing means shall be provided to obtain track occupancy data, switch position information, station data, and other pertinent data from any existing train control or TCS system.

Outputs	Command/control: Data communications shall be provided for the transmittal of control information to each train.
	Command/control: Route selection and individual switch overrides.
Supervisor Display	Active situation displays shall be provided for the supervisor with indications of train and switch positions, train identification and status, indications of normal system operation, train and wayside malfunction indications, caution and alarm signals requiring operator attention, and special displays on command for individual train status and routing information.

Hard Copy	Printed data outputs shall be provided for train sheet data, occurrence of unusual events, arrival/departure data, malfunctions, personnel assignments, and historical malfunction and maintenance data.
Magnetic Tape	Tape recording means shall be provided to allow permanent logging and recovery of all data listed as hard copy and in addition all supervisor actions and command inputs shall be logged.

3.1.7 System Malfunctions

Two broad categories of system failures shall be considered during system design. The first are failures within the overlay system which directly affect the operation of the system. The second are failures which are detected by other means and are reported to the overlay system by independent sensors and interfaces. The latter category of failure may or may not directly affect system operation. Certain types of malfunction data shall be logged in train or track status reports and maintenance-related files. However, other failures associated with a secondary system which impact operations of the overlay system shall be logged. The design for the overlay system shall use fail-safe or fail-operational concepts for all functions deemed vital or which impact the safety of the train.

For those failures of a serious nature which are likely to degrade into a safety-related failure, means shall be provided to alert the crew and the control supervisor of the failure. Other less serious malfunctions shall be included in the train or system status report as necessary. Failures and malfunctions which are outside the scope of the overlay system design and which are considered vital shall be treated in a fail-safe manner causing the trains to slow, stop or take other appropriate action. The system I/O shall be designed such that the following types of signals and malfunction reports can be acquired from other sensors or systems:

(a) Loose or broken wheels

(b) Broken rail

(c) Hot boxes

(d) Parted train

(e) Dragging equipment

(f) Load intrusion

(g) Brake failure

3.1.8 Applications

The proposed system shall have a wide range of applicability and be suitable for installation in conjunction with a variety of existing types of train control systems. It shall encompass the spectrum from minimal time table train order operation where there are no automatic controls through the full-blown ABS with a centralized TCS. The fundamental design objective shall define an overlay system compatible with these vastly different conditions and at the same time retain the maximum commonality between functions and hardware required by the system. General system concepts described in the preceding paragraphs shall be adhered to, since they satisfy to a large extent the goals of this design objective. At the same time the functions of the train equipment, including the cab signaling apparatus, shall remain essentially invariant regardless of what type of basic system is under consideration. The major differences shall be considered when requirements for backup operations are defined. For example, when it is required that the train operate with a different cab signal system in the event of failure, the basic system elements and functions shall be duplicated or added to the overlay system.

Other major areas where significant differences occur are in the interfaces acquiring system inputs which define unequipped train position, such as in those unsignaled areas presently using TT and TO. In such cases ABS with wayside signals shall be installed prior to or in conjunction with the subject overlay system. This requirement shall allow the definition of a standard block detection functional interface that is consistent with the entire spectrum of existing train control systems. One such interface is shown in Figure A-5. All track occupancy and switch position data shall be detected directly from the track and switch position repeater relays. All blocks within an existing system shall be identified, and, depending upon the throughput/headway analysis, the need for any additional wayside markers shall be determined.

Each equipped train shall determine its absolute positional data by detecting the crossing of block boundaries and/or the passing of wayside markers. These data shall be correlated by central with the occupancy data detected from the track relays. Various techniques shall be used as applicable either singly or in combination to detect the block boundary crossings (see Figure A-6). For example, detectors shall be used where appropriate to sense changes in voltage level or signal codes, carrier phase reversal sensing of the signal transients at locations of insulated joints or impedance bonds. Definition and selection of the signatures for various types of block controls and track circuits shall be used as applicable depending on the type of existing system. The sensor design shall accommodate existing types of track circuits, and more than one signal signature shall be used as required in order to improve detection of the track circuit boundary. Memory, logic and programs shall be provided on board the train to store specific data for each block (track) within a particular region. The expected encounter of a block boundary

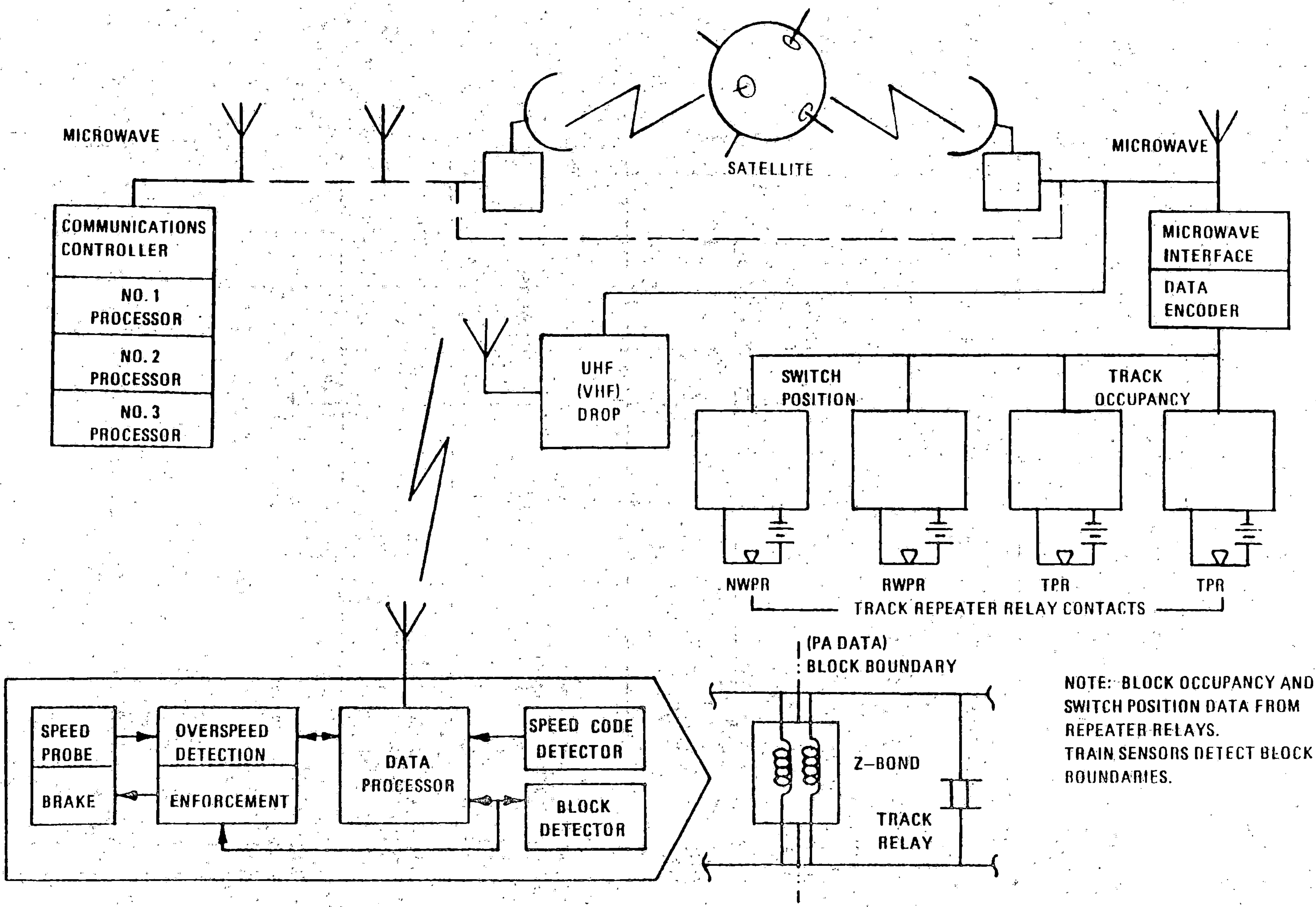


FIGURE A-5. OVERLAY SYSTEM INTERFACE

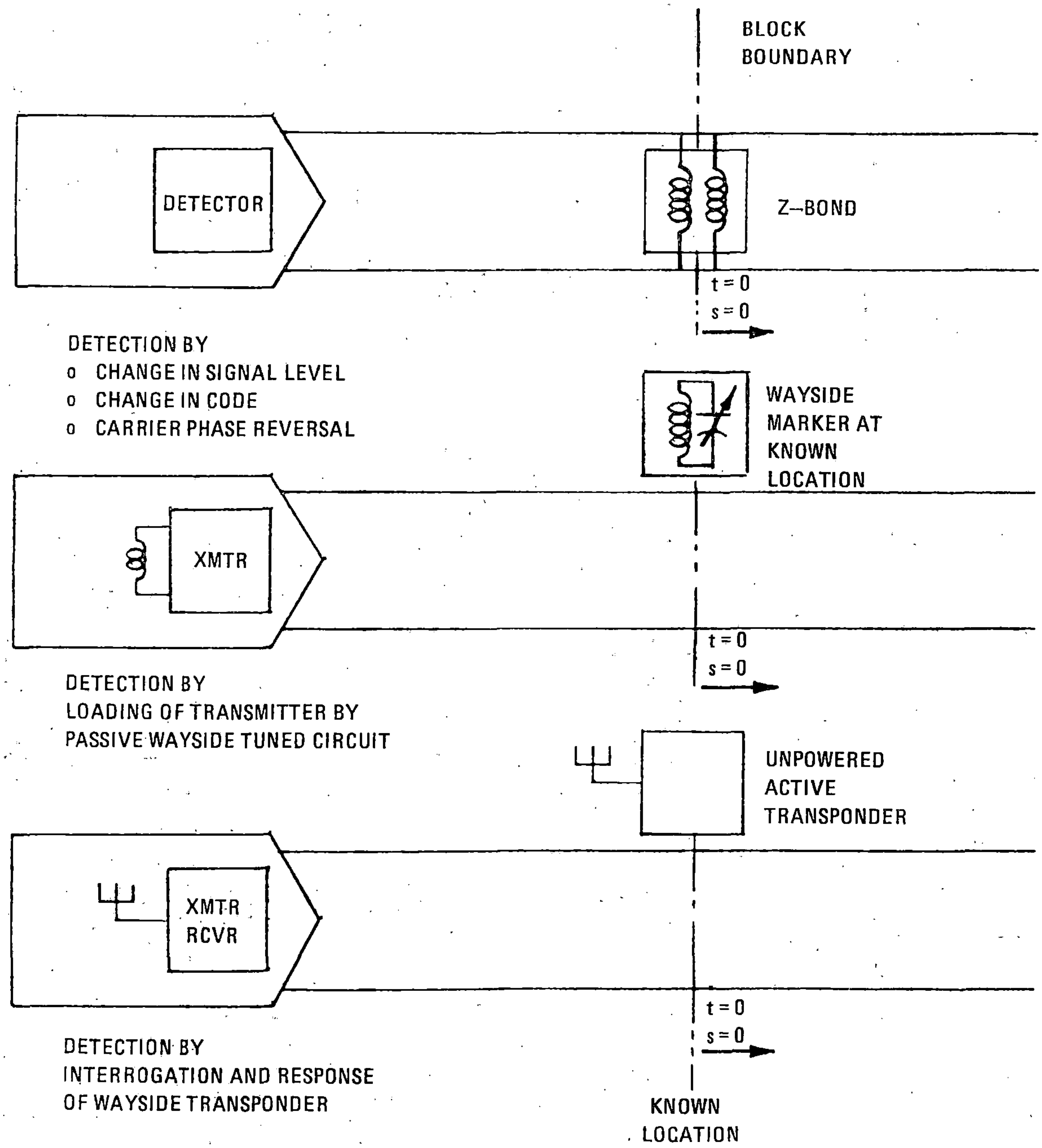


FIGURE A-6. TRAIN POSITION DETECTION

shall be predicted by the processor on board the train and the time and distance correlated with the actual boundary crossing to increase assurance of detecting improper system operation. Block boundaries shall be detected within a time and distance window consistent with the performance of the velocity channel and the integration function. Failure to detect a boundary within a predetermined tolerance shall generate a malfunction report and shall initiate whatever appropriate action is necessary to enhance safety, such as slowing, stopping, or operating in a fail-operational mode under the existing basic signal system until normal operation is restored and verified.

Trains equipped with the system shall be capable of detecting the standard cab signal codes as a backup function for speed control. These codes shall also be used to derive vital speed limits. The signals shall be reported to the central processor via the train-to-central control data communications channel. Using the occupancy data, modified by any civil restriction or operational condition, the central processors shall compute the speed command data for each train. (See Figure A-7). The on-board processor shall retain in its memory the latest track signal speed command until a modifying command is received from central control. (Note that in considering the response requirements of the train and the central-to-train data rates, the commands from the central control point shall be essentially continuous.) These data shall be displayed to the engineman as part of the cab signal display. (Discrete colored light signals shall also be displayed which mimic the wayside signals.) This arrangement shall provide two fallback modes of operation. First, any central processor or data communications failure shall not immediately impact the performance of the train, since the on-board processors shall allow for a transition to the conventional cab signals. Second, any cab signaling system failure shall be offset by reversion to wayside signals as the train reduces speed to less than 130 Km/h (80 MPH).

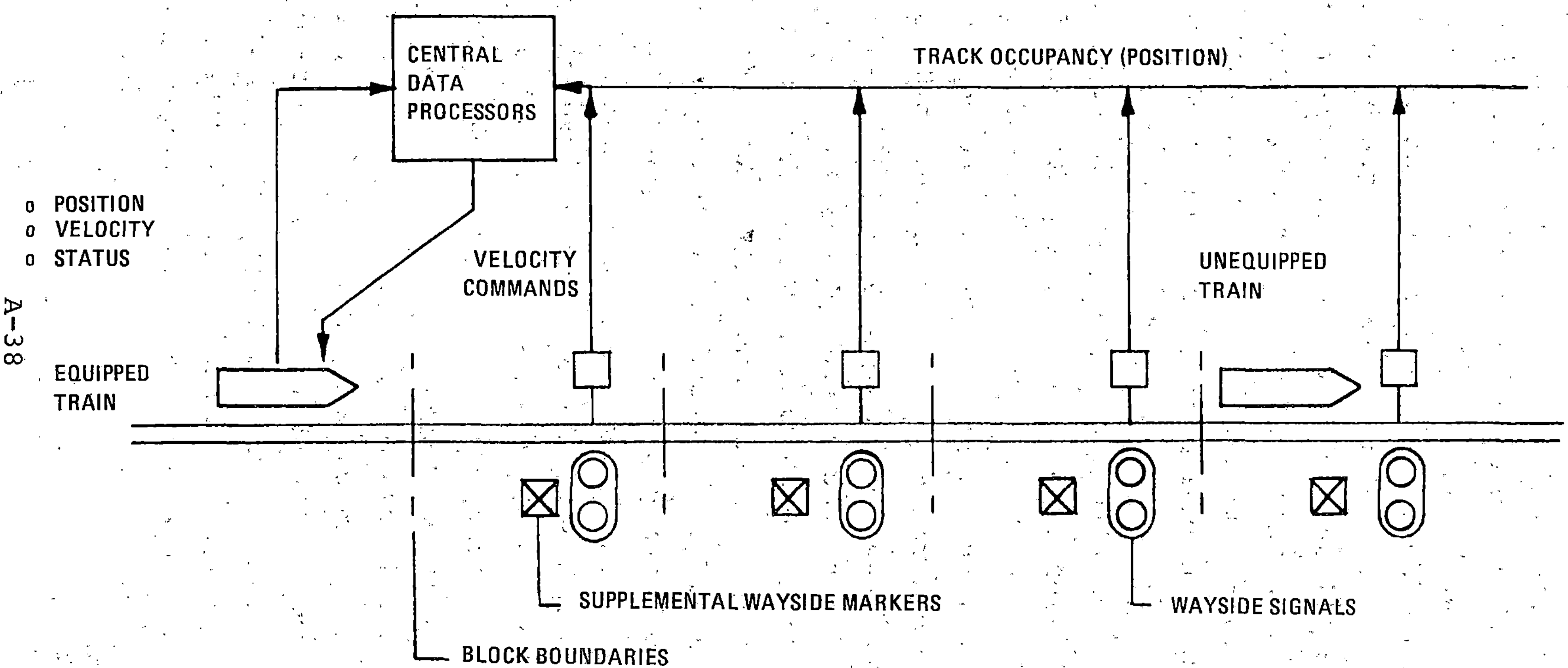


FIGURE A-7. BLOCK SYSTEM-WAYSIDE SIGNALS

In each region or operating area of consistent block signaling and block lengths, an analysis shall be made to assure safe braking distance as a function of the signal aspect and the braking performance of the train. Two sets of data shall be generated assuming two operational modes for the equipped train. One set of data shall be based on the normal operational mode whereby the overlay system shall be used to provide speed commands, and any existing ABS cab signals shall be used to derive speed limits. The second set of data shall assume that the train is operating in a fail-operational mode using the existing ABS system and governed by ABS cab or wayside signals. The purpose of the analysis is to derive quantitative values of compatible design data for speed commands, speed limits, block lengths, suitable interlockings, safe braking distance, and train separation. Braking performance shall be a constant parameter, while in order to make optimum use of the equipment other functions shall be allowed to vary, such as block length, signal spacing and number of aspects available.

If realistic data produce a solution where the values are incompatible, it shall be a requirement to indicate any necessary block realignment or to define the locations where additional wayside markers must be installed to supplement the existing block system. As an alternative to the addition of wayside markers, a preliminary design involving the addition of blocks and signal aspect codes to the existing system shall be made for cost comparison purposes. Any recommended block realignment shall not adversely affect existing traffic. If at least four aspects are already available in the overlay system the need for such additions is unlikely because of the flexibility available by virtue of the ability to program appropriate speed commands which will be compatible with existing system designs. Where a vital distance measuring subsystem is developed, the requirement for additional wayside markers or additional blocks may be reduced as appropriate.

3.1.9 System Interfaces

System interfaces are those points where the proposed signal/control system and the underlaying system exchange data and commands. There are three points where such interfacing may occur: the wayside track circuits, the onboard train equipment and traffic control centers of a TCS system. As a design goal, data interfaces at the existing control center shall be avoided. Data and commands should be acquired and injected as physically close as possible to the data source or operational control. The following are examples:

- Track occupancy data shall be taken from the track circuit relay or its repeater. This interface shall not interfere with the fail-safe performance of the track circuit.

- Switch position data shall be available at the switch position repeater relays used to check that switch.

- Train speed shall be a product of the vital tachometer outputs.

- Brake control shall interface directly with the control valve contacts on brake control equipment.

An engineering analysis shall be made of the existing track circuits on each railroad where improvements are to be made to determine the most cost effective approach to the interface requirement.

3.2 System Characteristics

The following paragraphs define the system functional requirements in terms of parameters which must be reduced to quantitative values during the preliminary design phases of the development cycle. Numerical values have been specified as typical where fundamental quantities are essentially invariant with different system hardware implementations.

3.2.1 Performance

System performance shall be evaluated in terms of headway capability and in terms of estimating, refining and maintaining train schedules. The control of train movement shall be effected by generating variable speed commands at the central control point and transmitting these commands to the equipped trains. Outside factors shall be considered for their impact on the ability of the system to modify the performance of the equipped train, and means to accommodate these factors shall be included in the design approach. Recording, storing, retrieving and analyzing historical data shall be considered key approaches to providing the capability of estimating and refining realistic schedules. Adequate bulk data storage shall be provided in the central processor to allow for the analysis of historical data trends of one to two weeks duration. It shall be a design goal to store on one disk the data from 100 train movements over a period of one month with data acquired every five minutes (approximately 1.5 million words of storage). Such information shall be used to establish trip times and schedules between stations as functions of such factors as the time of day and day of the week. Means and methodology shall be included to retrieve, collate, sort and print pertinent data and results. To accommodate other functions, storage and growth potential, the disk bulk capacity shall be in the order of 15 to 20 million 16-bit words. Magnetic tape units shall be provided for permanent records, programs and long term data storage.

The basic task of generating speed commands is directly associated with train performance modifications to meet schedules. This task shall be essentially a block-to-block process, and if the entire Amtrak system is considered as the basis for design purposes then data from approximately 16,000 blocks shall be analyzed as a part of the task to establish the information for generating speed commands. In addition, the system design shall consider the management of approximately 1,000 trains. A distributed network of data processors shall be required whereby the system would be segmented into 15 or 16 operational areas with the lower echelons of data processors accommodating approximately 1,000 blocks and 64 trains. The lower echelon of microprocessors shall interface directly with the track, switch and signal indicating relays and with the communication network to the central processors. Their functions shall include the I/O, data formatting and multiplexing, and the execution of simple standard data management and communications programs.

3.2.2 Data Rates

The transmission of command data and the reception of data messages from the trains shall occur periodically. The required message repetition rate for communications to and from a particular train shall be dependent on the block length and the allowable train speed. The period between transmissions to and from a train shall be five seconds nominal. A full duplex type system shall be used so that a message transaction can be completed to any train within the nominal time of five seconds, i.e., a message from central to the train and a reply from the train to central would comprise one transaction. The maximum allowable time between message transactions shall not exceed ten seconds.

The derivation of speed commands for all equipped trains within the system shall be accomplished by the data processors located at the central control point. The derivation of a single command shall be based upon the analysis of the set of blocks and switches on a line immediately adjacent to a particular train. The allowable speed limit and the speed command data shall be calculated by the central processor on the basis of block occupancy, block length, train speed and position, and full consideration shall be given to the operating criteria for any trackage zone. The servicing of 1,024 trains within one-half second shall be a minimum requirement for the set of data processors at central. Using a fan-out to 16 microprocessors each lower echelon processor shall manage data from not less than 64 trains. The message traffic shall be determined by design requirements but shall not be less than four 16-bit words to and from each train every five seconds. With a 50% duty cycle, these communications channels shall be capable of at least 1800 baud. The channel quality shall be voice grade with the short term error rate less than 0.05%. Switched commercial systems shall not be excluded from consideration if system availability is adequate. The nonavailability of the channels shall be less than 0.05%.

3.2.3 Reliability

The system developer shall establish and maintain a Reliability Program Plan of comprehensive depth beginning with the development phase and continuing through the evolution to a mature and reliable production design. An identifiable organizational element shall be designated the responsibility for planning and conducting the reliability efforts. The Reliability Program should include the following general tasks:

(a) Reliability predictions based on parts count and including environmental stress effects,

(b) Participation in design reviews and evaluation of engineering design changes,

(c) Documentation, reporting and analysis of all hardware failures,

(d) Generation and continuous refinement of a Failure Mode and Effects Analysis (FMEA),

(e) Preparation of reliability-related change proposals,

(f) Generation of any required reliability test and demonstration plans.

The system developer shall assure the quality and reliability of vendor-supplied material and parts by monitoring manufacturing methods and components to verify compliance with specification requirements. Vendor changes which influence system reliability shall be approved by the reliability organizational element. The system developer shall generate a reliability model adhering to the guidelines in MIL-HDBK-271B, Reliability Prediction of Electronic Equipment.

The model shall:

(a) Consider all operational modes,

(b) Consider various operational environments,

(c) Reflect appropriate success-failure definitions, and,

(d) Consider duty cycles.

The model shall be expressed graphically and mathematically. The model shall place particular emphasis on those failure modes which influence system safety functions or which concern vital or fail-safe system elements. Failure detection/indication and restoration cycles are an integral part of the FMEA when analyzing failure modes while operational in the "fail-operational" condition.

The system developer shall establish a predicted failure rate or probability of success for each identified element of the reliability model. The Parts Count Reliability Prediction Method (Section 3, MIL-HDBK-217B) may be used only during the development and early design phases. The Part Stress Analysis Prediction Method (Section 2, MIL-HDBK-217B) is preferred and shall be used when sufficient knowledge of parts application and induced stresses has been acquired.

The use of specific part quality level for reliability prediction purposes shall be interpreted as a subcontractor intention that the same quality level part will be procured and used in the production configuration. Necessary adjustments to the development reliability prediction shall be made in order to establish a production reliability prediction that reflects hardware failure rate predictions as they would actually appear in the production configuration. This prediction shall utilize the Part Stress Analysis Prediction Method (Section 2.0, MIL-HDBK-217B). These data will represent the production reliability baseline against which the reliability effects of engineering change proposals are to be assessed.

As a part of the overall Reliability Program design qualification tests shall be conducted. The objective of design qualification tests (or environmental qualification tests) is to demonstrate that parts and components, manufactured to the design specifications, will meet the performance requirements as defined in the appropriate performance specifications at both ambient and environmental extremes (to include specified combinations of environmental extremes).

The system developer shall require that reliability personnel be actively integrated into the design qualification function to assess the qualification test results as they pertain to reliability and to assure that all parts are approved prior to inclusion into the test program hardware.

The system developer shall establish and maintain a closed-loop system for collecting, recording and analyzing the information derived from all discrepancies and failures that occur at all phases of testing, fabrication and inspection, commencing with research and development model components and extending through production design and testing. Summary information and charts reflecting discrepancy and failure trends at all levels of inspection shall be developed for review and corrective action as follows:

(a) Problem Investigation - The failure and discrepancy recording system shall include procedures for documenting the investigation of the cause of each failure and type of discrepancy. Failure analyses shall be conducted to the lowest level of hardware necessary to identify the failure cause and mechanism and shall begin with an on-the-spot review by reliability and quality engineering and the responsible test engineer prior to removal of the failed hardware from the test configuration. Failure analyses shall differentiate between failures due to equipment alone, man-equipment incompatibilities, and those due to human error. Parts failure analyses shall be performed by parts engineers.

(b) Corrective Action - The purpose of the failure and discrepancy recording system shall be to detect failures, determine their cause and assure and verify that effective corrective actions, appropriately coordinated with design engineering, quality assurance and manufacturing, are taken on a timely basis to reduce or prevent failures.

3.2.4 Maintainability

The system design shall use as a guideline the maintainability requirement set forth in MIL-STD-470. A program plan shall be developed to assure that the system evolution produces a maintainable product which can be analyzed, repaired and checked out by relatively unskilled personnel.

An objective of the system design shall be to minimize manual procedures for troubleshooting and shall use self-diagnostic programs and built-in failure indicators to isolate malfunctions at the system unit or black box level. With a system operating on-line the maintenance requirements shall be reduced to simply replacing failed unit(s). During system periodic maintenance and bench check special test equipment and programs may be used to perform detailed malfunction analysis and to isolate failures to printed circuit board level or equivalent. Bench test equipment designs are required to allow isolation of faults to the component, board or part level such that the replacement cost of such a component is less than the calculated economic repair limit of the component. These requirements shall apply equally to either the trainborne or wayside equipment. The mean time to repair (MTTR) for a unit at the bench test level shall not exceed the calculated economic repair limit including setup, test, repair and verification.

Special attention shall be given to minimizing the possibility of damage to equipment during testing caused by improper removal, installation, and/or test procedures. Power supplies and circuits shall have self-protective designs which can tolerate grounding, shorts and opens without permanent damage. The designs shall incorporate keyway features, warning decals and special handling instructions for critical items to prevent damage from electrostatic charges, removal or installation under power, incorrect installation or other improper handling.

Accessibility to--and inspection of--malfunction indicators and test points are considered integral to the system's design and must be arranged so that relatively unskilled maintenance personnel can isolate faults and replace units easily and rapidly. Where parallel redundant designs are used, the failed unit shall be clearly evident without the necessity of removing either the operative or inoperative unit. The mean time to repair (MTTR) at the replaceable unit level shall not exceed 20 minutes as a design goal. The period includes any time required for initial diagnosis as well as testing and verification after replacement.

As a part of the Maintainability Plan, a Test and Demonstration Program shall be defined which can be used to verify and evaluate the diagnostic and repair procedures. Special faults and malfunctions shall be induced or simulated to verify the written test procedures, the operation of the bench test equipment, and the MTTR's.

3.2.5 Environmental Factors

The system developer shall plan and execute environmental demonstration tests to verify that all system elements meet established reliability criteria. The test plans detailing procedures and quantitative levels and limits shall be generated by the system developer and approved by the procuring agency. These plans shall be summarized and included in an Environmental Qualification Test Specification.

Test environments to be considered shall include vibration (periodic and random), surge, polarity reversals, shock, temperature, sand, dust and moisture. Meaningful combinations of environmental conditions shall be established and used in the demonstration tests. A complete set of acceptance and rejection criteria shall be established to define the requirements for retest and/or redesign. Preferred methods of testing are those that functionally exercise the system element during repeated cycles of the imposed environmental factor. Whenever possible the operational functions should be simulated and the proper operation of the equipment verified during the actual test.

Different equipment types shall be qualified to different sets of criteria suitably selected to evaluate the intended use of the system element. At least three general categories of equipment and corresponding tests are envisioned for the subject system. These categories would include wayside equipment installed out-of-doors, vehicle-borne equipment and equipment installed at the central control point in an environmentally controlled area.

3.2.6 Electromagnetic Interference (EMI) Control

The signal/control system shall be designed for compatible operation in electrification or other EMI environments. Interference control practices shall be incorporated during original equipment design and not as after-the-fact fixes. Any modification to equipment as a result of EMI testing shall be approved by the procuring agency prior to design changes. The signal/control system developer shall provide an Interference Control Plan and an Interference Test Plan describing the interference control program for the equipment.

The Interference Control Plan shall be prepared and submitted to the procuring agency for approval within 90 days after contract award. The plan shall describe the developer's implementation of the EMI requirements in accordance with paragraphs 4.2.1.1 through 4.2.1.7 of MIL-STD-461 and as follows:

(a) Transient and Surge Suppression - Transient and surge suppression shall be provided for each power lead and for interface conductors routed externally and exposed to lightning and induced transients. An analysis of the transient voltage withstand level of power and interface circuits shall be performed. Interface conductors shall be protected by solid-wall ferrous conduit, or transient suppression circuits shall be provided at conductor entrances to equipment. The control plan shall describe shielding and transient suppression devices and circuits for power and interface conductors.

(b) Conducted and Radiated Interference Requirements - The signal/control equipment shall not produce conducted or radiated interference exceeding the limits defined by MIL-STD-461A for Class I equipment.

(c) Conducted and Radiated Susceptibility Requirements - The signal/control equipment shall not be susceptible to the conducted and radiated interference levels defined by MIL-STD-461A for Class I equipment. In addition the equipment shall not be susceptible to the conducted and radiated levels of interference produced by electrification and other electrical environments. Electrification EMI levels and susceptibility test methods shall be as defined by separate attachment after test measurements.

The developer shall submit an Interference Test Plan to the procuring agency within 120 days after contract award. The test plan shall describe the facilities and test equipment and give detailed procedures for performance of the interference and susceptibility tests required herein. The contents of the test plan shall be in accordance with paragraph 4.3 of MIL-STD-461A. A test report shall be submitted within 30 days after completion of tests.

3.2.7 System Safety Program

3.2.7.1 Description

The system developer shall establish and maintain a System Safety Program. This program shall be integrated into all phases of the contract. The System Safety Program shall provide a disciplined approach to methodically evalute the signal/control system design with regard to safety and to identify hazards and prescribe corrective action in a timely, cost-effective manner. The System Safety Program shall prescribe a formal approach to the elimination of hazards through engineering, design, education, management policy, and supervisory control of conditions and practices. Guidelines established in MIL-STD-882, System Safety Program for Systems and Associated Subsystems and Equipment, shall be applied to this System Safety Program wherever applicable.

System Safety Program shall supplement the fail-safe design requirements of these Specifications but shall not relieve the system developer of fail-safe design responsibility in any way.

3.2.7.2 Objectives

The system developer's objectives shall be in consonance with FRA system safety objectives.

The primary objective of the System Safety Program shall be to eliminate hazards of a vital nature, whether actual or potential, from the signal/control system. These are hazards which could result in personal injury, damage or loss of a portion of the signal system. This applies both directly and indirectly, i.e., whether the injury, damage, or loss were to be caused directly by a signal system malfunction or indirectly by the resultant unsafe operation of one or more trains.

The secondary objective of the System Safety Program shall be to minimize the extent and seriousness of injury to personnel and/or damage to equipment and property due to any malfunction of the signal/control system.

3.2.7.3 Submittals

The system developer shall submit a detailed description of his proposed System Safety Program as part of his bid for the signal/control system contract. This description shall detail the methods to be used to achieve the specified objectives of the program and delineate how the System Safety Program is to be implemented and documented.

The system developer shall submit monthly system safety reports commencing no later than 60 days after receipt of notice to proceed, which shall include, but not be limited to, descriptions of hazards detected and progress in implementing corrective measures to eliminate or reduce the seriousness of hazards within the signal/control system.

The monthly report shall include an interface section which identifies hazards to the signal/control system which are best corrected externally to the system such as by changes in rules, procedures, training or maintenance. The interface section shall also identify external hazards which shall be corrected in the signal/control system such as protection against failure of incoming power, ATC and wayside signal systems.

The system developer shall submit separate reports evaluating the impact of design changes on the safety of the signal/control system.

3.2.7.4 Requirements

The system developer shall be responsible for the management and operation of the System Safety Program. The responsibilities and functions of those directly associated with system safety policies and implementation of the program shall be clearly defined.

The authority delegated to this organization and the relationship between line, staff, project, department and general management organizations shall be identified. However, it is not the intent of this sub-section to prescribe or imply organizational structure, management methodology, implementation procedures or internal documentation.

3.2.7.5 Hazard Categories

Hazards identified shall be classified and assigned a relative qualitative measure in accordance with the following categories:

A. Category I - Negligible

Hazardous conditions such that human error, environment, design deficiencies, component failure or procedural deficiencies will not result in personal injury or system damage.

B. Category II - Marginal

Hazardous conditions such that human error, environment, design deficiencies, component failure or procedural deficiencies can be counteracted or controlled without personal injury or major system damage.

C. Category III - Critical

Hazardous conditions such that human error, environment, design deficiencies, component failure or procedural deficiencies will cause personal injury or major system damage.

D. Category IV - Catastrophic

Hazardous conditions such that human error, environment, design deficiencies, component failure or procedural deficiencies will cause death or serious injury to human beings or major system loss.

3.2.7.6 Tasks and Procedures

The System Safety Program shall specifically describe the procedures which the system developer shall follow in order to accomplish certain safety oriented tasks. These tasks shall include, but not be limited to, the following:

A. Correct safety irregularities in the design phase as early as possible.

B. Eliminate from the system the evoking of any false proceed commands or false signal proceed aspects.

C. Minimize the number of false restrictive or stop commands and false signal stop aspects.

D. Evaluate design changes and the impact these changes will have on the safety of the complete signal/control system.

3.2.7.7 Products and Materials

The system developer shall supply all the materials, tools, equipment, computer time, reference literature and other items which are necessary to meet the requirements of the System Safety Program.

APPENDIX B

DOCUMENT REFERENCE LIST

This report and other reports in this study series have drawn upon a number of sources for data including technical papers, periodicals, books and government reports. The sources have been both domestic and foreign. Where extensive material was extracted for a specific report the appropriate acknowledgement was made in the text. However, none of the reports could have been completed without the general background information which was obtained from the documents listed in this appendix. The authors acknowledge these sources by including them here. It may be noted that some documents were requested for this study series and were not received. However, they are listed here for their topical value and the fact that they may be received after the final report is published.

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
1	CTC AND RADIO: STRONG TEAM FOR THE FAMILY LINES	PRO. R.R.	MAY 76	X	X				X	
2	NW's BACKBONE MICROWAVE: RELIABLE, ECONOMICAL COMMUNICATIONS	PRO. R.R.	MAY 76	X						
3	SHORT-TRAIN RAILROAD	PRO. R.R.	AUG 76	X				X		
4	CLEAR CHANNELS FOR BETTER SERVICE	PRO. R.R.	AUG 76		X				X	
5	CRT-DISPLAYED CTC	PRO. R.R.	SEP 76		X				X	
6	COMPUTERS . . . PLUS	PRO. R.R.	DEC 76		X				X	
7	LINDENWOLD: A TRANSIT SUCCESS STORY	MASS TRAN.	OCT 77		X					
8	JNR DEVELOPS NEW CTC EQUIPMENT	INT.RY.JOUR	NOV 76	X	X				X	
9	ELECTRONICS PLAY INCREASING ROLE IN DB SIGNALLING	INT.RY.JOUR	NOV 76	X	X					
10	C&S: HOW RAILROAD MICROWAVE SYSTEMS ARE GROWING -- AND WHY	RY. AGE	AUG 77		X					
11	CONRAIL HELPS PUMP NEW LIFE INTO THE C&S MARKET	RY. AGE	FEB 77					X		
12	EXPANDING CTC, CAB-SIGNALING SYSTEMS SPEED UP TRAFFIC	RY. AGE	DEC 76		X					
13	CHESSIE GOES FOR TOTAL DISPATCHING	PRO. R.R.	JAN 77		X					
14	TELE-COMMUNICATIONS TIES TOGETHER FRISCO'S BIG "X"	PRO. R.R.	MAY 77		X					
15	NW IS READY TO GO WITH SYSTEM MICROWAVE	RY.SYS.CONT	JUN 74	X	X					
16	ICG MOVES TO 12 CHANNEL RADIO	RSC	JUN 74	X	X					
17	D&RGW CENTRALIZES, COMPUTERIZES CTC DISPATCHER CONTROL	RY.SYS.CONT	MAR 74		X					

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
18	AXLE COUNTERS DEFINE BLOCK SECTIONS IN ELECTRIFIED TERRITORY (INDIA)	RSC	DEC 73	X			X			
19	POSITIVE TRAIN IDENTIFICATION (LONDON TRANSPORT)	RSC	MAR 75	X						
20	TRAIN LOCATION SYSTEM IS NOW IN OPERATION ON THE BRITISH COLUMBIA	RSC	MAR 75		X					
21	TRACK CIRCUITS -- ANOTHER ROLE (BR)	RSC	SEP 74	X						
22	C&S PROJECTS CONTINUING IN 1975	RSC	JUN 75					X		
23	PROBLEMS AND TECHNIQUES IN THE USE OF AUDIO FREQUENCY TRACK CIRCUITS	RSC	MAY 75	X			X			
24	ELECTRIFICATION: A STATUS REPORT	RSC	JUN 75	X						
25	PRESENT DESIGNS AND TRENDS IN GERMAN RAILWAY SIGNALING	RSC	JUL/AUG 75	X						
26	054365 ELECTRIC TRACTION IN JAPANESE NATIONAL RAILWAYS	IEE LONDON	1968	X						
27	050575 UIC#036N5 GENERAL DESCRIPTION OF THE JAPANESE NATIONAL RAILWAYS (NOT RECEIVED)	UIC	1971		X					
28	048016 BULLET TRAINS REVISITED (KALMBACH PUB. CO.)	TRAINS	OCT 73		X					
29	047906 COMPUTERIZED AUTOMATIC TRAIN OPERATION SYSTEM	TOSHIBA REV.	FEB 73		X				X	
30	050880 NEW TRAIN DIAGRAM RECORDER	RAIL. TECH. RES. INST. TOKYO		X						

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
31	050689 AUTOMATIC TRAIN OPERATION BY MINICOMPUTER (JNR)	RAIL INT.	1973	X					X	
32	051444 ATC EQUIPMENT FOR NEW SOBU LINE CARS OF JNR	HITACHI REV VOL. 22, No. 9	1973	X	X				X	
33	048861 TES SPONSORED STUDY OF SAN FRANCISCO TO ASSURE PUBLIC SAFETY (NOT RECEIVED)	RRB	1974			X				
34	052669 USE OF ELECTRONIC COMPONENTS IN SIGNALLING. DEFINITION OF TERMS CONCERNING ELECTRONIC SAFETY SIGNALLING SYSTEMS	UIC	APR 75	X		X				
35	HIGH VOLTAGE AC POWER TRANSMISSION LINES AND COMMUNICATIONS RECEIVER SITES	USCG	MAR 76				X			
36	ELECTROMAGNETIC INTERFERENCE IMPACT ON RAILROAD CLASSIFICATION YARDS (SUMMARY OF #156) 1978 JOINT ASME/IEEE/AAR R.R. CONF.	IEEE	1978				X			
37	099422 MANNED/UNMANNED TRANSIT SYSTEMS STUDY (NOT RECIEVED)	RRB	1975	X						
38	126411 TRAIN SAFETY CONTROL SYSTEM FOR SHINKANSEN-CPU SYSTEM WITH PRIORITY ON SAFETY (ASME JOURNAL OF DYNAMIC SYSTEMS)	RRB	JUN 75	X	X	X				
39	125868 BLOCKJOINTLESS TRACK CIRCUIT-LONDON TRANSPORT (NOT RECEIVED)	RRB	MAR 75	X						
40	126992 "UTRL"--AN ELECTRONIC FAIL-SAFE LOGIC IN RAILWAY SIGNALLING (NOT RECEIVED)	RRB	FEB 75	X					X	

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
41	127617 SPOORPLAN (GEOGRAPHICAL TYPE) INTERLOCKING SYSTEM SPDRS U FOR URBAN RAILWAYS (MICROFILM)	SIEMENS REV.	MAY 75	X					X	
42	127867 CHARTING THE LIMITS OF UNMANNED OPERATION	RGI	OCT 75	X					X	
43	127868 DESIGN PHILOSOPHIES IN AUTOMATIC TRAIN CONTROL	RGI	OCT 75	X						
44	127869 SWISS EXPERIMENTS WITH TRACK-TO-TRAIN COMMUNICATION	RGI	OCT 75	X						
45	128883 COMPUTERS, COMMUNICATION AND HIGH SPEED RAILWAYS (MICROFILM)	WIRELESS WORLD	AUG 75	X			X		X	
46	(DUPLICATE, SEE #25)									
47	129136 USE OF A COMPUTER IN THE DESIGN OF RAILWAY SAFETY SIGNALLING CIRCUITS	IEE LONDON	1974	X		X			X	
48	129165 INDUSTRIAL AND SCIENTIFIC APPLICATIONS OF DOPPLER RADAR	MICROWAVE JOUR	NOV 75	X						
49	129428 AUTOMATION AND SAFETY OPERATION OF METROPOLITAN RAILWAYS BASED ON HIGH TENSION IMPULSE TRACK CIRCUITS	RAIL ENG. INT.	OCT 75	X					X	
50	133290 (UMTA-IT-09-0014-75-5) NEW YORK CITY TRANSIT AUTHORITY DESIGN GUIDELINES SIGNALS AND COMMUNICATION	UMTA	MAR 75			X				

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
51	ELECTRICAL INTERFERENCE FROM THYRISTOR-CONTROLLED DC PROPULSION SYSTEM OF A TRANSIT CAR	IEEE	NOV 77				X			
52	138063 AUTOMATIC TRAIN CONTROL IN RAIL RAPID TRANSIT	GPO	1976	X					X	
53	138362 AN ECONOMIC ANALYSIS OF TRAIN CONTROL	UMTA	MAY 74					X		
54	139494 THYRISTOR CHOPPER CONTROL AND THE INTRODUCTION OF HARMONIC CURRENTS INTO TRACK CIRCUITS	IEE LONDON	JUN 76				X			
55	THYRISTOR CHOPPER CONTROL AND THE INTRODUCTION OF HARMONIC CURRENT INTO TRACK CIRCUITS	IEE LONDON	APR 74				X			
56	141423 BASIC TRACK CIRCUIT LIMITATIONS	WABCO	No Date	X			X			
57	141428 TRACK CIRCUIT CHARACTERISTICS ASSOCIATED WITH MOTION MONITORING	WABCO	OCT 75	X			X			
58	141424 COMPUTERS IN RAILROAD CONTROL: 1965, 1975, 1985	WABCO	No Date	X					X	
59	142260 RELIABILITY OF MICROWAVE COMMUNICATION SYSTEMS	RW TECH. RES. INST.	1976	X						
60	142279 COLOR-LIGHT AUTOMATIC BLOCK FOR TRACK CIRCUITS WITHOUT INSULATING JOINTS (NOT RECEIVED)	RRB	1975			X				
61	148290 THYRISTOR CONTROL OF LOCOMOTIVES AND ITS INTERFERENCE ON DATA TRANSMISSION (NOT RECEIVED)	IEEE	1975				X			

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
62	148304 EFFECT OF NOISE ON TRANSMISSION PERFORMANCE OF TELEPHONE CIRCUITS DUE TO THYRISTOR-CONTROLLED TRACTION (NOT RECEIVED)	IEEE	1975				X			
63	098056 RUNNING TIME CONTROL SYSTEM BASED ON ATC CENTER-CONTROLLED	RW TECH RES. INST.	MAR 75	X						
64	099410 THE DEVELOPMENT OF A TRAIN LOCATION IDENTIFICATION AND CONTROL SYSTEM (NOT RECEIVED)	RRB	1976	X						
65	052668 USE OF ELECTRONIC COMPONENTS IN SIGNALLING. TECHNICAL REQUIREMENTS FOR THE DESIGN OF CIRCUITS OPERATING ACCORDING TO THE FAIL-SAFE PRINCIPLE (NOT RECEIVED)	UIC	APR 75	X			X			
66	052685 UIC NO. A46/RP 3/E TRANSMISSION OF INFORMATION BETWEEN RAIL AND MOTIVE POWER UNITS GENERAL DESCRIPTION OF SPEED CONTROL SYSTEMS. DETERMINATION OF INFORMATION REQUIREMENTS. TEXT AND APPENDICES	UIC	JUN 64	X					X	
67	052709 UIC NO. A78/RP 1/E THE USE OF MICROWAVE FOR TRAIN CONTROL CIRCUITS	UIC	MAR 64	X					X	
68	052722 WARNING DEVICES USING RADIO. ENQUIRY REPORT: RADIO WARNING OF ONE TRAIN BY ANOTHER, EITHER DIRECT OR THROUGH A FIXED OR MOBILE RADIO ON THE TRACK, AND RADIO WARNING OF A TRAIN BY MEANS OF A FIXED OR MOBILE RADIO ON THE TRACK (NOT RECEIVED)	UIC	OCT 68	X		X			X	
69	052725 UIC NO. A118/RP 1/E USE OF ELECTRONIC COMPONENTS IN SIGNALLING. GENERAL CONSIDERATIONS	UIC	OCT 71	X					X	

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
70	052726 UIC NO. A118/RP 2/E USE OF ELECTRONIC COMPONENTS IN SIGNALLING. CATALOGUE OF FAILURES OF ELECTRONIC COMPONENTS. STANDARDS	UIC	OCT 72	X					X	
71	052727 UIC NO. A118/RP 3/E USE OF ELECTRONIC COMPONENTS IN SIGNALLING. FAULTS AND SAFETY IN RAILWAY SAFETY SYSTEMS	UIC	OCT 72	X		X			X	
72	052728 UIC NO. A118/RP 5/E USE OF ELECTRONIC COMPONENTS IN SIGNALLING. SYSTEM STRUCTURES FOR ACHIEVING SAFETY IN THE SIGNALLING TECHNIQUE-INTRODUCTION	UIC	OCT 75	X		X			X	
73	052729 UIC NO. A118/RP 6/E USE OF ELECTRONIC COMPONENTS IN SIGNALLING. METHODS FOR CALCULATING THE PERFORMANCE OF SAFETY SYSTEMS	UIC	APR 75	X		X			X	
74	052730 UIC NO. A118/RP 9/E USE OF ELECTRONIC COMPONENTS IN SIGNALLING. HOW CAN SAFETY BE GUARANTEED BY MEANS OF ELECTRONIC PROCESS COMPUTERS USED IN SIGNALLING TECHNIQUES? INTRODUCTION AND DEFINITION OF PROBLEMS	UIC	OCT 75	X					X	
75	052738 UIC NO. A122/RP 20/E APPLICATION OF THYRISTORS IN RAILWAY TECHNOLOGY: CONSEQUENCES AND REMEDIES, SIGNAL INSTALLATION INTERFERENCE FROM THE OPERATION OF THYRISTOR CONTROLLED TRACTION VEHICLES ON THE CSD RAILWAY SYSTEM	UIC	OCT 75				X			
76	052808 UIC NO. A4/RP 7/E SHUNTING SENSITIVITY OF TRACK CIRCUITS, ELECTRICAL CONTACT BETWEEN RAIL AND ROLLING WHEEL IN THE CASE OF OXIDISED SURFACES. IMPEDANCE OF WHEEL-SETS AS A FUNCTION OF THE FREQUENCY	UIC	MAR 62	X			X			
77	052809 UIC NO. A4/RF/E SHUNTING SENSITIVITY OF TRACK CIRCUITS	UIC	MAR 62	X			X			

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
78	093378 NORTHEAST CORRIDOR HIGH SPEED RAIL PASSENGER SERVICE IMPROVEMENT PROJECT. TASK 4A. SIGNALING AND COMMUNICATIONS (NOT RECEIVED)	FRA	SEP 75	X		X		X		
79	127637 AUTOMATIC TRAIN CONTROL AND COMMUNICATIONS FOR WASHINGTON METRO (NOT RECEIVED)	WMATA	NOV 74		X					
80	129655 BRITISH RAILWAY SIGNALLING THIRD EDITION	IAN ALLEN LTD.	1975			X				
81	129783 PROGRESS IN SIGNALING FOR TRACK GUIDED SYSTEMS	ASCE	NOV 75	X		X				
82	130673 SIGNALLING THE NEW LYON LINE OF THE PARIS SUD-EST NETWORK FOR 260 KM/H AND MORE	RAIL ENG. INT.	NOV 75	X	X	X			X	
83	130793 SAFE TRAIN SEPARATION IN MODERN RAPID TRANSIT SYSTEMS (NOT RECEIVED)	ASME	JUL 75	X					X	
84	131042 LIGHTNING AND ITS EFFECTS ON RAILROAD SIGNAL CIRCUITS	FRA	DEC 75	X			X			
85	131249 HIGH SPEED TRAFFIC SIGNALLING	IME LONDON	SEP 75	X		X			X	
86	131270 ELECTRONICS: ITS PLACE ON THE MODERN RAILWAY AND THE ATTENTION IT DEMANDS IN SERVICE (NOT RECEIVED)	IRSE	JAN 76	X					X	
87	138302 PACKAGING SYSTEM ESAS600 FOR ELECTRONIC RAILWAY SIGNALING EQUIPMENT (NOT RECEIVED)	SIEMENS REV. VOL 50 NO. 3	MAR 76	X					X	

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
88	138323 CN'S CTC COAST TO COAST	PROG. R.R.	MAY 76	X	X				X	
89	135191 SPEEDING TRAFFIC IN WEST GERMANY	ELECTRONIC PROD. MAG.	NOV 75	X						
90	135168 FUNDAMENTAL CHARACTERISTICS OF SYSTEMS FOR CONTINUOUS DETECTION OF VEHICLE POSITION BY INDUCTION LINES (NOT RECEIVED)	EE IN JAPAN VOL 95 NO. 1	JAN 75	X					X	
91	134059 PERFORMANCE OF LEAKY COAXIAL CABLES UNDER SOME INSTALLATION CONDITIONS	HITACHI REV.	1975	X						
92	131623 THE MINICOMPUTER-A FEASIBLE TOOL FOR AUTOMATING THE DISPATCHING FUNCTION (NOT RECEIVED)	IEEE	MAR 76	X						
93	RAILROAD OPERATION AND RAILWAY SIGNALING (BOOK)	SIMMONS-BOARDMAN	1942	X		X				
94	FRA-ORED-76-07 OPERATION OF HIGH SPEED PASSENGER TRAINS IN RAIL FREIGHT CORRIDORS	DOT	SEP 75	X					X	
95	DOT-TSC-OST-74-4 SAFETY AND AUTOMATIC TRAIN CONTROL FOR RAIL RAPID TRANSIT SYSTEMS	DOT ATA	JUL 74	X		X			X	
96	71-CP-272-IGA ELECTRIFICATION --ITS EFFECT ON SIGNALLING AND COMMUNICATIONS	IEEE CONF. PAPER		X			X			
97	06818-W019 R0-00 NETWORK CONTROL STUDY	TRW	JUL 70	X						
98	AUTOMATIC TRAIN CONTROL SYSTEM, DEMONSTRATION PROJECT BART TECH REPORT NO. 1	PARSONS, BRINCHERHOFF		X	X				X	

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
99	R FR 66 11 65 COMMAND AND CONTROL OF HIGH-SPEED GROUND ORIENTED TRANSPORTATION SYSTEMS	HUGHES AIRCRAFT CO.	MAR 66	X						
100	DUPLICATE SEE #97									
101	ESL R 327. C 85 65 OPTIMAL VEHICLE CONTROL FOR MERGING PROBLEM	MIT	NOV 67	X						
102	ESL R 399. C 85 65 SAMPLED-DATA CONTROL OF HIGH-SPEED TRAINS (NOT RECEIVED)	MIT	JAN 68	X						
103	C 85 65 ON THE OPTIMAL AND SUBOPTIMAL POSITION AND VELOCITY CONTROL OF A STRING OF HIGH-SPEED MOVING TRAINS	MIT	NOV 66	X						
104	R R66 55. C 85 65 OPTIMAL DISPATCHING POLICIES BY DYNAMIC PROGRAMMING	MIT	NOV 66	X						
105	C 85 65 ORGANIZATION OF SYSTEM CONTROL	MIT	NOV 66							
106	C 85 65 HEADWAY AND SWITCHING STRATEGIES FOR AUTOMATED VEHICULAR GROUND TRANSPORTATION SYSTEMS (NOT RECEIVED)	MIT	NOV 66	X						
107	MATCHING MODERN SIGNALLING TO TRAFFIC REQUIREMENTS	DEV. RY	1975	X						
108	BART'S HARDWARE FROM BOLTS TO COMPUTERS	IEEE	OCT 72	X	X					
109	MORE BART HARDWARE	IEEE	NOV 72	X	X					
110	BIGGER BUGS IN BART	IEEE	MAR 72	X						

DOCUMENT CROSS REFERENCE

DOCUMENT DESCRIPTION				APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
111	A PRESCRIPTION FOR BART	IEEE	APR 73	X						
112	DUPLICATE SAME AS #324									
113	4 BILLION FOR COMMUNICATIONS, DATA PROCESSING, AND SIGNALING	RY.SYS.CONT	APR 72	X						
114	RAILWAY SIGNALLING DEVELOPMENT	RY.EN.JOUR.	MAY 73	X		X				
115	SAFETY BOARD ASKS FRA TO WRITE RADIO RULES	RY.SYS.CONT	JUN 72	X		X				
116	RAILROAD SIGNALLING TECHNOLOGY: A NEW APPROACH	ELE. COMM.	1972	X						
117	ELECTRIFICATION HAS IMPACT ON SIGNALLING	RY.SYS.CONT	MAY 73	X			X			
118	ADVANCING TECHNOLOGY CAN AID SIGNAL DESIGN	RY.SIG.COM.	MAR 70	X						
119	LARGE-SCALE TRIAL OF AN INTEGRATED TRANSPORT CONTROL SYSTEM WITH THE GERMAN FEDERAL RAILWAY	RAIL INTER-NATIONAL	MAR 72	X						
120	NORTHEAST CORRIDOR - TASK 16, ELECTRIFICATION SYSTEMS AND STANDARDS (NOT RECEIVED)	FEDERAL RAIL ADM.	JUN 76	X			X			
121	053202 ELECTRONIC TEST INSTALLATION (VIENNA ARSENAL). TESTS MADE AT THE ELECTRONIC TEST INSTALLATION IN THE YEAR 1974/75 (FROM 1ST SEP, 1974 TO 31ST AUG, 1975) (NOT RECEIVED)	UIC	APR 76				X			
122	053228 TRANSMISSION OF INFORMATION THROUGH THE TRAIN LINE. ANALYSIS OF INTERFERENCE VOLTAGES ON INFORMATION CIRCUITS IN TRAINS (NOT RECEIVED)	UIC	OCT 76				X			
123	144081 ATC HELPS LAMCO MOVE INCREASING TRAFFIC	RAILWAY GAZETTE INT	OCT 76	X						

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
124	147832 COMPUTER-AIDED TRAFFIC CONTROL BETWEEN MAJOR RAILWAY CENTERS (NOT RECEIVED)	FRENCH NAT. RW	OCT 76	X					X	
125	DUPLICATE SAME AS #61									
126	148582 THE LATEST DEVELOPMENT IN CTC	JAPANESE RW ENG.	1976	X					X	
127	DUPLICATE SAME AS #54									
128	149438 SIGNALLING REVIEW (NOT RECEIVED)	INTERNAT'L RW JOURNAL	NOV 76	X						
129	DUPLICATE SAME AS #59									
130	150403 RADIO AND CTC WILL OPTIMIZE LINE CAPACITY	RW GAZETTE INTERNAT'L	DEC 76	X					X	
131	150406 INTERFERENCE AND ITS EFFECTS ON TRACK CIRCUITS	INST. OF RW SIG. ENG.	DEC 76				X		X	
132	THE ENVIRONMENTAL IMPACT ON ELECTRONIC EQUIPMENT	BART DIST.	APR 74	X			X		X	
133	AN INTERNATIONAL EFFORT TO DEVELOP A SMOKELESS CABLE INSTALLATION SYSTEM (NOT APPLICABLE TO TASKS)	NY TRAN. AUTHORITY								
134	TRACK SIDE TEST PROGRAM - CHOPPER CONTROLLED SUBWAY CARS (TORONTO)	TTC	APR 74				X			
135	TRACK CIRCUITS & NEGATIVE BONDING MAINTENANCE OF WAY	ATA	APR 74	X			X		X	
136	STUDY OF THE BART TRAIN CONTROL SYSTEM			X	X				X	
137	ATC AUTOMATIC TRAIN CONTROL	MT/32	JUN 77	X					X	

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
138	163787 THE SAFETY OF ELECTRONICS IN RAILROAD CONTROL SYSTEMS	FED. RR ADM.	JUL 77	X		X			X	
139	059365 ANALYSIS OF THE MORGANTOWN INDUCTIVE COMMUNICATION SYSTEM DESIGN (NOT RECEIVED)	BOEING CO.	SEP 76				X			
140	155351 VEHICLE-FOLLOWER CONTROLS FOR SHORT HEADWAY AGT SYSTEMS-FUNCTIONAL ANALYSIS AND CONCEPTUAL DESIGNS	J. HOPKINS	DEC 76	X						
141	158194 ANATOMY OF A TRAIN CRASH	MASS TRANS.	JUN 77			X				
142	053199 APPLICATION OF THYRISTORS IN RAILWAY TECHNOLOGY: CONSEQUENCES AND REMEDIES. EFFECT OF THYRISTOR CONTROLLED MOTIVE POWER UNITS ON 25 KV, 50 HZ POWER SUPPLY INSTALLATIONS OF CSD (NOT RECEIVED)	INT'L UNION OF RW	APR 76				X			
143	147701 NORTHEAST CORRIDOR HIGH SPEED RAIL PASSENGER SERVICE IMPROVEMENT PROJECT. TASK 16: ELECTRIFICATION SYSTEMS AND STANDARDS (NOT RECEIVED)	ELECTRACK INC.	DEC 76				X		X	
144	148624 CONSIDERATIONS IN THE DESIGN OF H.V. A.C. ELECTRIFICATION FOR THE SOUTH AFRICAN RAILWAYS (NOT RECEIVED)	QUAIL, JB S. AFR. RW	1974	X			X			
145	157930 ALTERNATING CURRENT FEEDING SYSTEM USING COAXIAL CABLE	JAP. RW ENG.	1976	X			X			
146	TOTAL RADIO CONTROL	WABCO	1972	X						
147	LONDON TRANSPORT			X	X				X	

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
148	SIGNALLING TECHNOLOGY FOR NEW OPERATING DEMANDS (ITALY)	IRJ	DEC 76	X		X				
149	156257 IMMUNISING DELHI MAIN INTERLOCKING READY FOR 25 KV 50 HA ELECTRIFICATION	RW GAZ. INT.	MAR 77				X			
150	156896 TELECOMMUNICATION CABLES FOR TRAIN RADIO SYSTEMS (NOT RECEIVED)	AEG TELE. PROGRESS	1976				X			
151	157539 THE "COMBINED SYSTEM": A NEW SYSTEM FOR IMPROVING THE PROBLEM OF SIGNAL REPETITION ON LOCOMOTIVES	RAIL INTER.	APR 77	X						
152	157573 RADIO SYSTEM OF THE SIHLTAL-ZURICH-UETLIBERG GERMANY (NOT RECEIVED)	BROWN BOVERI REV.	DEC 76	X						
153	157667 RESIGNALLING -- A TEAM EFFORT	BRITISH RW	MAY 77	X						
154	157699 TRACK CIRCUIT RESEARCH PROJECT BIBLIOGRAPHY (NOT RECEIVED)	ASSOC. OF AM RR TECH CEN	FEB 77	X						
155	157701 RAILROAD ACCIDENT REPORT: COLLISION OF TWO CONSOLIDATED RAILROAD CORPORATION COMMUTER TRAINS, NEW CANAAN, CONN., JULY 13, 1976	NAT'L TRANS. SAFT. BRD.	MAY 77			X				
156	159655 RAILROAD ELECTROMAGNETIC COMPATIBILITY: A SURVEY AND ASSESSMENT	ECAC	AUG 77				X			
157	159657 RAILROAD CAR PRESENCE DETECTION SYSTEM (NOT RECEIVED)	FED. RW ADM.	AUG 77	X						

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
158	163271 MICROPROCESSOR CONTROLLED RAILWAY SIGNALLING INTERLOCK (NOT RECEIVED)	IEEE	MAR 77	X						
159	163300 COMMUNICATION SYSTEM CUSTOM DESIGNED FOR THE MONTREAL METRO RAPID TRANSIT SUBWAY (NOT RECEIVED)	IEEE	MAR 77	X						
160	163774 OPTIC CABLE TRIED OUT BESIDE BUSY ELECTRIFIED LINE (BR AND GEC)	RW GAZ. INT.	SEP 77	X			X			
161	152406 QUALITY CONTROL -- RAILWAY SIGNALLING EQUIPMENT AND SYSTEMS (NOT RECEIVED)	INST. OF RW SIG. ENG.	NOV 76	X					X	
162	156462 WASHINGTON METRO AUTOMATIC TRAIN CONTROL SYSTEM (NOT RECEIVED)	SHELDON, RH WASH. METRO AREA TRAN.	1977		X					
163	152613 RADIO REMOTE CONTROL (NOT RECEIVED)	INST. OF RW SIG. ENG.	JAN 77	X						
164	152645 LONDON BRIDGE RESIGNALLING	INST. OF RW SIG. ENG.	FEB 77	X						
165	152676 THE IMPACT OF SOPHISTICATED ELECTRONICS ON SYSTEM MAINTAINABILITY (NOT RECEIVED)	GEN. RW SIG. CO.	SEP 75	X					X	
166	152677 A BASELINE AUTOMATIC TRAIN CONTROL SYSTEM INCORPORATING SYSTEM ASSURANCE CONSIDERATIONS (NOT RECEIVED)	GEN. RW SIG. CO.	--	X						

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
167	152678 FAILURE MODE AND EFFECT ANALYSIS FOR SYSTEM SAFETY ASSURANCE OF ELECTRONIC CONTROLS (NOT RECEIVED)	GEN. RW. SIG. CO.	APR 76	X			X			
168	152679 RELIABILITY ENGINEERING: ITS IMPACT ON TRANSPORTATION CONTROL SYSTEMS (NOT RECEIVED)	GEN. RW. SIG. CO.	MAY 74	X					X	
169	153800 SNCB CHOPPERS AND INTERFERENCE	BELGIAN NAT'L RW	MAR 77				X			
170	156220 TRAIN AND TRAFFIC CONTROL SYSTEMS FOR SUBWAYS (NOT RECEIVED)	HITACHI REV.	AUG 76	X						
171	156221 TRAFFIC CONTROL SYSTEMS FOR RAILWAYS (NOT RECEIVED)	HITACHI REV.	AUG 76	X						
172	156232 NEW CTC FOR HEAVY TRAFFIC RAILWAY NETWORK	RW TECHN. RESER. INST.	SEP 76	X					X	
173	(73-ICT-62) TRACK CIRCUITS FOR MODERN RAPID TRANSIT SYSTEM (NOT RECEIVED)	ASME	SEP 73	X						
174	ADVANCING TECHNOLOGY CAN AID SIGNAL DESIGN (NOT RECEIVED)	RSC	MAR 70	X						
175	095632 TELECOMMUNICATION FOR BRITISH RAIL	ELECTRONICS & POWER	MAY 74	X	X					
176	041035 TESTS MADE TO OBTAIN EXTENT OF TRACK CIRCUIT INTERFERENCE	RSC	AUG 71				X			
177	041059 HVDC TRANSMISSION MAY CAUSE INTERFERENCE TO COMMUNICATIONS CIRCUITS	RSC	DEC 70				X			

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
178	DUPLICATE SAME AS #323									
179	041001 ELECTRICAL INTERFERENCE IMPACTS ON RAILWAYS	RSC	JUN 72				X			
180	054326 MEASUREMENTS AND ANALYSIS OF 115 KV POWER LINE NOISE AND ITS EFFECT ON PUEBLO TEST SITE RADIO LINKS	FRA	MAY 72				X			
181	056798 INTERFERENCE TO TELECOMMUNICATION INSTALLATIONS BY RAPID TRANSIT SYSTEMS (W. GERMANY)	DB					X			
182	056836 RAILROADS AND ELECTROMAGNETIC COMPATIBILITY	IEEE					X			
183	046988 S&C CAN LIVE WITH 50KV, 60 HZ AC	RSC	JUL 73				X			
184	056790 ELECTROMAGNETIC COMPATIBILITY BETWEEN THYRISTOR-CHOPPER CONTROLLED CARS AND ELECTRIC FIXED INSTALLATIONS IN TOKYO SUBWAY	IEEE					X			
185	056791 ELECTROMAGNETIC COMPATIBILITY BETWEEN ELECTRIC TRACTION SYSTEM AND SIGNALLING AND TELECOMMUNICATIONS AT THE SWEDISH RAILWAYS	IEEE					X			
186	046072 SURGE PROTECTION FOR SOLID STATE RAILROAD SIGNAL EQUIPMENT (NOT RECEIVED)	RRB	JUN 71				X			
187	053865 REFINEMENTS IN SURGE PROTECTION	RSC	MAR 74				X			

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
188	IR ADAPTS SIGNALLING FOR AC TRACTION AT LOW COST	IRJ	NOV 76				X			
189	SIMPLICITY IS KEYNOTE OF LATEST SNCF SIGNALLING	IRJ	NOV 76	X						
190	SOVIET SIGNALLING IS BASED ON AUTOMATION	IRJ	NOV 76	X						
191	THE POCKET LIST OF RAILROAD OFFICIALS (BOOK) (QUARTERLY)	NAT. RR PUB. CO.	4th 77							
192	A PRACTICAL MANUAL ON THE APPRAISAL OF CAPITAL EXPENDITURE (BOOK)	SOCIETY OF MGT ACCTS OF CANADA	1971					X		
193	TOWARDS THE ALL-ELECTRIC RAILWAY	RGI	DEC 73	X						
194	ENERGY ECONOMIES THROUGH SOLID-STATE POWER CONVERSION	RGI	DEC 73	X						
195	ENERGY CONSUMPTION AT HIGH SPEEDS	RGI	DEC 73	X						
196	ELECTRIFICATION AT THE RIGHT PRICE	RGI	MAY 74					X		
197	ELECTRIFICATION GETS CHEAPER ALL THE TIME	RGI	MAY 74	X				X		
198	AUTOTRANSFORMER FEEDING ADOPTED AS STANDARD	RGI	FEB 72	X						
199	WEST GERMANY: THE PHOENIX RISES	SPECTRUM	APR 74	X						
200	RIDING SWEDEN'S SLICK RAIL SYSTEM	SPECTRUM	MAR 74	X						
201	THE MOST RECENT DEVELOPMENTS IN THE FIELD OF VERY HIGH SPEEDS IN FRANCE-ELECTRIC TRACTION AND TURBOTRAINS	SCNF	1973	X					X	
202	SYMPOSIUM ON DEVELOPMENTS IN ELECTRIC TRACTION (BOOK)	GEC	1976				X			

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
203	THE ARCHITECTURE OF COMMAND AND CONTROL SYSTEMS FOR MODERN RAPID TRANS	GRS		X					X	
204	SYSTEMS PARAMETERS AND THEIR EFFECT ON AUTOMATIC TRAIN CONTROL	DELEUW-CATHER		X					X	
205	OCCUPANCY DETECTION TECHNIQUES FOR TRANSIT SYSTEMS	WESTINGHOUSE		X					X	
206	DESIGNING TOTAL RADIO CONTROL IN RAILROAD COMMUNICATIONS SYSTEMS	TELECOM	OCT 73	X					X	
207	NEW DIMENSIONS IN CTC	PROG RR	SEP 74	X					X	
208	NEWLY DEVELOPED THYRISTER CHOPPER EQUIPMENT FOR ELECTRIC RAILCARS	IEEE	MAY 73				X			
209	AN AUTOMATIC TRAIN CONTROL SYSTEM	WESTINGHOUSE	1965	X					X	
210	ADAPTIVE CONTROL IN TRANSPORTATION	DOT	1974	X					X	
211	AUTOMATIC CONTROL SYSTEM TRADE-OFF STUDY	GRS	1971	X					X	
212	HIGH-SPEED RAIL: PROBLEMS AND PROSPECTS	DOT	1968	X						
213	SURVEY OF ELECTRONIC COMMAND & CONTROL SYSTEMS	DOT (GE)	1967	X					X	
214	CAN COMMUNICATIONS KEEP PACE?	PROG. RR	DEC 77	X						
215	THE NEXT BIG STEP: COMPUTER TO COMPUTER EXCHANGE	PROG. RR	DEC 77	X					X	
216	INTERFERENCE OF ELECTRIFICATION WITH SIGNALING AND COMMUNICATION SYSTEM	GRS	JUN 77				X			
217	HIGH SPEED APT FOR EXISTING ROUTES & THE ADVANCED PASSENGER TRAIN	RY. ENGR.	MAR 77	X						
218	ELECTRICAL SYSTEMS ON THE PROTOTYPE APT	RGI (TKD)	AUG 77	X					X	

DOCUMENT CROSS REFERENCE

DOCUMENT DESCRIPTION				APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
219	SIGNALLING FOR HIGH SPEED	MOD. RYS.	-	X					X	
220	RE-ACCELERATED EAST COAST SERVICE PAVES THE WAY FOR HST	MOD. RYS.	MAR 77	X					X	
221	BR ENTERS FINAL PHASE ON EAST-COAST SPEED-UP SCHEME	IRJ	JUL 77	X						
222	CAB DISPLAY OF APT'S PERMISSIBLE SPEED	RGI	NOV 77	X					X	
223	ROLE OF THE SIGNAL ENGINEER	RY. ENGR.	JAN 77			X			X	
224	ENGINEERING A 200 km/h LINE	RY. ENGR.	SEP 76	X						
225	THE ADVANCED PASSENGER TRAIN	MOD. RYS.	FEB 77	X						
226	DIRETTISSIMA: FIRST STAGE IS READY (ITALY)	IRJ	DEC 76	X						
227	FIRST SECTION OF DIRETTISSIMA IN USE	MOD. RYS.	-	X						
228	MADRID - BARCELONA STANDARD GAUGE LINE WILL BE DESIGNED FOR 300 km/h	RGI	FEB 77	X						
229	DUPLICATE SAME AS #148									
230	ITALIAN STATE RAILWAYS TODAY: 2	MOD. RYS.	-	X	X					
231	THE PARIS INTERCONNECTION	MOD. RYS.	MAY 77	X						

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
232	CURRENT COLLECTION WITH TWO-STAGE PANTOGRAPHS ON THE NEW PARIS LYON LINE	RGI	OCT 77	X						
233	CONTROLLING THE WORLD'S BUSIEST INTERCHANGE: CHALET-LES HALLES	RGI	NOV 77	X						
234	COMPLEX CIVIL WORKS CREATE EXPRESS METRO IN PARIS	RGI	OCT 77	X						
235	SNCF LEADS THE WAY TOWARDS THE INTEGRATION OF EUROPEAN RAIL COMPUTER SYSTEMS	MOD. RYS.	DEC 76	X					X	
236	POLITICAL CLIMATE IS RIGHT FOR BRIGHTER DB FUTURE	IRJ	AUG 77	X						
237	STRIVING FOR A RATIONAL RAIL OPERATION	IRJ	AUG 77	X				X		
238	PLANNING FOR INCREASED TRACK CAPACITY	IRJ	AUG 77	X						
239	RAILWAY TRANSPORT 77 ATTRACTS THE WORLD'S INDUSTRY (RUSSIA)	RGI	JUL 77	X						
240	NEW LINES TO MATCH ECONOMIC EXPANSION (RUSSIA)	IRJ	JUL 77	X						
241	DESIGNING MORE POWERFUL EQUIPMENT (RUSSIA)	IRJ	JUL 77	X						
242	NEW LINES WILL BE ELECTRIFIED TO GIVE HIGH TRACK CAPACITY (RUSSIA)	IRJ	JUL 77	X						
243	RUSSIAN TROIKA ENTERS SERVICE THIS YEAR	RGI	JUL 77	X						
244	DUPLICATE SAME AS #169									
245	PERMANENT WAY: RAILWAYS RESEARCH SLAB TRACK	IRJ	MAR 77	X				X		
246	ROME - FLORENCE HIGH-SPEED RAILWAY	RY. ENGR.	1977	X						

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
247	TILTING TRAIN WINS PRAISE FROM PUBLIC AND OPERATORS	IRJ	DEC 77	X						
248	LIVING WITH THE THYRISTOR	MOD. RYS.	JUL 76				X			
249	TRACK MAINTENANCE FOR HIGH SPEED	MOD. RYS.	OCT 76	X						
250	A WELCOME TO SHCHERBINKA (RUSSIA)	RGI	JUL 77	X						
251	SIGNALLING - - - WITHOUT POLE LINES?	PROG. R.R.	JAN 78	X		X				
252	OPTICAL-FIBER TRANSMISSION IN RAILROAD FUTURE?	PROG. R.R.	JAN 78				X			
253	GERMANY AUTOMATES ITS RAILS	IEEE	JUL 74	X					X	
254	ELECTRONICS AND SWISS RAILWAYS	IEEE	SEP 74	X					X	
255	AN INTEGRAL PART (COMPUTERIZATION)	MR	DEC 77	X					X	
256	DUPLICATE SAME AS #187									
257	FIXING BART	IEEE SPEC.	FEB 75	X						
258	FOR CTC --- "AN EXTREMELY REVOLUTIONARY PERIOD"	PROG. R.R.	FEB 78	X					X	
259	STATUS OF AGT DEVELOPMENT IN FEDERAL REPUBLIC OF GERMANY	---	---	X						
260	FOR THE SP - COMPUTER-BASED CTC	TRW CONT.	MAY 75	X	X				X	
261	NEW DEVELOPMENTS IN THE FIELD OF COMMUNICATION SYSTEMS PROTECTION ON ELECTRIFIED RAILROADS (TRANSLATED FROM RUSSIAN)	USSR	1972				X			
262	25 CPS PHASE SENSITIVE TRACK CIRCUITS (TRANSLATED FROM RUSSIAN)	USSR	1972	X			X			

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
263	RULES FOR THE PROTECTION OF WIRE COMMUNICATIONS SYSTEMS FROM THE INFLUENCE OF AC TRACTION LINES (TRANSLATED FROM RUSSIAN)	USSR	1973				X			
264	HANDBOOK FOR SIGNALLING ON SOVIET RAILROADS (TRANSLATED FROM RUSSIAN)	USSR	1972			X				
265	REED RELAYS IN REMOVE CONTROL EQUIPMENT (TRANSLATED FROM RUSSIAN)	USSR	1975	X						
266	PRINCIPLES FOR THE DESIGN OF CIRCUITS FOR SIGNAL BOXES OPERATED BY MEANS OF STATIC ELEMENT MODULES (TRANSLATED FROM RUSSIAN)	USSR	1976	X						
267	A CENTRALIZED TRAFFIC CONTROL SYSTEM (TRANSLATED FROM RUSSIAN)	USSR	1975	X					X	
268	FS "DIRETTISSIMA" HIGH SPEED LINE SIGNALLED FOR 250 km/h	RY. ENGR.	1978	X						
269	TRAIN AND TRAFFIC CONTROL SYSTEMS FOR SUBWAYS	HITACHI REV	1976	X						
270	RECENT RAILWAY AUTOMATION SYSTEMS	HITACHI REV	1978	X					X	
271	MAINTAINING ALERTNESS IN RAILROAD LOCOMOTIVE CREWS	FRA	MAR 77			X				
272	THE FIRE IS UNDER CONTROL	RY AGE	MAR 74					X		
273	PROPAGATION OF VIBRATIONS AND STRUCTURE - BORNE SOUND CAUSED BY TRAINS RUNNING AT A MAXIMUM SPEED	JOUR. OF SOUND & VIBRATION	1977				X			
274	EXAMPLES OF SIGNALS AND NOISE IN THE RADIO-FREQUENCY SPECTRUM	IEEE	AUG 77				X			
275	MBTA RAPID TRANSIT SYSTEM WAYSIDE AND IN-CAR NOISE AND VIBRATION LEVEL MEASUREMENTS	TRANS. SYS. CENTER CAMBRIDGE, MASS.	AUG 72				X			

DOCUMENT CROSS REFERENCE

No.	DOCUMENT DESCRIPTION: Title	Source	Date	APPLICABLE TASK: 1	2	3	4	5	6	7
276	SIGNAL SPACING ANALYSIS (SIGANAL) DOT-FR-76048	FRA	DEC 77			X				
277	AN EVALUATION OF RAILROAD SAFETY (ONE COPY ONLY)	OTA	MAY 78			X				
278	OPERATING COSTS OF RAIL RAPID TRANSIT (UMTA-NY-11-0009-74-2)	UMTA	MAY 74					X		
279	CAPITAL STOCK MEASURES FOR TRANSPORTATION, VOL. 3, (DOT-OS-10195) PROJECTIONS FOR INVESTMENT NEEDS	DOT	FEB 73					X		
280	SPECIFICATIONS FOR MBTA CONTRACT NO. 068-107, SIGNAL AND COMMUNICATION SYSTEM BOSTON, QUINCY AND BRAINTREE, MASS. (BOOK)	UMTA NO. MA-23-9001	NOV 77						X	
281	THE STANDARD CODE OF OPERATING RULES (JAN. 1965) A.A.R. WITH RULE CHANGES	AAR	1965			X				
282	COMPATIBILITY OF SIGNALLING WITH AC PHASE CONTROLLED MOTIVE POWER (WABCO) 1978 JOINT ASME & IEEE RAILROAD CONFERENCE, APRIL 12, 1978 (ONE COPY ONLY)	WABCO	1978				X			
283	FUNCTIONAL SPECIFICATION OF THE CENTRAL CONTROL SOFTWARE, LIC PROTOTYPE SYSTEM	BRITISH COLUMBIA RAILWAY	NOV 76						X	
284	C.I.S.P.R. PUBLICATION 7 THROUGH PUBLICATION 16 (ONE SET ONLY)	INT. ELEC. COMM.	1969-1977				X			
285	ELECTRICAL NOISE: GET IT OUT OF THE SIGNAL PLANT	RSC	APR 75				X			
286	TRACK CIRCUIT SHUNTING TESTED ON ELECTRIFIED SUBURBAN LINE	RSC	APR 70				X			
287	CONTINGENCIES IN THE DESIGN OF THE AUDIO TRACK CIRCUIT	REI	MAY 74				X			

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
288	HULL GENERATED INTERMODULATION INTERFERENCE REDUCTION TECHNIQUES FOR FORCES AFLOAT (NAVALEX 0967-LP-266-1010)	USN	OCT 71				X			
289	ELECTROMAGNETIC COMPATIBILITY AND INTERFERENCE CONTROL FOR RAPID TRANSIT VEHICLES, ARP 1393 (SAE RECOMMENDED PRACTICE)	SAE	MAY 76				X			
290	VANDALISM SUPPRESSION BY HELICOPTER	FRA	JAN 73					X		
291	RADIO FREQUENCY EMISSION CHARACTERISTICS AND MEASUREMENT PROCEDURES OF INCIDENTAL RADIATION DEVICES AND INDUSTRIAL, SCIENTIFIC AND MEDICAL EQUIPMENT (REPORT NO. FAA-RD-72-80, 1)	FAA	SEP 72				X			
292	APPLICATIONS OF THYRISTORS IN RAILWAY TECHNOLOGY: CONSEQUENCES AND REMEDIES 1. TESTS TO COMPARE THYRISTOR-CONTROLLED TRACTIVE UNITS FOR 16-2/3 Hz ON THE SAME TEST TRACK (REPORT ORE A 122/RP 4) 2. ADDITION OF PSOPHOMETRICALLY WEIGHTED INTERFERING CURRENTS PRODUCED BY SEVERAL THYRISTOR-CONTROLLED A. C. TRACTIVE UNITS (REPORT ORE A 122/RP 5)	RAIL INT.	FEB 73				X			
293	SIGNALLING AND COMMUNICATIONS FOR KOREA'S FIRST ELECTRIFIED LINES	RGI	DEC 73				X			
294	ELECTRO-MAGNETIC COMPATIBILITY DESIGN FOR RAPID TRANSIT SYSTEMS (EMC SYMPOSIUM)	IEEE	1973				X			
295	THE AUTOMATIC DIGITAL COMPUTER CONTROL OF VEHICLES IN RAPID TRANSIT SYSTEMS FOR URBAN TRANSPORTATION (PROC. IME, VOL. 184, PT. 3S)	IME LONDON	AUG 70	X					X	
296	POWER ELECTRONICS IN A. C. AND D. C. TRACTION SYSTEMS (GEC JOURNAL OF SCIENCE & TECHNOLOGY, VOL. 40, NO. 4, 1973)	GEC	APR 73				X			

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
297	STUDY OF TRANSIENT VOLTAGES IN TRANSIT SYSTEMS	IEEE	AUG 75				X			
298	SIGNALLING AND TELECOMMUNICATIONS WORKS ON THE EUSTON MAIN LINE ELECTRIFICATION (PROC. IME, VOL. 181, PT 3F)	IME LONDON	JUN 66	X			X			
299	SUMMARY REPORT ON VANDALISM AND PASSENGER SECURITY IN THE TRANSIT INDUSTRY (TRANSPORTATION RESEARCH RECORD NO. 487, 1974)	ATA	1974					X		
300	SCOPE OF CRIME AND VANDALISM ON URBAN TRANSIT SYSTEMS (TRANSPORTATION RESEARCH RECORD NO. 487, 1974)	ATA	1974					X		
301	AUTOMATION AND CONTROL IN TRANSPORT F. T. BARWELL (BOOK)	PERGAMON PRESS	1973	X					X	
302	SIMPLIFIED EQUATION FOR THE SHIELDING FACTOR OF MULTIPLE SHIELDING CONDUCTORS	EE IN JAPAN V. 96, No.2	1976				X			
303	PRINCIPLES AND PRACTICES FOR INDUCTIVE COORDINATION OF ELECTRIC SUPPLY AND RAILROAD COMM/SIGNAL SYSTEMS (ONE COPY ONLY)	AAR/EEI	SEP 77				X			
304	AFSCM DH 1-4 ELECTROMAGNETIC COMPATIBILITY (ONE COPY ONLY)	USAF	JAN 77				X			
305	GE 4/4 II THYRISTOR LOCOMOTIVES NOs. 611 TO 620 OF RHAETIAN RAILWAYS	BROWN BOVER REVIEW	DEC 73				X			
306	HUMAN FACTORS IN SIGNALLING SYSTEMS M. MASHOUR (BOOK)	JOHN WILEY & SONS	1974			X				
307	OPTICAL AUTOMATIC CAR IDENTIFICATION (OACI) VOL. IV - SYSTEM ALTERNATIVES EVALUATION MODEL (FRA/ORD -78/15. IV)	FRA	MAY 78							
308	INDUCTIVE INTERFERENCE MEASUREMENTS	GEN. CABLE CORP.	AUG 73				X			

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
309	TREATMENT OF INFLATION IN ENGINEERING ECONOMICS ANALYSIS	IEEE	MAY 76					X		
310	L&D PREVENTION IS WORKING	PROG. RR	OCT 78					X		
311	1.29 AND COUNTING (L&D)	PROG. RR	OCT 78					X		
312	ENGINEERING TESTS FOR ENERGY STORAGE CARS AT THE TRANSPORTATION TEST CENTER. VOLUME II. PERFORMANCE POWER CONSUMPTION AND RADIO FREQUENCY INTERFERENCE TESTS.	UMTA	MAY 77				X			
313	SIGNALS PLUS (COMPUTERIZATION)	MOD. RR	SEP 78	X					X	
314	WHEN THEY SWITCH POWER IN THE NEC, WHICH TRAINS WILL SHOW UP?	MOD. RR	SEP 78							
315	THE SIGNALS OF THE GERMAN RAILROADS (BOOK - TRANSLATED FROM GERMAN)	ALBA BUCHVERLAG DUSSELDORF	1974			X				
316	FRA WILL WORK WITH RAILROADS	RSC	AUG 69			X				
317	WAYSIDE CONTROLS ARE DIFFERENT	RSC	AUG 69		X					
318	AUTOMATIC TRAIN STOPPING HAS BEEN DEVELOPED FOR RAPID TRANSIT	RSC	MAY 70		X					
319	BART CONTROLS "DRY RUN" TESTED	RSC	MAY 70		X					
320	ELECTRIC RUNNING HAS 60 Hz CURRENT	RSC	MAY 70				X			
321	ELECTRIFIED LINES CAN USE PMC SIGNALLING	RSC	NOV 70				X			
322	INDUCTIVE CIRCUIT WORKS AT CROSSINGS	RSC	MAR 72		X					
323	DUPLICATE SAME AS #178									

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
324	ALL ABOUT SIGNALS JOHN ARMSTRONG	TRAINS	1957			X				
325	AUTOMATIC TRAIN CONTROL SYSTEMS ARE FEASIBLE AND COST EFFECTIVE	RSC	JUL 72	X	X					
326	LATEST SIGNAL TECHNIQUES LET RAILROADS DECREASE JOINT USAGE	RSC	JUL 72					X		
327	WASHINGTON SUBWAY AUTOMATES	RSC	AUG 72	X	X					
328	TRACK CIRCUIT IS 100 YEARS OLD	RSC	AUG 72	X						
329	CTC HAS COMPUTER CONTROLS (GRS TRAFFIC MASTER II)	RSC	SEP 72		X					
330	COMMUNICATIONS VITAL TO CTC (GTE LENKURT)	RSC	DEC 72		X				X	
331	PROBLEM: INDUCTIVE INTERFERENCE - SOLUTION: BURY CABLES	RSC	DEC 72				X			
332	BN BURIES 5 CONTROL CABLES	RSC	DEC 72				X			
333	ELECTRIFYING COULD SAVE MONEY	RSC	MAY 73					X		
334	ELECTRIFICATION HAS IMPACT ON SIGNALLING	RSC	MAY 73				X			
335	RELIABILITY ENGINEERING: IMPACT ON TRANSPORTATION CONTROL SYSTEMS	RSC	JUL/AUG74					X		
336	RAILROADING 1980 - FUTURE TRENDS IN COMMUNICATIONS & SIGNALLING	RSC	NOV/DEC74	X					X	
337	RENFE INTRODUCES CAB SIGNALLING (WABCO)	RSC	JAN 75	X					X	
338	IMPLICATIONS OF MODERN TRANSIT SIGNALLING CONCEPTS FOR MAINLINE RAILROAD OPERATION	RSC	JAN 75	X					X	
339	MOPAC GIVES A NEW FACE TO CTC	RSC	APR 75		X				X	
340	NORTHERN C&S MEETING: NEW SOLUTIONS FOR LONG-TERM PROBLEMS	RSC	MAY 75	X						

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
341	PITTSBURG CONSOLIDATION: PHASE I NEARS COMPLETION (PENN CENTRAL)	RSC	JUL/AUG75	X						
342	MODERN RAILROAD STATUS REPORT: ELECTRIFICATION	MOD. RR	JUN 78							
343	PROCEDURES FOR ANALYZING THE ECONOMIC COSTS OF RAILROAD ROADWAY FOR PRICING PURPOSES - VOLUME I - PROCEDURES (ONE COPY ONLY)	FRA	JAN 76					X		
344	IMPACT OF RESEARCH AND DEVELOPMENT ON RAILROAD ELECTRIFICATION	DOT	1978					X		
345	REPORT ON THE VISIT TO THE U.S.S.R. BY THE U.S. ELECTRIFICATION DELEGATION (1975) (ONE COPY ONLY)	FRA	1975	X			X	X		
346	RESIGNALLING ON THE SCOTTISH SECTION OF THE WEST COAST MAIN LINE	IRSE	MAR 74	X			X			
347	THE DEVELOPMENT OF TRAIN DESCRIBER - BASED FACILITIES ON THE SOUTHERN REGION	IRSE	FEB 74	X					X	
348	MODERN DEVELOPMENTS IN GEOGRAPHICAL CIRCUITRY TECHNIQUES	IRSE	NOV 74	X					X	
349	VICTORIA LINE SIGNALLING PRINCIPLES	IRSE	NOV 66	X						
350	DEFINING A SIGNAL CONTROL AREA	IRSE	OCT 72	X					X	
351	THE AUTOMATIC TRAIN CONTROL SYSTEM FOR HIGH SPEED TRAINS ON THE DEUTSCHE BUNDESBAHN	IRSE	DEC 66	X	X				X	
352	SOLID-STATE AUTOMATIC BLOCK SIGNALLING ON THE ITALIAN STATE RAILWAYS	IRSE	OCT 73	X	X				X	
353	TURBOTRAIN TESTS PROVIDE DATA FOR 260 km/h OPERATIONS	RGI	SEP 73	X						
354	YOUR DEPARTMENT: COMMUNICATIONS - TELECOMMUNICATIONS	PROG. RR	MAY 78	X						
355	RAILROAD SAFETY IN PERSPECTIVE	PROG. RR	MAY 78			X				

DOCUMENT CROSS REFERENCE

DOCUMENT DESCRIPTION				APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
356	D&RGW CONSOLIDATES CTC	PROG. RR	MAY 78	X					X	
357	ADVANCED COMMUNICATIONS FOR SCL OPERATIONS CONTROL	PROG. RR	MAY 78	X						
358	SCL DEVELOPS PUSHBUTTON RADIO	PROG. RR	MAY 78	X						
359	RAILROAD ACCOUNTING (224p. - 1 COPY ONLY)	DOT	MAY 77					X		
360	AN EVALUATION OF RAILROAD SAFETY (216p. - 1 COPY ONLY)	OTA	MAY 78			X				
361	NORTHEAST CORRIDOR - TASK 18 SUPPORT SERVICES: ENGINEERING, ECONOMICS AND COST ESTIMATING (456p. - 1 COPY ONLY)	FRA	JUL 76					X		
362	CFR 49 - TRANSPORTATION PARTS 200 TO 999 (CODE OF FEDERAL REGULATIONS) (ONE COPY ONLY)	FED. RGSTR.	JUL 77			X				
363	THE MAGIC OF THE COMPUTER AND TELECOMMUNICATIONS	PROG. RR	DEC 78						X	
364	A NEW WAY TO MEASURE PERFORMANCE	RY. AGE	NOV 78					X		
365	COMPUTER CONTROLLED DISPATCHING SYSTEMS	IEEE	AUG 78						X	
366	NEW ELECTRIC LOCOMOTIVES FOR THE TAIWAN RAILWAY ADMINISTRATION	IEEE	AUG 78							
367	BATTERY - POWERED TRAINS CRISSCROSS GERMANY	PROG. RR	MAR 75							
368	HIGH-SPEED TRAINSETS READY FOR THE 1980's	RGI	DEC 78						X	
369	ELECTRIC TGV's SPOTLIGHT FRENCH LEAD IN HIGH-SPEED TECHNOLOGY	RGI	DEC 78						X	
370	WHEEL-ON-RAIL RESEARCH IN WEST GERMANY	RGI	DEC 78							

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
371	NEW SIGNAL ASPECTS FOR THE GERMAN RAILROADS	SIGNAL + DRAHT, VOL. 67, No. 7/8	1975			X				
372	VHF COMMUNICATIONS USAGE BY U. S. RAILROADS (263p. - ONE COPY ONLY)	FRA	1977				X			
373	RF NOISE RADIATED BY A RAPID TRANSIT SYSTEM (74CHO 803-7EMC)	IEEE	JUL 74				X			
374	OPERATING CONTROL CENTERS ON THE DB	RAIL INT.	JAN 78						X	
375	THE PRICE OF SAFETY	IME	JAN 77			X				
376	AN OPTIMAL DECISION RULE FOR REPAIR vs REPLACEMENT	IEEE	AUG 77					X		
377	IMPROVED PASSENGER SERVICE FOR THREE CORRIDORS	FRA	APR 73					X		
378	ECONOMETRIC ANALYSIS AND FORECASTS OF INTERCITY RAIL PASSENGER DEMAND ON SELECTED AMTRAK CORRIDORS: A CASE STUDY	DOT	DEC 78					X		
379	ELECTRIFICATION OF YUGOSLAV RAILWAYS	TRB	JAN 79							
380	REDIRECTION AND COORDINATION OF THE NORTHEAST CORRIDOR PROJECT	TRB	JAN 79							
381	NORTHEAST CORRIDOR IMPROVEMENT PROJECT: LONG TERM IMPLICATIONS	TRB	JAN 79						X	
382	SCR DRIVES - AC LINE DISTURBANCE, ISOLATION, & SHORT CIRCUIT PROTECTION						X			
383	REAR END COLLISION OF THREE MBTA TRAINS, BOSTON, MASSACHUSETTS, AUGUST, 1975 (PB-253-360)	NTSB	APR 76			X				
384	PROCEED, PREPARED TO STOP - THE ABC's OF PROTOTYPE SIGNALLING BY GORDON ODEGARD (ONE COPY ONLY)	MODEL RR	SEP 76			X				

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
385	THE COMPENDIUM OF SIGNALS - BY ROGER F. R. KARL (BOOK - 1 COPY ONLY)	BOYNTON & ASSOC.	1971			X				
386	A PROSPECTUS FOR CHANGE IN THE FREIGHT RAILROAD INDUSTRY (ONE COPY ONLY)	DOT	OCT 78					X		
387	A GREEN LIGHT FOR ADVANCED TRAIN CONTROL	IEEE SPECTRUM	FEB 79						X	
388	IMPLEMENTING AN ELECTRIFICATION PROGRAM: THE NEC IMPROVEMENT PROGRAM - A PROGRESS REPORT	TRB	JAN 79						X	
389	COUNTERMEASURES AGAINST INDUCTIVE INTERFERENCES GENERATED BY 60 Hz AC ELECTRIFICATION	JNR	SEP 78				X			
390	RAILROAD ELECTROMAGNETIC COMPATIBILITY - VOLUME I - ELECTRIFICATION BIBLIOGRAPHY	ECAC	MAR 78				X			
391	PROPOSED SIGNAL SYSTEM FOR THE NORTHEAST CORRIDOR	DE LEUW CATHER/ PARSONS	FEB 79			X				
392	RIGHTS OF TRAINS BY PETER JOSSEAND (BOOK - ONE COPY ONLY)	SIMMONS-BONDMAN	1957			X				
393	IMPROVED PASSENGER TRAIN SERVICE (TRANSPORTATION RESEARCH INST., CARNEGIE-MELLON UNIVERSITY)	TRI	1976						X	
394	EVALUATION OF SIGNAL/CONTROL SYSTEM EQUIPMENT AND TECHNOLOGY. TASK 1 - ASSESSMENT OF SIGNAL/CONTROL TECHNOLOGY AND LITERATURE REVIEW	FRA	DEC 78	X						
395	EVALUATION OF SIGNAL/CONTROL SYSTEM EQUIPMENT AND TECHNOLOGY. TASK 2 - STATUS OF PRESENT SIGNAL/CONTROL EQUIPMENT	FRA	JAN 79							

DOCUMENT CROSS REFERENCE

	DOCUMENT DESCRIPTION			APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
396	PRACTICAL ELECTRONIC PROJECTS FOR MODEL RAILROADERS BY PETER J. THORNE (ONE COPY ONLY)	KALMBACK	1974			X				
397	MOTOR SECTION CAR SIGNAL SYSTEM	MODEL RAILROADER	OCT 70			X				
398	VANDALS CREATE "COMBAT ZONE" FOR RAILROADERS, A FEDERAL CRIME?	MOD. RR	MAR 79					X		
399	NORTHEAST CORRIDOR IMPROVEMENT PROJECT TASK 206: COMMUNICATION SYSTEM DEVELOPMENT (FRA/NECPO-78/4)	FRA	NOV 78				X			
400	AN ANALYSIS OF AMTRAK'S FIVE YEAR PLAN	GAO	MAR 78					X		
401	AAR/IEEE/AREA RR EMC WORKING GROUP - MINUTES OF MEETING MARCH 7, 1979	SANDERS/ THOMAS	APR 79				X			
402	TRANSCRIBED PROCEEDINGS FRA GENERAL SAFETY INQUIRY PUBLIC HEARING ON SIGNAL AND TRAIN CONTROL REGULATIONS AND ORDERS DOCKET NO. RSSI-78-5 NOTICE NO. 6	FRA	JUL 79			X				
403	EVALUATION OF SIGNAL/CONTROL SYSTEM EQUIPMENT AND TECHNOLOGY TASK 3 - STANDARDIZATION, SIGNAL TYPES, TITLES	FRA	JUL 79			X				
404	EXAMPLES OF SIGNALS AND NOISE IN THE RADIO FREQUENCY SPECTRUM	IEEE	JUN 77							
405	UNION PACIFIC FIRST TO USE OPTICAL FIBERS	PRO. RR	JAN 79				X			
406	INTERFERENCE SUSCEPTIBILITY OF THE SIGNALING SYSTEM PART I CAB SIGNALING	WABCO	JUN 79						X	
407	AMTRAK - FIVE YEAR CORPORATE PLAN FISCAL YEARS 1978 - 1982	NRPC	OCT 77					X		

DOCUMENT CROSS REFERENCE										
DOCUMENT DESCRIPTION				APPLICABLE TASK						
	Title	Source	Date	1	2	3	4	5	6	7
408	A REEXAMINATION OF THE AMTRAK ROUTE STRUCTURE	US DEPT OF TRANS.	MAY 78					X		
409	EVALUATION REPORT OF THE SECRETARY OF TRANSPORTATION'S PRELIMINARY RECOMMENDATIONS OF AMTRAKS ROUTE STRUCTURE	INTERSTATE COMMERCE COMMISSION	SEP 78					X		
410	NOISE DISTURBANCE (FINAL REPORT) EVALUATION OF SIGNAL/CONTROL SYSTEM EQUIPMENT AND TECHNOLOGY, TASK 4 - ELECTRICAL	FRA	JUL 79				X			
411	TASK 5 - ECONOMIC STUDIES (FINAL REPORT)	FRA	JUL 79					X		
412	TASK 6 - SPECIFICATION DEVELOPMENT (FINAL REPORT)	FRA	AUG 79						X	
413	WE WANT THE JOB DONE RIGHT (A "PARED DOWN" AMTRAK)	PRO. RR	MAR 79							