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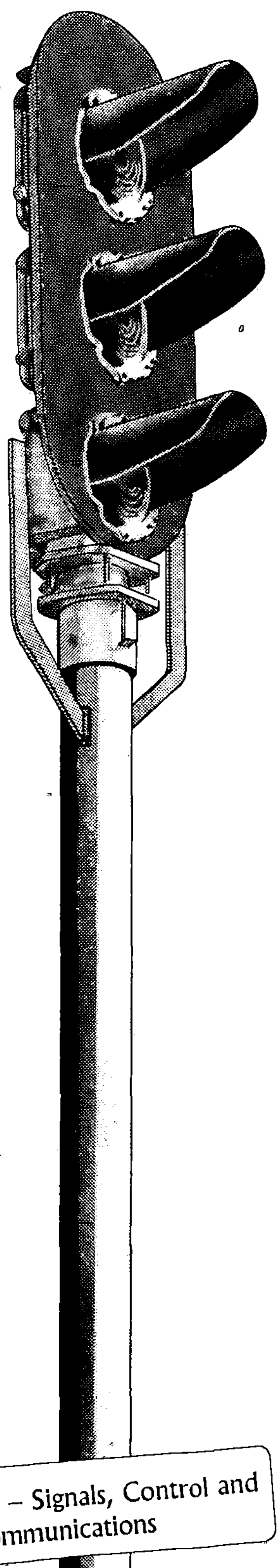
Evaluation of Signal/Control System Equipment and Technology



TASK 3
Standardization, Signal Types, Titles

DECEMBER 1979

FINAL REPORT

Prepared for

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16. Abstract

This report analyzes and summarizes current signal types and associated aspects, titles and indications employed by U. S. Railroads over which Amtrak operates as well as by several foreign railroads. A review of the historical development of signal technology is presented. The report concludes with recommended standards for signal types, aspects, titles and indications.

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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".

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

The study contract includes the following seven (7) 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 of major domestic and foreign railroad signaling systems now in use; discussion of candidate systems for adoption by Amtrak; recommendations for further activity.

Task 3 - "Standardization, Signal Types, 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 contain 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, costs 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 3 - "Standardization, Signal Types, Titles". This task was accomplished through a review of technical reports and papers both domestic and foreign; a review of data taken during on-site visits to domestic and foreign railroad and transit systems; and interviews with technical and managerial personnel associated with railroads, transit systems, manufacturers, government agencies, and engineering associations.

The authors wish to acknowledge with appreciation, the efforts and cooperation given by the many individuals in governments, railroads, transit systems, signal manufacturers,

universities, trade associations, the signal industry, 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. This report does not constitute a standard, specification or regulation.

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SECTION 1.0

INTRODUCTION

This task report presents the results of Task 3 of the DOT contract DOT-FR-773-4236, entitled "Evaluation and Assessment of Signal/Control Equipment and Technology". The Task 1 Final Report, Document Reference 394, Appendix A, assesses the specific technologies available for use in the design of signal/control systems, and Task 2 Final Report, Document Reference 395, Appendix A, the status of present signal/control systems. This report provides a description and assessment of signal aspects, titles and indications along with operating standards and regulations.

1.1 Purpose and Scope

The purpose of this report is to relate the status of present equipment, systems and standards used on passenger train routes throughout the world; to compare the advantages and disadvantages of selected domestic and foreign signal/control systems; and to recommend a standard set of rules, aspects, titles and indications. A review of signaling on the routes over which Amtrak operates was made in order to avoid a recommendation of a final signal system that would be incompatible with existing signal systems or future electrification.

1.2 Procedure

As in Tasks 1 and 2, the 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 1973 to 1977. Since these bulletins are issued biannually, a separate search was conducted by RRIS to identify documents released early in the calendar year 1978. Other sources of data were also identified and utilized such as the National Technical Information Service (NTIS), and various public, private, and university libraries. The technical publications were received from several sources with the principal contributors being the Northwestern University Transportation Center Library and the International Union of Railways (UIC), Office of Research and Experiment (ORE) Library. Over 400 documents were accumulated and reviewed in the conduct of the overall program. Additionally, 14 transportation periodicals subscribed to were reviewed continuously to obtain current technical data.

Based on these data, detailed questionnaires were developed and sent to railroads on which Amtrak operates, transit properties, and suppliers to obtain specific information for each signal system. Responses were obtained from the domestic railroads, several European rail systems, the transit properties and suppliers. Based on these responses, survey trips were made to obtain additional data and to physically inspect the systems. In the U.S., the Chicago Transit Authority and the Bay Area Rapid Transit system in San Francisco were surveyed. Railroads on which Amtrak operates were included in the U.S. portion of the railroad survey which included visits to the Union Pacific, Chessie System, Burlington Northern and Southern Pacific railroads. 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). Also, the British Columbia Railway (BC) in Canada was visited. The U.S. suppliers surveyed included 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 Thomson-Ramo-Woldridge (TRW.) 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.

1.3 Background

Present day signal/control systems vary in complexity from fixed signs, written train orders, to the more sophisticated computer aided Traffic Control Systems (TCS).

Since the major differences between signaling and control systems implemented in the U.S. and Europe are due, in large part, to the design philosophy involved, it is important that the reader have knowledge of the philosophical background involved.

In the United States, railroad signal and control systems began to evolve in the last decade of the 19th century. Each railroad worked with the existing suppliers to improve operational safety and efficiency through the use of innovative designs. As a result of this relatively uncontrolled development, a somewhat chaotic evolution took place during the period from 1900 to about 1930. As early as 1906, steps were being taken to introduce Federal regulation, but real controls were not established until the 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 these equipments.

During this period an organization evolved within the railroad industry which fostered a cooperative effort in signal technology. Initially a coalition of railroad signal engineers, it was subsequently expanded to include supplier representation. This organization, known today as the Communication and Signal (C&S) Section of the Association of American Railroads (AAR), was largely responsible for preparation of current standards for design, installation and maintenance. In 1922 the ICC, after conducting hearings on the subject, ordered 40 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. Given this impetus, suppliers and railroads developed both continuous and intermittent cab signaling systems. Continuous ac track circuits using code rates of 75, 120 and 180 pulses per minute had become the most common cab signaling system prior to World War II.

The Signal Inspection Act of 1937 gave the ICC additional authority to control these systems. The constraints of cab signaling, train control or train stops were made mandatory (ICC Order 29543) for operation above 130 km/h (80 MPH) and required for all trains running in cab signal, train control or train stop territory. After World War II the character of railroad operations changed dramatically. The impact of the increased availability of automobiles and improved highways resulted in a decreased demand for passenger railroad service. This trend was accelerated by the rapid development of air transportation and cross-country bus systems. Meanwhile the railroads, faced with ever mounting maintenance costs, concentrated on freight traffic with fewer but much longer and heavier tonnage trains. One result of this activity was a decrease in train speeds, and since train stops, train control or cab signaling were not required below 130 km/h (80 MPH) most automatic equipment was removed. The end result is that, while there has been limited introduction of solid state technology, the remaining cab signal systems in use on U.S. railroads for the most part incorporate 30 to 40 year old technology.

On the other hand, the need to move freight efficiently and economically has led to a rapid development of highly sophisticated centralized traffic control systems (TCS). These systems came into being in the mid 1930's as pure hardware implementations.

Their use has steadily expanded over the years. By providing real time information to remote supervisory centers they have made possible the elimination of many manned signal towers and reduced or eliminated the use of train orders to govern train operations. The recent availability of minicomputers and microprocessors has expanded the functional capabilities of TCS.

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, the develpment patterns markedly diverged. Because of wartime devastation in Europe and Japan, the top priority was placed on redevelopment of the rail transportation systems. This resulted in a continued passenger train market and the need for much higher train densities (shorter headways) than were utilized prior to World War II. These requirements forced a rapid growth in cab signaling and ultimately full automatic train control.

The UIC, through its 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 the new technologies as they became available. 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 highly secure, 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 7-minute headways and has proven so successful that the Japanese National Railways (JNR) have implemented the basic design of the signal/control and communication system as the standared for all JNR. 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 railways.

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 full automatic train operation is standard. The U.S. transit properties, with one exception, utilize standard railroad signaling equipment with cab signaling or automatic train operation on the newer systems or the upgraded existing systems. The exception to these technologies is the Bay Area Rapid Transit system (BART) in the San Francisco-Oakland area. This system, which became operational in 1972, utilizes highly sophisticated computer-based signal and control system with digitally modulated audio frequency carriers.

There are two basic functions in a signal system: one is train detection and the second is to convey information to the train engineer or operator. The train detection function can be accomplished in different ways. In the United States and throughout much of the world the track circuit is employed to detect the presence or absence of a train and to provide broken-rail protection. A track circuit is defined as an electrical circuit of which the rails form a path. Basically, three types of circuits are employed:

- dc track circuits
- ac track circuits
- af track circuits

The dc track circuit can be further classified as a neutral, polarized or coded circuit and the ac can be further classified by its frequency (normally below 200 Hz) and the code rate. AF track circuits use audio frequencies usually above 500 Hz and are normally coded.

In most foreign countries, the track circuit is used for train detection; however, in some instances, train detection is accomplished by axle counters in conjunction with inductive loops. This type of detection does not use the rails as part of the circuit.

The other function of signaling is to convey visual information which is carried out by color light, searchlight, position light signals, semaphore or cab signals. The aspect of the signal conveys to the engineer the condition of the track ahead and in turn he controls the train in accordance with the indications. Additionally, the wayside signal can also indicate to the engineer the route his train will take and/or the speed at which the train may proceed. In the U.S., signal aspects are normally used to provide indications of authorized speed (speed signaling), while in Europe wayside signal aspects at interlockings normally provide route information (route signaling).

For higher speed operation on domestic and foreign railroads some form of cab signaling with or without enforced overspeed control is employed. Such systems are commonly used in conjunction with wayside block signals but may be used without them.

1.4 Definitions

For the purpose of this report, the following definitions of words, terms and phrases used in railroad signal and train control systems are presented. They are drawn from various government and industry sources and are intended only as an aid to understanding the material contained herein.

Aspect, False Restrictive - The aspect of a signal that conveys an indication more restrictive than intended.

Aspect, Signal - The appearance of a fixed 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.

Absolute Permissive Block (APB) - A block signal system between sidings, consisting of two or more blocks which, when occupied, cause the opposing fixed entering signal to display an aspect indicating Stop.

Following movements are governed by intermediate fixed signals, cab signals, or both, whose most restrictive aspects indicate: Stop, then Proceed at Restricted Speed; or Proceed at Restricted Speed.

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 Stop System - A track-side system working in conjunction with equipment installed on the locomotive, so arranged that its operation will automatically result in the application of the air brakes at designated restrictions, should the engineer not respond, until the train has been brought to a stop.

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.

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.

Block - Manual - A block or series of consecutive blocks, governed by signals operated manually upon information received by means of communication between train dispatchers.

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

Cab Signal - A signal located in the engineer's compartment or cab, indicating a condition affecting the movement of a train or engine 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 an engine.

Circuit, Acknowledgment - 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 cab signal system exists. The ATS must be a continuous inductive type with a two-indicator cab signal to enforce acknowledgment by the engineer at each signal that displays an aspect requiring a speed reduction or stop.

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

Circuit, Cut-in - A roadway circuit at the entrance to automatic train stop, train control or cab signal territory by means of which locomotive equipment of the continuous inductive type is actuated so as to be in operative condition.

Circuit, Line - A term applied to a signal circuit on an overhead or underground line.

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 current voltage on rails, low impedance energy source, and transformer-rectifier unit between rails and direct current track relay.

Circuit, Track; Impulse - A track circuit whose track relay is activated by controlled high energy pulses of short duration.

Circuit, Track, Overlay - A compatible but different track circuit, added to an existing track circuit.

Circuit, Track; Phase Selective - An ac track circuit consisting of code transmitters, code following relays and a phase selective detector unit. Local and operating coils of the relay must be in proper phase relationship.

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

Contact - A conducting part which co-acts with another conducting part to open or close an electric circuit.

Contact, Back - A part of a relay against which the current carrying portion of the movable neutral member rests, when the relay is de-energized, so as to form a continuous path for current.

Contact, Front - A part of a relay against which the current carrying portions of the movable neutral member is held when the relay is energized, so as to form a continuous path for current.

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

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 an operative relation with the track elements and is immediately responsive to a change of conditions in the controlling section which affects train movement.

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

Device, Acknowledging - A manually operated electric switch or pneumatic valve on a locomotive equipped with automatic train stop or train control device, which can forestall an automatic brake application or silence the audible warning device.

Distance, Stopping - The distance between the point where full service application of brakes is initiated and the point where the train comes to a stop under its most inefficient braking mode from its maximum authorized speed.

Element, Roadway - That portion of the roadway appartus of automatic train stop, train control or cab signal system, such as electric circuit, inductor, magnet, ramp or trip arm to which the locomotive apparatus of such system is directly responsive.

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.

Engineman - The driver or operator of a locomotive, the term is used synonymously with engineer.

Engineer (Train) - See Engineman.

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

False Restrictive (FR) - A failure of a system device or appliance to indicate or function as intended which results in greater signal restriction than is required.

False Proceed (FP) - A failure of a system device or appliance to indicate or function as intended which results in a less restrictive indication than is required.

Filter, Electric Wave - A wave filter designed to separate electric waves of different frequencies.

Filter, High Pass - A wave filter having a single transmission band extending from some critical or cut-off frequency, not zero, up to infinite frequency.

Filter, Low Pass - A wave filter having a single transmission band extending from zero frequency up to some critical or cut-off frequency, not infinite.

Filter, Low Pass Code - A low pass filter connected between coding equipment and line to pass direct current code impulses and prevent code equipment from shunting carrier and communication circuits. It prevents line coding contacts from introducing undesired high frequency currents into the line.

Filter, Receiving - A band pass filter associated with the input circuit of a carrier receiver or repeater.

Filter, Transmitting - A band pass filter associated with the output circuit of a carrier transmitter or repeater.

Filter, Voice and Carrier Pass - A high pass filter that passes voice frequencies and carrier frequencies and attenuates frequencies below the voice range.

Forestall - The acknowledgment and/or manual speed control adjustments made by the engineer to preclude an automatic brake application by an automatic train stop or train control device.

Frequency - The number of cycles through which an alternating current passes per unit time.

Impedance - The apparent resistance in an electric circuit to the flow of an alternating current, analogous to the actual electrical resistance to a direct current, being the ratio of electromotive force to the current.

Indication, Signal - The order or instruction that is apparent to the engineer from a given signal aspect.

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

Insulated Joint - rail 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 mechanical or electric locking that their movements must succeed each other in proper sequence. Train movements over all routes are governed by signal indication. Interlocking also refers to the territory where switches are used to connect multiple tracks and routes.

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

Interlocking Limits - The track between the 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 electric locking that their movements must succeed each other in proper sequence. Train movements over all routes are 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 are 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.

Line of Lights Indication - A visual display, used in conjunction with a control system, wherein the route called for and train occupancy is displayed on the console or model board by a series of lights.

Mast, Signal - The vertical supporting structure of signals or signs. Also called a standard.

Meet - A preprogrammed or predetermined point where one train meets another as prescribed by train orders, timetables or signal indications.

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, Biased - A relay which will operate to its energized position by current of one polarity only, and will return to its de-energized position when current is removed.

Relay, Centrifugal - An alternating current frequency selective relay in which the contacts are operated by a fly ball governor or centrifuge driven by an induction motor.

Relay, Code Following - A relay which will follow a code consisting of a series of electrical pulses and reproduce the code without distortion within practical limits.

Relay, Magnetic Stick - A relay, whose armature remains at full stroke in its last energized position when the coil 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.

Resistance, Ballast - The resistance offered by the ballast, ties, etc., to the flow of leakage current from one rail of a track circuit to the other.

Resistance, Train Shunt - The actual resistance in ohms from rail to rail through wheels and axles of a train, engine or car. This resistance will vary with rail and wheel surface conditions and with weight of equipment.

Route Locking - Electric locking, effective when a train passes a signal displaying an aspect for it to proceed, which prevents the movement of any switch, moveable point frog, or derail in advance of the train within the route entered. It may be so arranged that as a train clears a track section of the route, the locking affecting that section is released.

Routing - A function of interlocking whereby a predetermined course for movement of trains has been established.

Shunting Sensitivity - Shunting sensitivity of a track circuit is:

1. Non-Coded track circuit - The maximum resistance in ohms which will cause the relay contacts to open when this resistance is placed between the rails at the most adverse shunting location.

2. Coded track circuit - The maximum resistance in ohms which will prevent the code responsive track relay from following the code when this resistance is placed between the rails at the most adverse shunting location.

Siding - A track auxiliary to the main track for meeting or passing trains.

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.

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

Signal, Color Light - A fixed signal in which the indications are given by the color of a light or lights only.

Signal, Color Position Light - A fixed signal in which the indications are given by color and the position of two or more lights.

Signal, Distant - A term synonymous with approach signal.

Signal, Dwarf - A low home signal.

Signal, Fixed - A signal of fixed location indicating a specific condition affecting the movement of a train.

Signal, Home - A fixed signal at the entrance of a route or block to govern trains or engines entering and using that route or block.

Signal, Interlocking - A roadway signal which governs movements into or within interlocking limits.

Signal, Position Light - A fixed signal in which the indications are given by the position of two or more lights.

Signal, Semaphore - A signal in which the day indications are given by the position of semaphore arms. Night indications are given with a light indication associated with the arm position.

Speed, Limited - A speed not exceeding the miles-per-hour designated by operating codes.

Speed, Medium - A speed not exceeding 40 miles per hour.

Speed, Restricted - A speed that will permit stopping short of another train or obstruction, but not exceeding 20 miles per hour.

Speed, Slow - A speed not exceeding 20 miles per hour.

Standard, Signal - The vertical supporting structure for signals and signs. Also called a mast.

Switch - Spring - A switch equipped with a spring mechanism arranged to restore the switch points to normal position after having been trailed through.

System, Absolute Permissive Block - A block signal system usually from siding to siding, for governing opposing movements of trains. The fixed signals governing the entrance into an absolute permissive block displays an aspect indicating Stop when the block is occupied by an opposing train. For following movements the section between sidings is divided into several 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 the Proceed at Restricted Speed, and the cab signal displays an aspect indicating Proceed at Restricted Speed, as their most restrictive indications.

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

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

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 stop.

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

Title, Signal - The name used to describe the order provided by a specific signal aspect and indication instruction.

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 the trains and wayside.

Train - Superior - A train having precedence over another train.

Transmitter, Code - A device that periodically varies an electrical circuit at a predetermined code frequency.

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

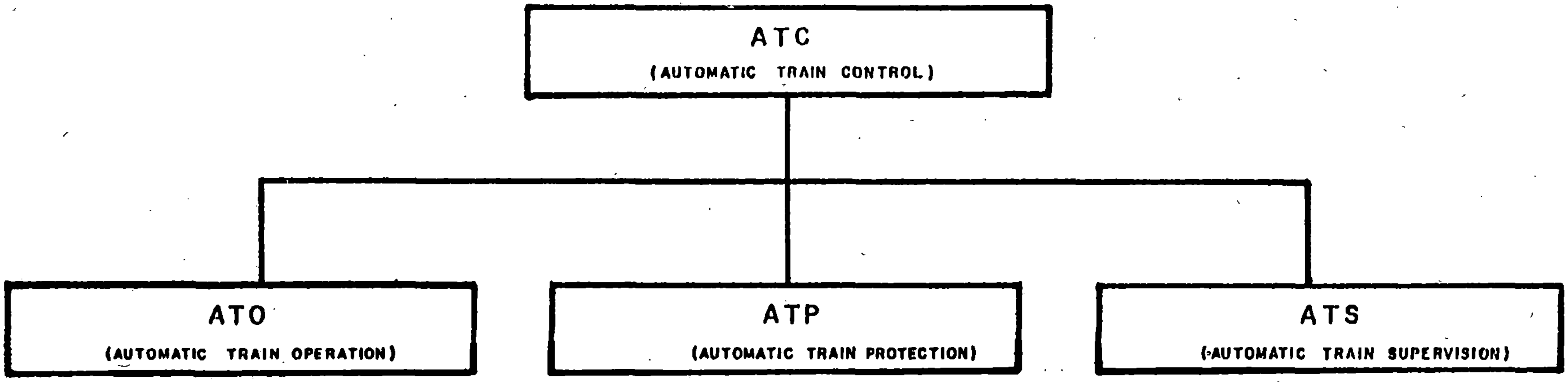
Considerable difference in interpretation or meaning of technical system terms exists within the signal industry. These different interpretations have often caused confusion between U.S. railroad and transit signal engineers, and between meanings intended by domestic and foreign technical publications. One group of terms has particular importance in categorizing the various technologies described in this report: (1) Automatic Train Control, (2) Automatic Train Operation, (3) Automatic Train Protection, and (4) Automatic Train Supervision. These terms have already been defined above. However, a variety of definitions may be found from other sources. They have therefore been specially identified and compared in Figure 1-1 in order that the reader fully understand the context in which the material is presented.

1.5 Report Organization

This report has been prepared to familiarize the reader with signal systems, signal types, signal aspects, titles and indications, and the operational standards utilized to describe or enforce the signal indications.

This report summarizes the findings in Task 1 and Task 2 Final reports, document references 394 and 395 (Appendix A), as applicable to this task in defining signal technologies, equipments and the state-of-the-art.

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, BORKEN FLANGE, ETC. DETECTORS

FIGURE 1-1

The report has been organized to present a historical development for familiarization with the evolution of signal technologies; to identify, classify and describe current signal equipments and operational rules; to discuss the Federal regulations and industry standards that exist; and finally to make recommendations for signal and operating standards relative to high speed passenger train service.

An overview of signals that are currently in use is included in Section 3. Discussion includes signal types and the associated aspects, titles and indications. Human engineering principles applicable to signaling are included for analysis.

Section 4 discusses foreign signal aspects, titles and indications to support comparative analysis for development of a standard signal system.

Section 5 is dedicated to discussion of operating rules and standards of individual railroads and the AAR. Federal regulations governing signal systems and train operations are identified and analyzed for applicability.

Section 6 provides an analysis of signaling rules, standards and aspects relative to a standardized signal system for high speed passenger train service. A standard signal aspect, title and indication system is recommended. This recommended system is compared with current Federal Regulations to identify conflicts which may arise. Recommendations have been included for revisions to Federal Regulations to assure that a standard signal aspect system will be compatible and that the regulations will enhance the development and installation of signal systems that reflect state-of-the-art technologies.

SECTION 2.0

SIGNAL/CONTROL SYSTEMS

Since railroads came into being early in the nineteenth century the development of signal systems has played an important role in the progression of railroad technology. In some cases, the approach has differed here in the United States from that of Europe. However, all strategies have held as central goals the separation of trains in a positive manner in order to minimize accidents and optimize traffic movement. The strategies have taken various forms while usually progressing in steps with each step improving a weak element of its predecessor. Tasks 1 and 2 of this study presented some of the domestic systems currently in use as well as some in the development stage in Canada. European systems were included to show how various high speed operations are controlled. The Japanese National Railroad signaling system was also examined for unique design features that might be employed in the United States. Some of the more common features of signal and control technology used in the United States are summarized to emphasize the diversity of systems employed to operate wayside as well as cab signaling systems. As background to today's signal technology, a history of signal system development is presented in order to blend strictly engineering aspects with some of the lore of the past.

2.1 Historical Development

The current state-of-the-art in railroad signaling and train control is the result of more than a century of creative thinking by many individuals representing a number of organizations who worked toward the goal of safely moving more and heavier trains at higher speeds. It has been an evolutionary achievement which, without doubt, will continue since the efficiency of the steel wheel on steel rail is a factor which will become more attractive as the national energy crisis becomes more severe.

2.1.1 <u>Railroad Signal Development</u>

All forms of transportation, including ships, airplanes, automobiles, railroads and animal powered transport, require "rules of the road" to reduce the chance of injury, death, damage or inconvenience due to collision between two vehicles. Rules are also significant to the vehicle operator's well being in that they remove some of the otherwise unknown action another vehicle might take. In railroad transportation early operations were conducted using rules of the road devised by each railroad to suit its individual needs. The first railroads had only one locomotive, so collisions between trains was not a concern. Some early trains had no brakes at all. The engineer relied on station crews to stop the train after he removed the power from the driving wheels. Often braking was accomplished by a workman forcing a wooden stave through the spoked wheel of the locomotive. Train speed, weight and braking power were factors with which all railroads had to eventually contend. Even in early operations when train speed and weight were low compared to the present day, braking technology was often inadequate for bringing a train to a stop before striking an obstacle sighted in its path.

In 1825, on the first day of operation of the first steam powered locomotive in England on the new Stockton and Darlington Railroad, the "Rocket" struck and fatally injured a member of Parliament. The engineer saw the man clearly enough, but even at a moderate speed the train could not be stopped before running him down. This incident along with many others which resulted in deaths of people or livestock and damage to train equipment clearly indicated to the railroads that the trainmen needed to be forewarned of the condition of the track ahead. Otherwise, the only safe way to operate would be at such low speeds as to be impractical and uneconomical. Some railroads assigned men to patrol sections of track for the specific purpose of providing the engineer with the information required. They conveyed this information to train crews by various positions of the arms or sometimes with colored flags and lanterns. This was the introduction of the term, "semaphore," or "sign-bearer," into railroading. These first signals evolved into signaling systems when communications became standardized throughtout individual railroads. However, industry-wide standards were slow in developing. A railroad employee changing jobs to another railroad had to learn a new signal system and a train crew using another railroad's trackage had to know both systems.

Manually operated fixed wayside signals were devised for several reasons. One was to make a signal more visible. However, the principal one was probably to relieve the signalman from unnecessary exposure to unfavorable weather conditions. These devices had numerous configurations and utilized many ways of conveying information. In England a paddle, or "Semaphore," was placed on a high staff and manipulated to imitate the arm positions of an employee. In the United States the first signals were quite different and assumed a variety of shapes and sizes. Eventually they were replaced by signals of the semaphore form.

It is possible to operate a railroad safely without signals and approximately one-half of the trackage in the United States does not have signals. However, most of the unsignaled tracks are branch lines where only one train operates at a given time.

The first signals were not primarily to prevent collisions between trains but rather to warn the train crew of conditions ahead. In his handbook, "Railroad Operation and Railway Signaling", document reference 93 (Appendix A), Mr. E. J. Phillips Jr., stated in humorous yet elementary terms that train collisions may be prevented by arranging for trains to be in the same place at different times or at different places at the same time. These two methods of maintaining separation of trains developed over the years, one using a time interval and the other a space interval. The separation of trains where one follows another is referred to as controlling headway.

The time interval system came first chronologically (1849). Time interval systems began with time tables which regulated train movement on a specific line. However, unscheduled events made it necessary to include a way of modifying the time table to minimize delays in train movement. For example, a time table may have required one train to pull off onto a side track and wait for a train moving in the opposite direction to pass. If the train for which the side tracked train was waiting experienced a lengthly delay, the time table required the train to stay in the side track for an indefinite period. The use of unscheduled trains also had to be accomodated in some fashion. A central authority was established to issue "train orders" to accomodate these unscheduled events. The central authority prevented the issuance of conflicting instructions but required a considerable amount of communications between stations. Therefore, modifications to a time table were not implemented until the telegraph came into use (1851).

The telegraph also made feasible the first manual block system which utilized space separation of trains. In England such a block system was established in 1858. This system divided the railroad into sections called "blocks" separated by stations. The rule of the first English block system was that the block was assumed to be "clear" unless a red signal was displayed. The communication to display a red signal at Station A came by telegraph from the next station down the line when a train failed to show up there at the appointed time, after passing Station A. The signal thus displayed warned a following train not to enter the block.

The first block system in England had some features that were undesirable in that it was overly dependent upon the human element. The use of the space interval of governing train movements received considerable impetus in the U.S. by the public reaction to a disasterous rear end collision between two trains carrying Union Soldiers to New York and New England in 1863. The first manual block system was installed in the U.S. in 1863 on the United New Jersey and Railroad Company. The method used improved upon the English system by changing the rule of the block to prohibit a train from entering a block unless a clear signal was displayed. In this block system stations were not over 9.6 kilometers (six miles) apart. For the most part men were on duty at the station 24 hours a day and communicated via independent telegraph which extended from one station to the next. The signals were arranged to show a white disk, about 61 centimeters (two feet) in diameter, when the block was clear. The absence of a white disk indicated the block was occupied and not to be entered.

The manning requirements for such manual system were considerable: at least one signalman for every 9.6 kilometers (six miles) of track. It was therefore inevitable that a more efficient method would be devised. Since the train itself was an indispensable element in the operation, it was likewise inevitable that the train should operate the wayside signals. The available technology dictated the sequence in which this logical development took place.

The first automatic block signals (1866) were electrically operated using the tracks as conductors and wheel operated treadles as circuit actuators. Power was direct current furnished by battery. The circuit was normally open and the passage of the train over the treadle closed the circuit and actuated the signal. Automatic block signals were improved (1872) by eliminating the treadle and using the train wheels and axles as a part of the circuit. This arrangement detected and displayed a restrictive signal for an uncoupled car, a feature which was not inherent in the earlier design. The system was further improved (1879) to provide a fail-safe feature which involved using an electrical track circuit which was normally closed, and opened by the passage of a wheel over the track. The system was considered fail-safe because a loss of power or failure of a part of the circuit resulted in a signal display of the most restrictive aspect and not a false indication that the block was clear, as would be the case in the earlier system.

As previously indicated, the semaphore type signal had already been introduced for manual operation because of its good visibility. However, it was not used in the early automatic block systems because there were neither electrically operated valves for control of hydraulic or pneumatic power nor electric motors with sufficient power to operate semaphore arms. The arms were particularly difficult to manipulate because they were heavily counterweighted to assure return to the horizontal position, or the most restrictive aspect, if a failure occurred.

Semaphore signals returned to railroading in 1883 when penumatically operated semaphore signals were incorporated into an automatic block signal system. The pneumatic valves were electrically controlled by track circuits. By 1893, electric motor technology had progressed to the stage where electrically operated semaphores were in use.

The requirement for illuminated signals developed with the block system for separation of trains. A common signal lamp was a rectangular metal case with a magnifying lens on the front side. An early light source was a kerosene lamp, but the need for brighter distant signals led to the development of acetylene lamps and later the introduction of the electric light bulb. The first electric signal light was introduced in the U.S. in 1895, using a band of lights to outline the semaphore blade. It was not until 1900 that the first semaphore displaying aspects with electric lights was introduced.

The early semaphore signals had two aspects - one indicating that the block ahead was clear and one indicating that it was occupied. Such a system gave inadequate warning under the conditions where a train stopped just inside the block and the signal was not visible to a following train due to a curve or other obstruction. To cover this eventuality a "distant" signal was placed in front of the "home" signal to provide the necessary distance to slow the following train before it reached the entrance to the block. In automatic block signaling where blocks were short because of the limiting factors of the track circuit, the distance signal was incorporated into the signal to the rear so that each signal gave an indication of conditions in its own block plus an indication of the condition of the block ahead. The resulting system is called a two-block system. The concept has been expanded to a three-block system which provides indication of another block ahead and a four-block system yet another block ahead. Such systems have the obvious advantage of allowing a following train to pace itself to the train ahead and maintain an optimum separation. The first four-block system was installed on the New York Central Railroad in 1931.

At the turn of the century semaphore signals began to be phased out, although they are still in use in many places. Night operation required a system involving lights or lamps of different colors. With the development of sufficiently bright color lights, they were adopted for day time operation and the double system, one for day and one for night began to be phased out.

It may seem that the colors, red for danger, green for clear, and yellow for warning are obvious choices. However, the manner in which these colors came to be so generally accepted is deeply rooted in railroad development. In the late 1800's, the colors accepted by most industrially developed countries were white for safety, red for danger, and green for caution. There were several serious shortcomings in using a white light as a clear signal. One of them was that the colors, other than white, were produced by white light behind a colored lens, and a broken red or green lens could give a false clear sign. Another shortcoming was disasterously demonstrated in 1898 when an engineman mistook a white lantern at a highway crossing for a clear signal. The true signal should have been red but was extinguished. For these reasons, white light was dropped as a signal color by some railroads in 1899, and green was adopted as the "clear" signal and yellow as "caution." But for U.S. railroads in general, the old colors were still in use well into the twentieth century. Early usage of colors was far from standardized. Colors varied considerably; reds varied from orange to deep red, greens from chrome yellow to blue, and yellow from reddish yellow to greenish yellow. Colors were frequently confused. As a result, color definitions were devised and standardized in 1918, contributing substantially to the evolution of wayside signals.

Providing wayside signals required considerable expenditure of capital by the railroads - - all to alert the train crewmen of conditions of the road. The employees responsible for obeying the signals were usually sincere and dedicated men who, nonetheless, were capable of missing a signal and thereby endangering both themselves and the train. To prevent such catastrophic events, devices were sought to automatically stop a train should an engineer miss a stop and proceed into an occupied block.

Some railroads employed a device called a "Smashboard" which was swung into the path of the train when a stop signal was in effect. The noise made by the object striking the train alerted the crew to the fact that a stop signal had been missed. This was a noisy but passive device and more positive means were needed.

The year 1880 saw the first experiments with a system which completely bypassed the engine crew. But it had serious flaws, and in the following years a succession of automatic systems sought to achieve greater reliability. Most were based on the principle of an arm, or trip, which was raised in the stop position to strike a lever on the passing train and automatically apply the brakes. Most mechanical devices of this sort were adversely affected by icy conditions, and in addition the lever on the train could be actuated by debris on the track.

A system which is less susceptible to these problems was developed and a trial installation was made in 1919. By inductive coupling the system transferred the stop command from a device alongside the track to one mounted on the train. Technology continued to improve, and in recent years with the advent of the coded track circuit automatic stop has been incorporated into automatic train control. However, automatic train stop systems were never widely adopted by the railroad industry.

The dc track circuit was not without its problems but was nonetheless widely used in the United States by 1900. When dc electric locomotive propulsion supplied from wayside power first became practical the use of dc track circuits in dc propulsion territory was no longer feasible because of the economic necessity to use at least one of the rails as a power return. Some partially effective systems were tried but the ac track circuit proved to be the most effective in dc electric propulsion territory. The ac track circuit was made possible by the development of the vane type relay which operates by induction. The passage of dc current through the coils will not actuate the vane relay. Although the ac track circuit was designed specifically for dc electric propulsion trackage, it was also found to be effective in areas where dc track circuits were being adversely affected by stray currents from outside sources. Therefore, ac track circuits were installed on some railroad sections which were not electrified. The first ac track circuit was tested in 1903 by the North Shore Railroad in California.

Prior to the 1900's, all power for track circuits whether ac or dc was fed to the rails in a continuous flow. However, the pressing need to use the rails for purposes other than automatic wayside signal operation led to the development of coded track circuits. The equipment developed for this purpose opened several separate channels in track circuits where the steady state track circuit offered only one. Among the improvements provided by this increased number of channels were multiple aspect cab signals, train speed control, communication with wayside equipment and greater shunting sensitivity of the track circuit. The first of such improvements followed closely on the heels of coded track circuit development.

Cab display of signal information has obvious advantages over signaling with wayside devices. One is that the signal is clearly visible regardless of weather conditions. Another is that it can be seen or referred to at the discretion of the crewmen and with continuous type systems it presents a change in aspect in an immediate response to a change in conditions, which is not true of the widely spaced wayside signals. Nonetheless, cab signals have been slow in achieving widespread usage in the U.S. because of their higher cost of installation and the difficulty of tying on-board equipment in with the signal systems employed on the various routes a train must use in traversing the railroad network of the U.S.

Automatic speed control of trains is a development which holds vast potential as a safety measure. Such a system can function as a reminder to a trainman of restrictive changes in aspect announced by an audible indicator which may be overridden or, in a more possitively enforced manner, by automatically reducing power and applying brakes if the operator of the train ignores the warning or is indisposed. Its development was also important as a step toward automatic train operation.

Safety and economy of operation strongly favor automatic train operation where no train crew is required for such purposes as ticket collecting or security. Capital investment and the tendency of the public in general to distrust unmanned machines have been the principal factors against its widespread use. The technological advances in the 1950's made possible the first crewless passenger train which was operated on the New York, New Haven and Hartford Railroad. Shortly thereafter in the 1960's, a completely automatic subway train system was placed in service in New York between Times Square and Grand Central Station.

2.1.2 <u>Switch and Signal Interlocking Development</u>

Trains on a railroad track, unlike other means of transportation, are guided by the track and therefore require no steering by the train operator. The development of switches to transfer locomotives and cars from one track to another was a necessary adjunct to the development of railroads. However, the need for such switches carries with it some inherent problems. For example, switches can be in the wrong position and result in a derailment or collision with another train. For this reason, early in railroad operation, locks were added to switches to restrict the accessibility of the switch mechanism to key-carrying switchmen. Even with these precautions in yards and stations with many tracks and switches the human factor and poor communications between switchmen sometimes resulted in derailments and collisions.

To alleviate these costly mistakes or misunderstandings all switch control levers were grouped in a central position to be operated by a single man. Signal control levers were also grouped at this location. These switch machines were marvels of levers, rods and cables. They actuated switches and signals as far away as a half-mile. The actuating levers were located in a central position of the station or yard in an elevated building with windows which commanded a clear view of the tracks, switches and signals.

The first such installation was made in England in 1843 at a place with the unlikely name of Bricklayer's Arms Junction. Even with such a one man operated device, switches were sometimes operated under a train, and signals were sometimes placed in the "clear" position when the switches involved were not properly set. The first of these problems was combated by the development of a locking device which locked the switch in a given position when a train or any of its cars was in the vicinity of the switch. These were mechanical devices actuated by the train wheels, which made it impossible for the switchman to move the switch lever in the tower when the train was traveling over the switch. The second problem was solved by placing interlocks on the lever frame to require a sequence of operations which always resulted in safe condition of switches and signals.

Consider a hypothetical example of a simple "branch off" intersection of track where traffic is allowed in both directions. In such a case three signals would be required displaying the condition of the switch in each direction. A "STOP" aspect would indicate that the switch was against travel in that direction and "CLEAR" aspect would mean travel was permissible. The interlocks on the lever frame would be arranged to require all signals to be changed to "STOP" before the switch lever could be moved and, after switch closure, only the levers that were appropriate for the switch position could be moved to change the signals to "CLEAR".

This is by no means the only problem solved by the mechanical interlock concept. In a complex having multiple tracks and switches there are many combinations of switch and signal conditions which require a certain sequence of operation to assure that signals always display the proper warning to a train approaching along a section of track. The first such frame was installed in England in 1857 and required considerable set-up time, each interlocking part being hand fitted by a skilled craftsman. Maintenance of the machine was expensive.

The mechanical actuation of a switch or signal from a central location is restrictive in that the maximum distance a switch or signal can be actuated is limited to the combination of friction in the rod supports and pivots which can be overcome by a lever of practical dimensions. Even with these limitations the locking frame on some mechanically interlocked switches and signals was so large that more than one man was required to operate the levers. The structure of the interlocking frame became so complex that means other than mechanical linkages had to be found when further expansion of the system was required. An early example of such a technical evolution was installed in 1883 at Victoria Terminal in London, England. Instead of installing mechanical levers and rods to actuate 50 additional signals, electric contactors were added which controlled remotely operated electric signals. The electric contactors were operated by miniature levers which were interlocked with switch levers as required.

A correlative development of power operated switches was a system to assure the switchman that the switch had completed the cycle as directed. Among the factors forcing this development was the lack of "feel" of the small levers which actuated only electrical contactors as opposed to the mechanical levers which required a considerable amount of force to actuate. Devices were installed for this purpose to detect the position of the switch points and signal positions. The miniature levers were so designed as to restrict the initial movement of the lever to an incomplete position which would cause the actuation of the switch or signal. When the directed switch or signal had completed its movement, an electrical feed back released a solenoid latch to allow the lever to complete its movement. This arrangement thus provided a feel somewhat like the mechanical system. Several power sources were used in actuating switches and signals remotely; among them are hydraulic, pneumatic and electric motors.

There are several logical adjuncts to the interlocking principle of controlling switches and signals beside the more obvious one of remotely controlling the movement of the devices themselves. The complex mechanical interlocking of miniature levers which operated electrical contactors was eliminated when it became acceptable to accomplish the required interlocking function electrically using relays arranged in logic sequence. Because of the familiar feel of levers and the mechanical locks which heretofore had disallowed the movement of levers under certain conditions, some signalmen were appalled that the more compact relay interlocking frame would allow the movement of a lever even though the function it normally directed was locked out electrically. However, when the first relay interlocked system was installed at Blue Island, Illinois, on the Chicago, Rock Island & Pacific Railroad in 1929, it was quickly recognized as a significant development. Because of the depressed economy in the 1930's and the frozen status of industry during the 1940 war years, relay interlocking systems did not achieve wide usage in the United States until the 1950's.

When the dc closed track circuit was introduced around 1872, it opened the way for additional precautionary measures to be incorporated into the interlocking system. For example, a problem occasionally arose from a signalmen changing a signal and switch position after a train had passed the signal and entered the block containing the switch. To alleviate this possibility a system was devised to utilize the track circuit to detect the presence of a train and use that presence to enable certain electromagnetic (and later relay) interlocks to prevent movement of such switches and signals. A similar interlock was devised to replace the mechanical device which was used to prevent a switchman from moving a switch under a train. In addition, where a complex interlocking system allowed a route to be established for a train movement, a similar detection system was introduced to lock all signals and switches in the route when the train entered the first block and to hold them in that position until the train cleared the last block in the interlocking system.

Many other interlocking variations were devised for specific applications. Some were in operation as early as 1878, but most did not become widely used until the 1890's.

When the first power interlocking systems were installed, the physical restriction of geographical size was no longer a factor. The elevated switch towers, which were of questionable efficiency with large mechanical interlocking systems, began to be equipped in 1900 with schematic display boards to assist the switchman in keeping track of operations in their interlocking territories. A "mimic" board was a miniature representation of the tracks in an interlocking territory. Each switch, signal and block was represented by a lighted indication to denote switch position, signal aspect and block occupancy. The value of the mimic board increased as interlockings were extended geographically. Boards could be expanded instead of constructing new towers since visual observation was no longer necessary. Relay logic also made possible an improvement which allowed a route to be established in a complex interlocking system by pushing only two buttons, one at the entering point and one at the exit. This interlocked system was called entrance-exit routing, or "NX" by a GRS trademark, which has become a standard description applied to the system.

Another advancement made possible by the development of interlocking technology is the consolidated control of operations. A traffic Control System (TCS) is essentially the centralized control of an expanded interlocking territory that may include a major portion of a railroad line. The total geographic area covered by a TCS is governed by a number of parameters, among which are: complexity of track layout, density of traffic interchange points with other railroads, terrain. In centralized control of traffic, the movements of all trains over routes and through blocks in the area are directed by signals controlled from a central point. Switches are remotely operated from the central facility by way of safety circuits. Coding technology made communications circuits possible by use of one pair of wires, with return to an unlimited number of outlying blocks to obtain block occupancy and switch position indications for the center. Applying this information to a mimic board makes it possible for a dispatcher to establish a route for a train and watch its progress by following lighted symbols. At the same time he can monitor switch positions and other train movements by the lighted symbols. The first TCS installation was made on the Ohio division of the New York Central Railroad in 1927 and included 40 miles of road.

2.1.3 Chronology of Signal Development

A chronological history of significant events relating to the technical development of signal equipment and systems is included in Appendix B.

2.2 Overview of Signal/Control Technology

Task 1 of this study presented a detailed assessment of signal/control systems, equipments and technology which includes theory of operations, advantages, disadvantages and relative costs. A brief summary of the pertinent information applicable to this task is presented here to emphasize the factors affecting signal operation.

2.2.1 Track Circuits

Signal systems perform two primary functions: to detect the presence of a train on a section of track and to convey that information to other trains and crews operating in the vicinity of that occupied track. The historical development section of this report noted that train detection has been accomplished in the United States as well as in most other parts of the world by track circuits.

A track circuit is an electrical circuit formed by isolating a section of track, or "block," from adjacent sections by the use of insulated joints. Types of track circuits used in the United States may be classified as:

Direct current (dc)
Alternating current (ac)
Audio frequency (af)

The dc track circuit may be further categorized as neutral, polarized and coded. AC track circuits may be either normal or coded. All track circuits utilize a relay device whose contacts are so arranged that gravity will return it to the de-energized mode in absence of the actuating dc, ac or af current or pulses. Train wheels on the track act as a shunt to the current or pulses, thereby functioning as a short circuit de-energizing the track relay. Broken rails, shorts to the ground, and power failures also result in a de-energized relay. Relays are used to control wayside signal aspects. In dc track circuits where more than two aspects (STOP & CLEAR) are necessary, three choices are available. Polarized track relays, coded track circuits or line control circuits may be used. AC track circuits have generally been used with dc propulsion power systems that utilize the rails as return conductors. AC coded track circuits have been employed where ac propulsion power systems utilize the track rails as a power return. Modulated af track circuits have been used with welded rail because the inherent characteristics of the af track circuit allow establishment of blocks without the use of insulated joints in the rail.

In France, high voltage impulse track circuits have been used to help break down the oxide film on tracks that are used infrequently.

2.2.2 Cab Signals and Enforced Speed Control

The first significant application of cab signals and associated train stop devices in the United States occurred in 1922 when the ICC ordered 40 railroads to install automatic train stop and train control on their passenger divisions. Cab signals have a number of advantages when compared to wayside signals. Signal experts disagree as to the maximum speed at which wayside signals become ineffective, but most concede that at speeds between 160 km/h (100 MPH) and 193 km/h (120 MPH) wayside signal viewing time is marginal. Cab signals do not have that viewing time limitation. Continuous cab signaling, which is almost exclusively used in the United States, has the further advantage of responding instantaneously to a change in conditions. In addition, cab signals provide an audible warning to alert the engineman of a change in aspects.

Continuous cab signaling systems use a coded ac or af signal in each block. The signal in each block specifies the speed for that block. The signal is picked up by an inductive device mounted in front of the locomotive wheels. Code rates of 0, 75, 120 and 180 pulses per minute are generally standard for the United States.

However, pulse rates of 50, 270 and 420 are also used in some locations. Zero is the most restrictive aspect (STOP or STOP & PROCEED) and 180 pulses indicates a clear track. The intermediate speed restrictions are denoted by 75 and 120 pulses. With this cab signaling system only 4 aspects are possible, unless back contact coding is used with a different carrier frequency, or additional code rates are used.

Automatic train stopping and speed control are included as part of the onboard equipment with most cab signaling systems. The automatic train stopping sequence begins with an audible alarm when a cab signal is not received from the track. The engineer has the choice of overriding the sutomatic stopping sequence if he acknowledges the alarm and reduces speed within a specified period of time. Otherwise, an automatic application of the brakes occures.

In Europe, a form of intermittent cab signaling is now in use. This system uses inductive coupling between train and track tuned magnetic units. The track magnetic units are located in the vicinity of wayside signals. The train and track units are tuned to one of three frequencies: 2,000 Hz, 1,000 Hz and 500 Hz. The 2,000 Hz track magnetic units are normally located near the main signals and are controlled by the signal position. When the signal is CLEAR the resonant circuit is deactivated. When the signal is at STOP or CAUTION, the track magnet is in the effective (fail-safe) condition. The 1,000 Hz track units are normally located near approach signals. The 500 Hz magnetic units are normally installed at an adequate distance in front of the main signals to function as automatic speed controllers. On the engine, three magnetic units, each tuned to one of the above resonant frequencies are constantly supplied voltage at the resonant frequency. The voltage maintains the associated relay in the energized position. When a train-borne magnetic unit passes over a track unit of the same frequency, energy is transferred from the engine magnet to the track magnet causing a drop in current in the engine unit. This drop in current in the engine magnetic circuit causes the associated relay to de-energize and initiate appropriate cab signal display lights or braking action.

The inductive loop is another form of cab signaling used in Europe. A cable laid in the roadway between the rails is the wayside-to-train communicating element. This system provides a continuous updating of the cab signal display by inductive-coupling between the cable and train-mounted pickups. The cable consists of two conductors which are laid between and parallel to the track with crossover points spaced at regular intervals. The crossovers serve two purposes: (1) to establish known location points along the track, and (2) to compensate for influences on the characteristic impedance of the line. Train movements are directed through a control center where train position and speed are monitored. Train commands for speed are transmitted to the train-borne equipment via a remote feeding device, inductive line conductors and antenna. These commands are processed by the train equipment and presented to the cab signal display or brake control mechanism. The display provides three numeric indications: the actual speed, the target speed and the distance to the next speed change. This system is designed to be used where a "higher level" signaling system is required and overlayed on the existing system which is retained for slower traffic.

Cab signal displays are positioned in the locomotive cab for easy sighting by the engineer. The displays are usually adjacent to the locomotive control levers in order to minimize focus shift between the two. Domestic cab signal indicators repeat the wayside signal aspects. The number of aspects to be displayed are limited by the available track circuit codes. The overlay systems utilized in Europe for high speed train operations display scaler quantities for speed, distances and time. Ideally, scaler or numeric displays will provide a combination of train speed, target speed, maximum limits, time, next speed restriction, distance to next speed restriction, running time to next station and scheduled arrival time at next station.

2.3 Proposed Signal/Control Systems

The Task 2 final report of this study/program, established three categories of signal/control overlay systems which were identified as candidates for further study to define the system which will be proposed in Task 6 of this study program. The three categories are summarized below:

2.3.1 Category A

This category encompasses the basic requirement of controlling the operations of 255 km/h (160 mph) passenger trains intermixed with slower freight traffic in electrified territory. The minimum technology necessary to meet this requirement is 5-aspect cab signaling with enforced overspeed control.

The ATP system candidates have been found to be capable of satisfying the Category A requirement are:

- Single carrier 100 Hz ac coded systems as used in the U.S. The fifth aspect could be accomplished by superimposing another carrier frequency.

- Intermittent Cab Signal System with either active or passive wayside transponders. This system could be derived from the BR configuration or the FS system described in the Task 2 final report or the DB configuration described in the Task 1 final report.

- Continuous Inductive Loop System as described in the Tasks 1 and 2 final reports.

- The dual carrier coded ac system used by the FS railroad described in the Task 2 final report.

- Location-Indication-Control (LIC) system used by British Columbia Railway described in the Task 1 final report.

2.3.2 Category B

The Category B configuration is one which fulfills the Category A requirement plus providing passenger train identity and tracking data to a central monitor point.

The system which satisfies Category B requirements can utilize any of the above ATP mechanizations, but must add a data link from the passenger trains or the wayside portion of the cab signal system to a central monitoring point. This data link could be the existing train-borne VHF radio, could be comprised of separate telephone links to the existing TCS centers or be telephone/microwave links to the overlaid cab signal system.

2.3.3 Category C

The implementation of a Category C overlay system requires that a data link be added between the central control point and the overlaid Category B system so that commands can be sent to the Amtrak trains (and stations if required) to control schedule performance.

The above considerations result in identification of the following potential interfaces:

- Individual signal blocks in existing ABS systems.

- TCS data centers.

- Train to wayside VHF radio links.

- Wayside to TCS control center telephone or microwave links.

It has been assumed that the potential system candidate will be overlaid on an existing ABS system. This assumption was made to simplify the design requirements for the overlay system and to avoid over-complicating the system. Where TT and TO is in effect (less than 6% of the total track miles over which Amtrak operates) any one of the existing signal types could be installed. If broken rail detection is not required, an axle counter system with wayside signals could be implemented. Similarly, if the existing ABS system is presently incompatible with electrification, the overlay system is not required to correct that imcompatibility.

SECTION 3.0

SIGNALS

Signal systems were developed primarily to achieve safety. Many other benefits have been achieved by block signal systems. However, safety is still paramount. Originally signals provided block separation of trailing or opposing trains while the control of movement depended on train priority and train order. With the automatic block and traffic control systems in use today, operating rules now utilize the signal system to convey authority for both opposing and trailing movements. Train movements are now governed by automatic block signals while switches and interlockings are controlled by dispatchers, train directors or automatically.

The development of signal systems in the United States was an evolutionary process, and as each new system was installed it provided an incremental expansion of the national signal network. Railroading is a large capital investment industry and the cost of a signal system is a major capital expenditure. As a result many of the systems installed early in this century are still in use and represent different levels of technology. Operating Rules were added or changed to accomodate the variety of systems. Over the decades each railroad independently developed its own signal policies and practices. While mergers have reduced the number of separate companies, the high cost of hardware replacement has militated against standardization. For these reasons this broadly focused study of U.S. railroad signaling has found an astonishing proliferation of signal aspects, titles and indications.

Appendices C, D and E summarize the aspects, titles and indications currently in use today by the domestic railroads over which Amtrak trains operate. Appendix C illustrates the aspects, titles and indications by individual railroads as summarized from each railroad's operating rules. The Association of American

Railroads (AAR) and predecessor organizations developed a Standard Code of Operating Rules which is the foundation of all rule books developed by domestic railroads. The AAR Standard Code establishes eighteen rules that include signal aspects, titles and indications which are sufficient for train operation under all anticipated conditions. The code is an adequate base from which standard signaling could emerge as intended. Figure 3-1 summarizes the AAR Standard Code aspects, titles and indications. It is obvious upon review of appendices C, D, and E that the signal aspects, titles and indications should be more closely aligned with the intent of the AAR Standard Code. The standardization of signaling to the AAR Standard Code would be a worthwhile industry objective. This is not to criticize the railroads but to point out the need for standardization.

When the historical development of domestic signal systems is analyzed, it is easily understood why operating rules vary. Unlike European railroads that were virtually rebuilt following World War II, U.S. railroads utilize evolutionary and antiquated signal equipments that represent technological advances in signal/control systems spread over years of development. Following World War II, domestic railroad patterns changed. The airline, bus, automobile and trucking industries developed rapidly, providing faster and more convenient transportation to passengers and small package shipments. Railroads were reduced to carriers of bulk and large tonnage materials. Trains became longer, axle loadings heavier, necessitating revisions to existing signal systems, especially in areas of heavy traffic density or passenger and freight intermix. Since train length and tonnage affect braking distances, signal block spacing requirements were reflected in this change of operating requirements. Where it was not economical or practical to alter signals, intermediate signals were added to provide advance signaling information for engineers to reduce speed at the proper point for safety. APPROACH and ADVANCE APPROACH titles were created to provide these needed indications.

AAR STANDARD CODE EQUIVALENT INDICATIONS FOR SEMAPHORE, COLORLIGHT, POSITION LIGHT AND COLOR POSITION LIGHT SIGNALS

RULE	NAME	INDICATION
281	CLEAR	PROCEED
281 A	ADVANCE APPROACH MEDIUM	PROCEED APPROACHING SECOND SIGNAL AT MEDIUM SPEED.
281 B	APPROACH LIMITED	PROCEED APPROACHING NEXT SIGNAL AT LIMITED SPEED.
281 C	LIMITED-CLEAR	PROCEED: LIMITED SPEED WITHIN INTERLOCKING LIMITS.
282	APPROACH MEDIUM	PROCEED APPROACHING NEXT SIGNAL AT MEDIUM SPEED.
282 A	ADVANCE APPROACH	PROCEED PREPARING TO STOP AT SECOND SIGNAL.
283	MEDIUM-CLEAR	PROCEED: MEDIUM SPEED WITHIN INTERLOCKING LIMITS.
283 A	MEDIUM-ADVANCE APPROACH	PROCEED PREPARING TO STOP AT SECOND SIGNAL: MEDIUM SPEED WITHIN INTER-LOCKING LIMITS
283 B	MEDIUM-APPROACH SLOW	PROCEED AT MEDIUM SPEED APPROACHING NEXT SIGNAL AT SLOW SPEED.

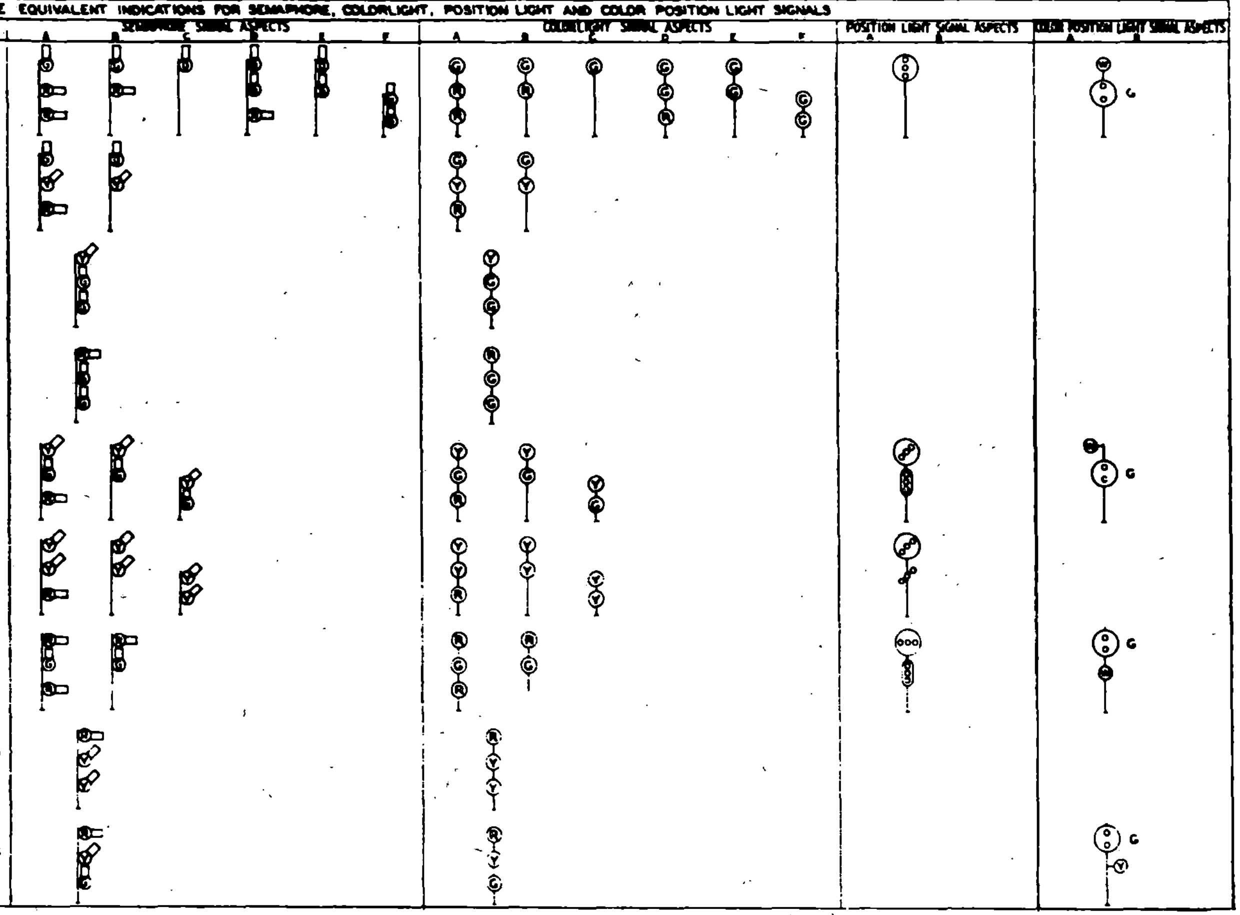


FIGURE 3-1. AAR STANDARD CODE SIGNAL ASPECTS, TITLES AND INDICATIONS (SHEET 1 OF 2)

AAR STANDARD CODE EQUIVALENT INDICATIONS FOR SEMAPHORE, COLORLIGHT, POSITION LIGHT AND COLOR POSITION LIGHT SIGNALS						
RULE	NAME	INDICATION	SEMAPHORE SIGNAL ASPECTS (A B C D E F)	COLORLIGHT SIGNAL ASPECTS (A B C D E F)	POSITION LIGHT SIGNAL ASPECTS (A B)	COLOR POSITION LIGHT SIGNAL ASPECTS (A B)
284	APPROACH SLOW	PROCEED APPROACHING NEXT SIGNAL AT SLOW SPEED. TRAIN EXCEEDING MEDIUM SPEED MUST AT ONCE REDUCE TO THAT SPEED				G
285	APPROACH	PROCEED PREPARING TO STOP AT NEXT SIGNAL. TRAIN EXCEEDING MEDIUM SPEED MUST AT ONCE REDUCE TO THAT SPEED				Y
286	MEDIUM-APPROACH	PROCEED AT MEDIUM SPEED PREPARING TO STOP AT NEXT SIGNAL.				Y
287	SLOW-CLEAR	PROCEED: SLOW SPEED WITHIN INTERLOCKING LIMITS.				G
288	SLOW-APPROACH	PROCEED PREPARING TO STOP AT NEXT SIGNAL; SLOW SPEED WITHIN INTERLOCKING LIMITS.				Y
289	PERMISSIVE	BLOCK OCCUPIED; PROCEED PREPARED TO STOP SHORT OF TRAIN AHEAD	DESIGNATE BY: 1-LETTER PLATE OR 2-MARKER LIGHT OR 3-SHAPE OF ARM OR 4-COMBINATION OF THESE DISTINGUISHING FEATURES.	DESIGNATE BY: 1-LETTER PLATE OR 2-MARKER LIGHT OR 3-SHAPE OF ARM OR 4-COMBINATION OF THESE DISTINGUISHING FEATURES.		LW
290	RESTRICTING	PROCEED AT RESTRICTED SPEED				LW
291	STOP AND PROCEED	STOP; THEN PROCEED AT RESTRICTED SPEED.	DESIGNATE BY 1-NUMBER PLATE OR 2-MARKER LIGHT OR 3-POINTED BLADE OR 4-COMBINATION OF THESE DISTINGUISHING FEATURES	DESIGNATE BY 1-NUMBER PLATE OR 2-MARKER LIGHT OR 3-POINTED BLADE OR 4-COMBINATION OF THESE DISTINGUISHING FEATURES		R
292	STOP	STOP				R

FIGURE 3-1. AAR STANDARD CODE SIGNAL ASPECTS, TITLES AND INDICATIONS (SHEET 2 OF 2)

Unfortunately, the railroads often developed aspects, titles or indications independently. Most often, aspects and titles conformed to the AAR standards. However, rule numbers and indications did not. It appears that the signal indications were developed to conform to the specific requirements of each individual railroad with consideration being given to installed equipment, established operating rules and train traffic requirements.

Signals may be classified into two general categories: block signals and interlocking signals. Block signals are used to maintain separation of converging or following trains on the same track. These signals are used on open stretches of track between stations, sidings or yards. Interlocking signals are used in those sections where one or more tracks intersect, or where switches are provided for routing trains from one track to another. Signals at interlockings and control points are used to protect established direction of traffic in TCS territory for bidirectional operation. The switches and signals are interlocked in those areas to prevent conflicting routes from being set up at the same time.

Both types of signals may be automatically or manually operated. More often block signals are automatic and interlocking signals manually operated. Most interlocking areas are manually controlled by operators, who may be located either within the interlocking areas or in control centers which are often miles from the interlocking areas. Computer controlled interlocking equipment has been developed and is used to select routing through an interlocking limit. Block signals are further classified as "home" and "approach." Home signals are located near the boundaries of the block, and approach signals are used to repeat the home signals when distances or obstructions interfere with the view of the home signals.

Home and approach signals may not be delineated as such in the signal system and may look the same with the same number of lights or semaphore arms. The factor which determines whether the signal is a home or approach signal is the indication assigned to the aspect. In some cases, a home signal may be used as an approach signal for the next home signal. The aspects and the associated indications vary in their usage in the United States, although there is a cohesive pattern of signal aspects due to the fact that all are generally based upon the AAR recommendations.

3.1 Wayside Signal Types

There has been a variety of wayside signals developed and put into use throughout the United States. To describe all of them would be of little value except to demonstrate how numerous they are. Nonetheless, a representative sampling from signal systems now in use will be examined briefly. Signaling systems utilized in connection with classification yards have not been addressed in the study.

3.1.1 Semaphore

Semaphore signals were among the first devices to be utilized as wayside signals. Most railroads agree that semaphores are obsolete, and they are being phased out because of high maintenance costs. The semaphore arms may be manually operated, but more often the power to change the semaphore arm position is provided by either an electric motor or pneumatic actuator and is automatically or remotely initiated. Government regulations now require all semaphore signals to have color lights for night operation. The night operating requirement for signal lights was partly responsible for the obsolescence of semaphore signals. Figure 3-2 illustrates some semaphore signals currently in use. Semaphore arms in the United States usually point to the right side of the mast, away from the train. While those using the right side of the mast may use the upper or lower quadrant, the lower quandrant is seldom used. In any case, a semaphore

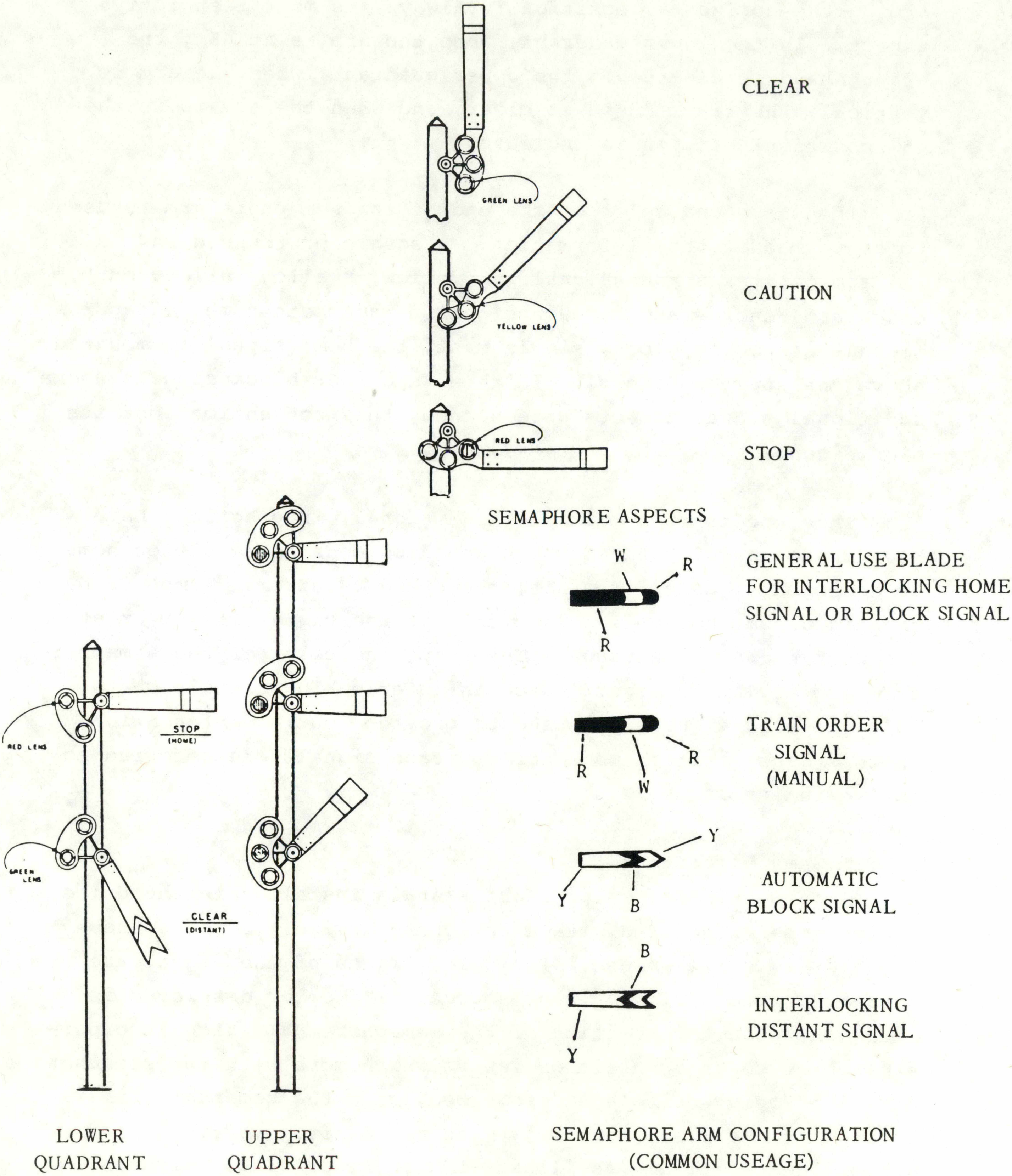


FIGURE 3-2 SEMAPHORE SIGNALS

arm in the horizontal position is always its most restrictive aspect. In the lower quadrant, when the arm is at 45°, the track ahead is clear. In the upper quadrant, when the arm is vertical, the track ahead is clear, and when the arm is in the 45° position, caution is indicated.

The shape and color of the end of the semaphore arm is used to convey additional information. A square or rounded end on a red arm denotes a home signal. A yellow, swallow-tailed, or "V" ended arm denotes an approach signal. When both home and approach signals are mounted on a single mast, the home signal is mounted above the approach signal. In three and four-block signals where additional signal aspects were needed, this convention lost its significance.

The aspects of a multiple-head signal, in practice, have been assigned indications which could be considered either home or approach signals. That is, the speed requirement imposed by the signal may be applicable either at the signal itself or at the next signal in advance. The shape and color of the semaphore arms are of little significance in interlocking signals where multiple-head signals are used to provide routing information. In this case, neither home nor approach signals are referred to in the indication.

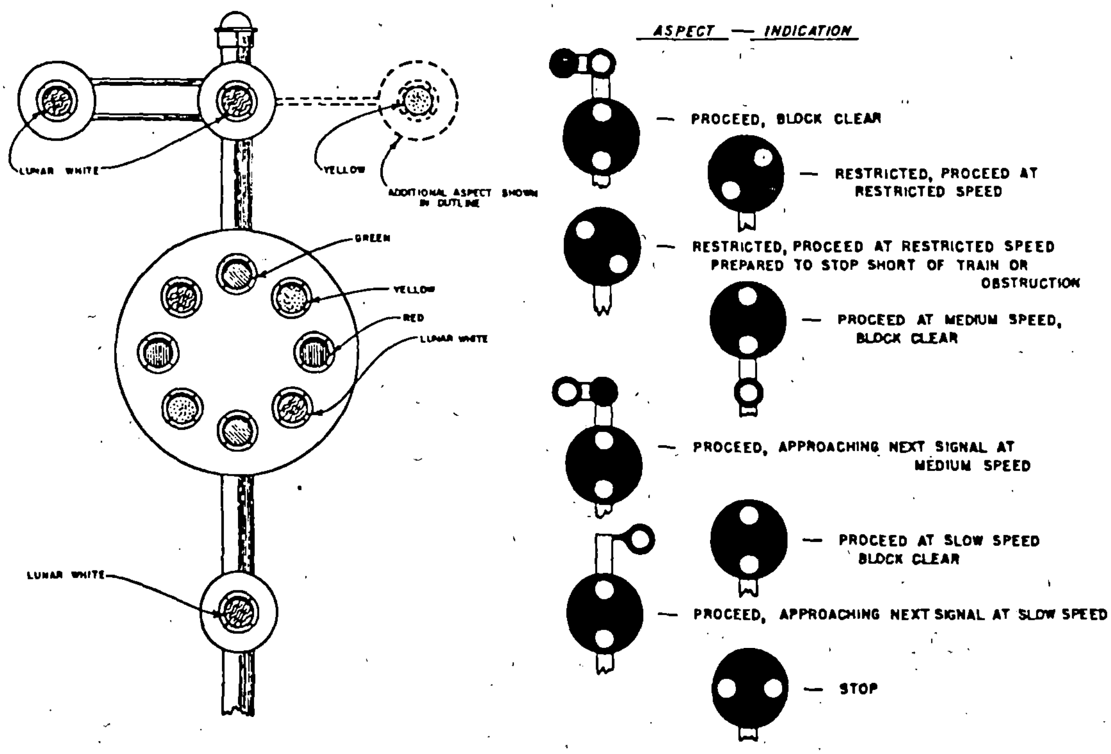
3.1.2 Semaphore Light

Among the first color light signals installed in the United States were those used with a semaphore device. Some of these signals are still in use. The color lights of the signal are displayed from a single light source. The color displayed is dependent upon the position of the semaphore arm which incorporates three color roundels or lenses which move with the semaphore arm. The colors displayed are: red, when the semaphore arm is horizontal; yellow, when the arm is at 45° from vertical; and green, when vertical, as illustrated in Figure 3-2. Signals of this type are no longer manufactured, the last having been installed around 1940. However, many have been repaired and reinstalled. The mechanism for changing positions of the semaphore arm is either pneumatically or electrically operated. The mechanism incorporates a feature which will allow gravity to return the semaphore arm to the horizontal position should electric power or air pressure fail. This design is referred to as a "fail-safe" feature. However, as commendable as the intention is, unsafe failures occur due to jamming of the mechanism by ice or other foreign material causing false CLEAR indications.

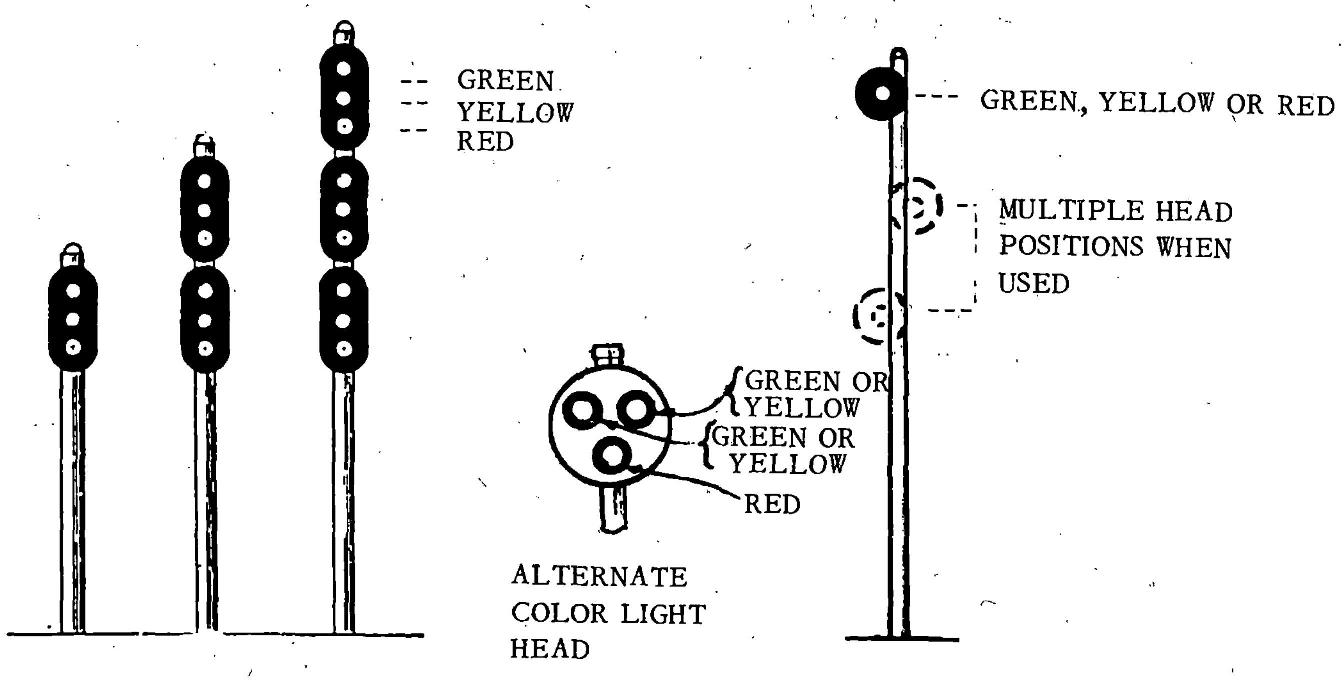
3.1.3 Searchlight

A further development in illuminated signals occurred as a result of improvements in long range lights and color lenses. Around 1920 the searchlight signal was introduced. Its name is derived from the narrow beam projected from a single lens. It employs a signal lamp to display each of three colors: red, yellow and green, through the single lens opening. The signal does not utilize a semaphore arm but has an electrically or pneumatically driven lens mechanism which may fail in a manner similar to the semaphore mechanism and produce an unsafe indication. As with all light signals the lamp is surrounded by a black shield - - known as the "background" - - to enhance daylight visibility. A typical searchlight signal is shown in Figure 3-3.

The advantages of this signal over the semaphore with color lights are that the signal is visible at greater distances, is smaller in size and uses fewer parts. The disadvantage of this light system, along with any other electrically powered light system, is that a power failure results in the absence of a signal (dark signal). All railroads have operating rules which require a dark signal to be considered at its most restrictive aspect. However, a dark signal can be missed by the train crew - - particularly at night.



COLOR POSITION LIGHT



COLOR LIGHT

SEARCHLIGHT

FIGURE 3-3 LIGHT SIGNALS WITH MULTIPLE COLORS

As a concession to the fail-safe philosophy, signal lamps were developed with two filaments instead of one. Two filaments, however, do not extend the life of the lamp if both are operating simultaneously. Both are likely to fail at about the same time since both are subjected to the same stresses. If one filament burns out the other may not last much longer. It is possible that the reduced light produced by a single burned-out filament could be used as an indication to maintenance personnel to replace the lamp. It seems likely that one filament may be used at a time and that the failure of one filament caused a transfer of power to the other filament. However, this surmise has not been confirmed in the literature research during this study.

There are other color light systems in use which change color aspects by moving color filters into the projected light beam. All of them are susceptible to mechanical failure. Their advantage is that they require smaller housing on the supporting mast.

3.1.4 Color Light

The most widely used illuminated signal employs three separate lamps displaying three colors: Red, yellow and green. This device called a color light signal, has no moving parts and is usually arranged in a vertical row with the green light on top, the yellow in the middle and the red at the bottom. A typical color light signal is shown in Figure 3-3. Multi-head installations are often used for approach or advance signal indications.

3.1.5 Position Light

Position lights, imitating semaphore blades, were put into use around 1915. In these signal devices, eight lights are arranged in a circle around a center light so that a group of three of the lights can be used to display a horizontal row, a vertical row, a row of lights ascending to the right (upper quadrant), and a row ascending to the left (lower quadrant). Additional aspects are possible but seldom used. Figure 3-4 illustrates a typical position light signal. A "cross" consisting of five lamps is sometimes used to indicate that a diverging route is to be taken, and a circle of eight lights is used to order the lowering of the electric power pantograph on electrified railroads. Flashing lights provide additional aspects. However, four basic aspects conforming to the traditional semaphore are most often used. The vertical row denotes a clear track, the 45° positions are both of a warning nature and the horizontal row denotes stop.

When additional aspects are required, double heads are seldom used. Instead, a variety of auxiliary lights and appurtenances are added to the signal mast below the primary signal. Some auxiliary lights are singular, and some have three lamps in a row. The multiple lights may be arranged either 45° to the left, 45° to the right, or vertical, but only one of the three. See Figure 3-4. These are all static displays. Auxiliary lights can change the position light aspect only by being lit or off. The color amber is the same for all lights in both the primary and qualifying fixtures. Its advantage is that it provides maximum visibility under adverse weather conditions. The use of three lights in the primary signal allows one to fail and still convey the proper aspect. The signal system is designed so that the failure of the auxiliary lights will produce a more restrictive aspect.

3.1.6 Color Position Light

Color position lights became operational in 1921, combining the color light and position light features as illustrated in Figure 3-3. The color position light display is the same physically as the position display except the center light is omitted. The position aspect of the color position signal is conveyed by

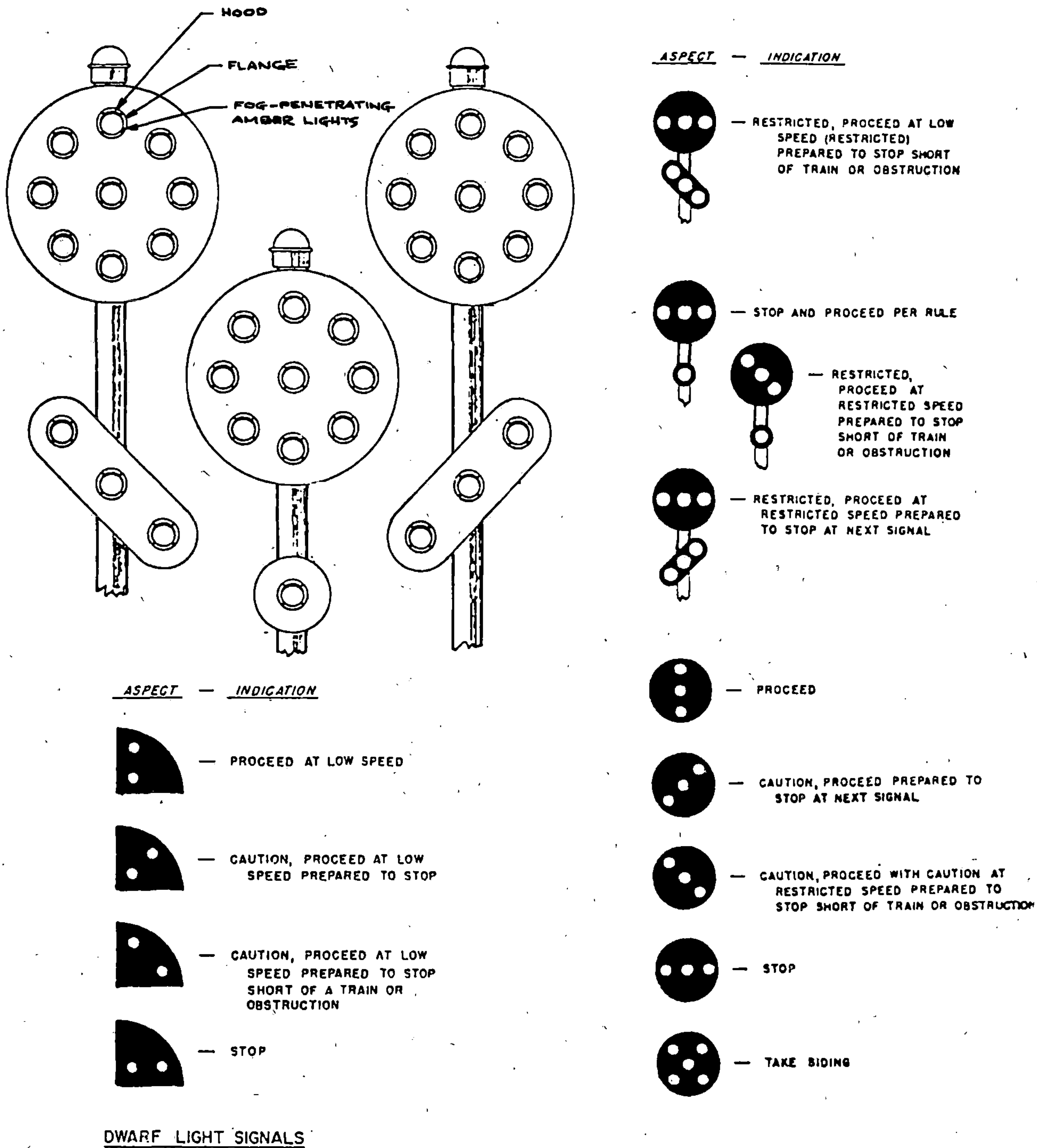


FIGURE 3-4 POSITION LIGHT SIGNALS

only two lights where the position light uses three. The vertical arrangement of two green lights denotes a clear track. Two yellow lights ascending to the right (upper quadrant) convey a warning indication denoting medium speed. Two lunar white lights ascending to the left (lower quadrant) convey a warning indication for limited speed. A horizontal arrangement of red lights denotes danger. These four basic aspects are expanded using qualifying lunar white lights above, below, and to the left of the primary lights, and yellow lights to the upper and lower right quadrant of the primary signal. The primary signal has a fail-safe feature in that the indication is the same even with one light extinguished. The aspects are arranged as in the position light signals so that a loss of the secondary qualifying lights will produce a more restrictive indication than the automatic signals initiated. The disadvantage of this signal light system is that it is larger and takes up more space than other systems which convey the same information. The advantage is that the redundancy of the display assures reliable operation.

3.1.7 Auxiliary Markers

There are many auxiliary signals that are used to supplement or provide added instructions for a block or interlock signal. Each railroad has a system of auxiliary markers, and they are not always common among properties. Figure 3-5 illustrates the most common markers associated with ABS and TCS signals.

- Number Plate - The number plate is used to designate block signals and indicates the signal number.

- Permissive - This signal is usually a fixed triangular sign with yellow background and black letter "P." It indicates to the engineer that he may proceed through the signal at restricted speed without stopping, if permitted by operating rules.

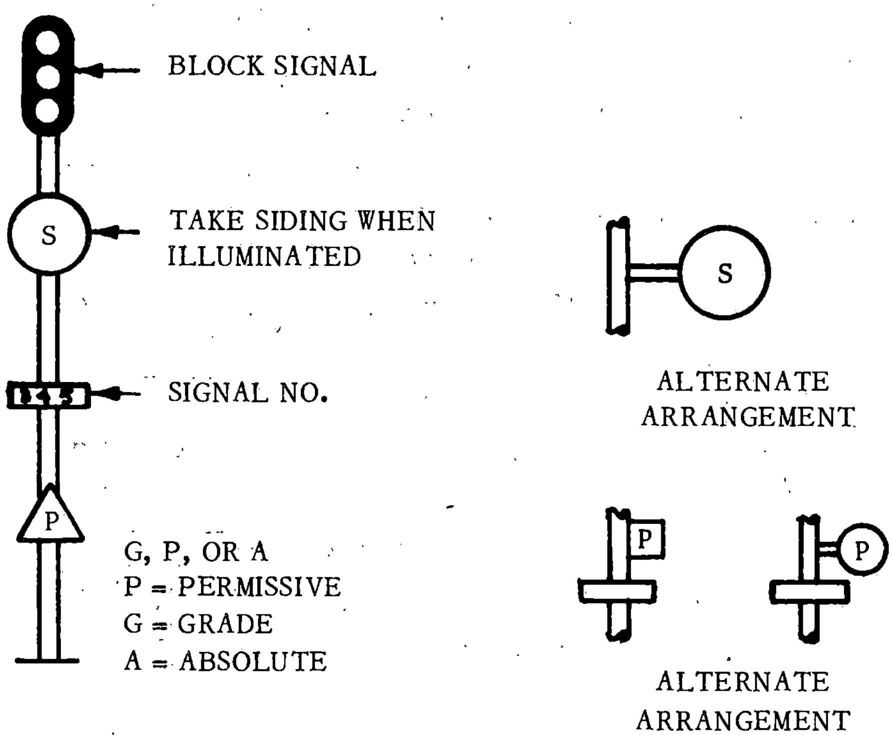


FIGURE 3-5 AUXILIARY MARKERS

- Grade - This signal is usually a triangular sign with a yellow background and black letter "G". It is associated with signals at heavy grades where trains exceeding a certain tonnage or length can proceed at restricted speed through a "stop and proceed" signal without stopping.

- Absolute - This signal is usually a fixed sign of yellow background and a black letter "A". It indicates the associated home signal STOP is absolute and the engineer man cannot proceed past the signal without authority.

- Siding - An illuminated roundel provides an indication for the train to move into the siding usually at a reduced speed. The signal is located on the signal mast below the home signal head and consists of an illuminated (lunar) background with black letters. "S" indicates take siding. Other letters are used to convey different indications but are not necessarily common among operating railroads.

3.2 Wayside Signal Aspects, Titles and Indications

The following description of aspects, titles and indications is based on The American Association of Railroads (AAR) Standard Code, Figure 3-1. Appendices C, D and E clearly show that most railroads have expanded these aspects, titles and indications to meet their operational requirements.

The most important aspects found on signals having only one head or semaphore arm are:

- CLEAR - Green light: "Proceed." Other aspects that are used for this include a vertical semaphore blade, a blade dropped 45 degrees or more below horizontal, a vertical row of amber lights, or a vertical pair of green lights.

- APPROACH - Yellow light: "Proceed prepared to stop at next signal. Train exceeding medium speed must immediately reduce to the approach speed." This signal is used one block in advance of a STOP or a STOP and PROCEED signal to give the engineer early warning. The APPROACH aspect may also be displayed by a diagonal semaphore position, a horizontal blade either painted yellow or with a fishtail, or diagonal yellow or amber lights rising to the right.

- STOP - Red light: "Stop." A horizontal semaphore blade or a row of horizontal amber or red lights may be used. Because a train may not pass a STOP signal, it is also known as an "absolute" signal. Sometimes a letter "A" is added to the mast to ensure this. Sometimes a second red light directly under the first is used; but a single red light is all that is required for absolute STOP.

The absolute stop is always used at interlockings and control points, but it is considered a nuisance by most railroads in block signal territory. The reason is that any signal which has become red because of a circuit failure could hold a train in a remote location for hours although the track is actually clear. To avoid this, a STOP and PROCEED signal is preferred for automatic block signals.

- STOP AND PROCEED - Red Light with a marker: "Stop; then proceed at restricted speed." The signal may be identical to the STOP signal, but railroad men will recognize it by a definitive marker. A pointed semaphore blade may be used or a marker light may be mounted on the mast below to indicate STOP AND PROCEED. It will usually be in a staggered position so the signal will not be misread as an interlocking signal where the lights are in vertical alignment. Alternatively the marker may be a number plate, or the letter "P" for permissive or letter "G" for grade painted on the mast or on a plaque. A "grade signal" is sometimes used on an ascending grade to permit slow-moving tonnage trains to pass the signal without stopping. This prevents the train from stalling on the grade if forced to a full stop before proceeding.

An operational deficiency of the STOP AND PROCEED concept is that the broken rail feature of the track circuit is not used. A train can proceed on a STOP AND PROCEED signal with the engineer erroneously assuming that there has been a signal failure. The train can then become derailed by a broken rail which was responsible for causing the STOP AND PROCEED aspect.

"Restricted speed" may be from 5 Km/h (3 MPH) to 32 Km/h (20 MPH), the exact figure being specified in the railroad's operating rulebook. After making the stop the train crews are expected to be on the watch for broken rails, another train, a washout, or other obstructions.

These one-head signals displaying aspects for STOP AND PROCEED; APPROACH, and CLEAR are adequate for most automatic block signal needs, but a few railroads use two-head block signals. A need for an advance signal arises with higher speeds or short blocks where heavy tonnage trains require earlier warning in advance of a STOP signal. For this the APPROACH-MEDIUM signal is sometimes used.

APPROACH-MEDIUM - Yellow above green: "Proceed, approaching next signal at medium speed." Medium speed may be defined in the rulebook as 24 Km/h (15 MPH) to 72 Km/h (45 MPH) depending on the terrain, the traffic density, traffic type, turnouts and switches; but 48 Km/h (30 MPH) seems to be the accepted medium speed.

The APPROACH-MEDIUM signal will be located two blocks in advance of a STOP signal. At one time two blocks of identical, single-head APPROACH signals were used for this extra protection, but this was a tragic mistake that resulted in disastrous accidents. Locomotive engineers tended to assume that any train ahead was moving away and that they had another yellow block ahead as they passed each yellow signal. If the train ahead was, in fact, stopped, the following train proceeded through the last yellow signal too fast to stop at the red signal.

Another reason for two-head block signals is historic. Lower-quadrant semaphores usually did not have a middle position for APPROACH. In that case a lower head was added, and this was treated as an independent signal displaying the APPROACH aspect for the next block. It had yellow and green lenses and a yellow blade, whereas the upper head was red with red and green lenses. The only interconnection between the signals was that if the upper was at red, the lower could not be green. Such signals are still used at a few locations on the Union Pacific.

Automatic block signals are normally CLEAR, displaying other aspects only as trains occupy their blocks. Originally light signals were continuously illuminated, but "approach lighting" has come into widespread use. With this system a signal is dark until a train approaches. It then turns on and performs normally. When the train clears the signal by two blocks, the signal flashes to green for a moment before going dark. This system has the obvious benefit of saving batteries and reducing maintenance costs.

Interlocking signals need only one head. Red means absolute STOP. However, most interlocking signals have two or more heads in a perfectly vertical alignment and they normally display red. No matter how many heads, this means absolute STOP. Only when a specific train movement is anticipated, or is to be favored, is the interlocking signal given some other aspect.

In general, each head of the signal is related to travel through the interlocking plant at a certain speed, and usually on a certain route. If the top head is cleared, it is for the normal-speed route--usually the main and straightest route. If the next head is cleared, it is for a medium-speed route, usually the most important of any branch routes. It can be used for more than one such route if there are several. The third head, if used, is devoted to a low-speed route in the same way. Four heads are used for four routes in the same way, but four-head signals are rare.

Each of these heads can display red, yellow or green. The indication given depends on the combination of all the heads. Usually all heads but one are red. There are some instances of displaying green or yellow on more than one head.

CLEAR - Top head green with any and all lower heads red.
APPROACH - Top head yellow with lower heads red.
STOP - All heads red. It is absolute.

So far the aspects are identical to those of single-head signals except for the added lower heads which display red.

MEDIUM-CLEAR - <u>Second head green, others red</u>: It indicates "Proceed at medium speed within interlocking limits." This means the train either is being diverted to the branch line or is entering from the branch.

SLOW-CLEAR - Third head green, others red: It indicates "Proceed at slow speed within interlocking limits." It is used for less important branch routes or several such routes. One use is when traversing crossovers that have low frog numbers, or when diverting into a sharp curve. The railroad operating rulebook may define "slow" as 16 Km/h (10 MPH) to 40 Km/h (25 MPH), but the most common is 24 Km/h (15 MPH).

So far signals and indications have been straightforward, but the use of a yellow aspect on interlocking signal heads is another indication. The rule for interlocking signals provides an exception to what is generally expected for block signals. It is called RESTRICTING.

RESTRICTING - Yellow at bottom, all other heads red: "Proceed at restricted speed." Instead of the yellow bottom head applying to the expected route, it applies equally to all routes. Engineers can tell the route only by looking at the switches. The speed limit is approximately 3 MPH, but no stop is required. The RESTRICTING signal is used to call a train into an occupied block, so it is popularly called a "call-on" signal. Here are some of its uses:

- To let a train into any route to couple onto other cars occupying the route.
- To let a work train into the plant for repair or rescue.
- To let a train enter one-way track in a direction against normal traffic.
- To let a train through the plant when for any reason the signal or interlocking system is out of order.

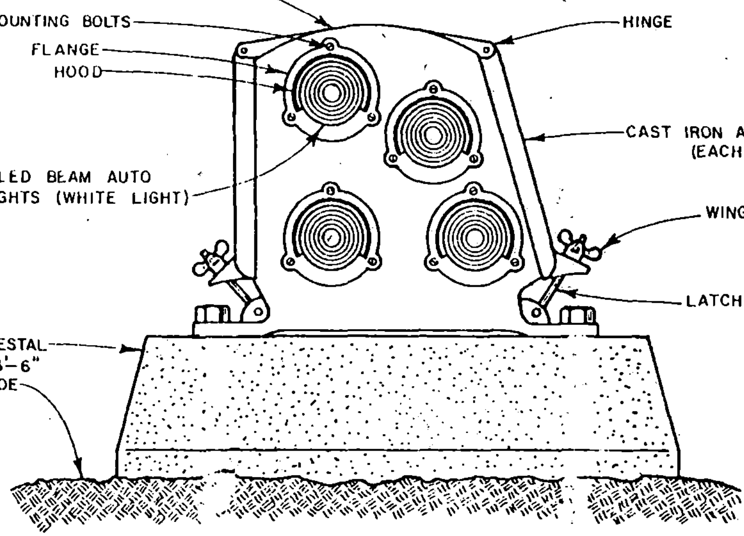
- To let a train enter non-signaled track such as an unprotected passing track or an industrial spur that happens to connect with the interlocking-plant zone.

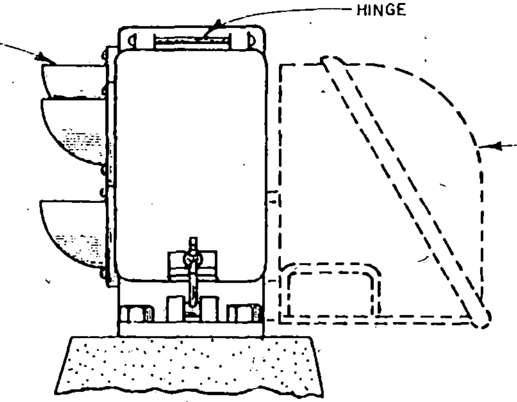
- To let a train from such minor track as the foregoing re-enter the plant. For this a dwarf signal is usually used.

- To let a train enter the plant from one-way track when coming from the wrong direction. A dwarf is frequently used here as well.

The dwarf signal is equivalent to the bottom head of a three-head interlocking signal. When it displays red it means STOP. When it displays yellow it means RESTRICTING. When it displays green (rare, but used in stations) it means SLOW-CLEAR. Dwarfs are used for minor track entrances to interlockings; for wrong-direction movements, as starting signals in large passenger terminals; and sometimes at junctions in heavy traffic areas, especially where speeds are slow. Figure 3-6 illustrates dwarf signals and signal aspects.

When yellow appears on any of the upper heads of an interlocking signal, it gives the indication APPROACH-MEDIUM-APPROACH (not the same as APPROACH-MEDIUM); and on a four-head signal the third head can display SLOW-APPROACH. SLOW-APPROACH cannot ordinarily be displayed on a three-head signal because the red/red/yellow aspect is reserved for RESTRICTING. However, a few railroads do have the practice of using a short semaphore arm for call-on and a normal-length arm when route information is intended. When the bottom arm is long, the only way a call-on can be given by such a signal is with a flagman on the ground. On a few railroads this deficiency is obviated by the use of a flashing yellow light at the bottom position to indicate





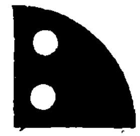
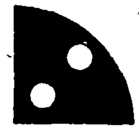
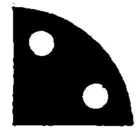
ASPECT	— INDICATION
	— PROCEED AT LOW SPEED
	— CAUTION, PROCEED AT LOW SPEED PREPARED TO STOP
	— CAUTION, PROCEED AT LOW SPEED PREPARED TO STOP SHORT OF A TRAIN OR OBSTRUCTION
	— STOP

FIGURE 3-6 DWARF SIGNALS

MEDIUM-APPROACH or SLOW-APPROACH, while a steady yellow indicates RESTRICTING. In these cases the approach means that the next signal is STOP.

One more practice in interlocking signals requires consideration. That is the use of dummy signal heads that never change their aspect. Suppose the interlocking protects a crossing and there are no track switches. Then only one route is possible for each track through the crossing. This will often be signaled with two-head signals at each entrance. The lower head of each will be permanently red. Another use of the dummy head is with junction switches. Going in one direction, trains have a choice of main or branch routes. The upper head will indicate a cleared main, the lower head, a cleared branch. However, in coming in the other direction the two tracks converge into one, so the upper head will be active and the lower may be a dummy along the main line, while the upper head must be a dummy on the branch entrance, because clearing it would give false information. Sometimes a dummy head is represented by a permanent marker light displaying red at the location where the otherwise useless head would be positioned.

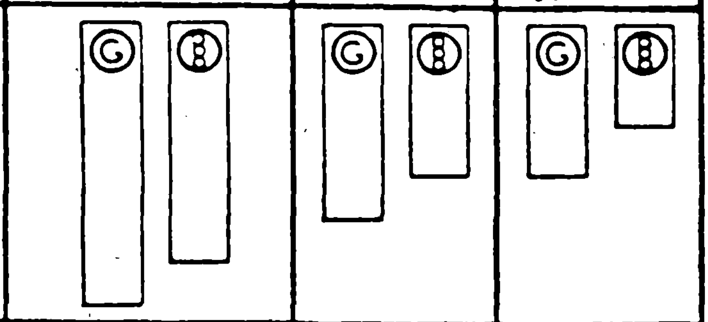
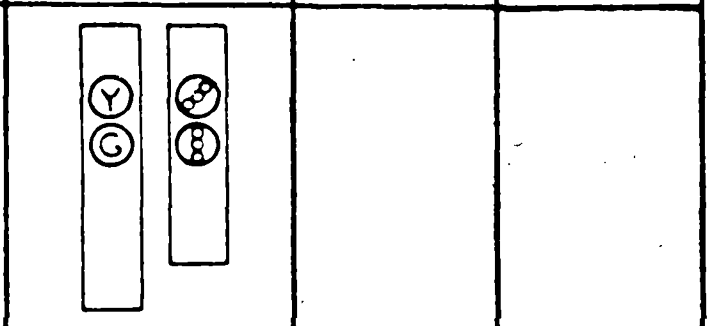
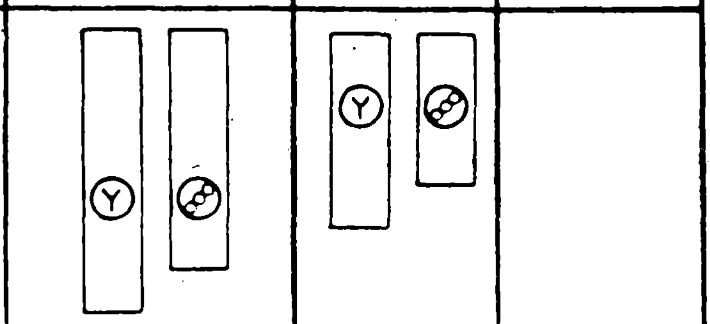
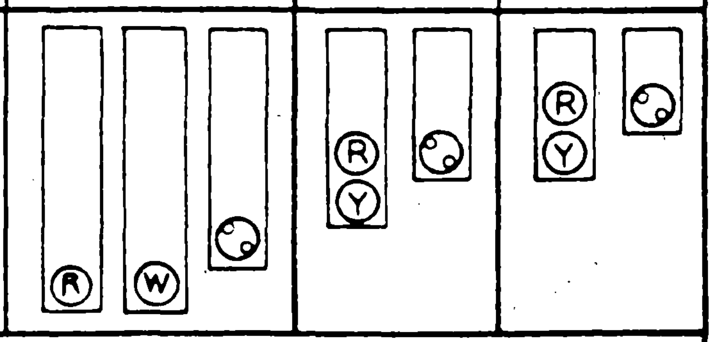
Most signals are primarily safety devices, but with traffic control systems (TCS), signals are also used to hold a train in a siding so other trains with higher priority can be expedited. At each passing track, and at the beginning of double track in TCS territory, there will be a set of signals. The dispatcher can position the turnout switch and he can clear any one of the signals at a time. He does this with levers, switches or CRT light pens on his TCS console located at some central office. Computer controlled systems are being used more and more to provide traffic control and train routing almost automatically with the dispatcher making decisions of conflict. Consider a train approaching a diverging route from a single track. The upper head of a two-head signal controls mainline movement. The lower head is for TAKE SIDING and it may display yellow for RESTRICTING movement into the sidetrack or some other aspect such as flashing yellow or green for faster movement, depending on the operating rules of the railroad and whether the sidetrack has track circuits. Leaving the main track, a single-head signal is adequate. Leaving the sidetrack, a dwarf signal is often used, but a mast signal is also appropriately used. The dwarf has the advantage of its not being confusing to passing mainline trains.

The track section between the three signals at the end of a siding forms a sort of interlocking plant, and it is called an OUT OF STATION (OS) section. When a train passes through it, an automatic recording pen marks the fact on a roll of moving graph paper in the TCS machine. This makes it unnecessary for a station operator to "OS" the train by telephone.

Along the mainline between sidings there usually are block signals controlled by the automatic block system, and therefore it is not necessary for the dispatcher to control them. Rather, they are controlled by track circuits and appropriate block configurations.

3.3 Cab Signaling Aspects and Indications

There are two commonly used cab signal displays in the United States. One is a color light display and the other a modified version of the wayside position signals. These are shown in Figure 3-7 and Appendix F. In both there are four circular fields arranged in a vertical row. In the color light display only one circular field is lighted in presenting an aspect. Therefore only four aspects are possible in the system. The top circular field contains a green light which, when lit, indicates a clear track. The second circular field is split,

NAME	INDICATION	ASPECT (4 INDICATION / 3 INDICATION / 2 INDICATION)
CLEAR (corresponds to a 180-code rate)	PROCEED. (STANDARD CODE RULE 281.)	
APPROACH MEDIUM (corresponds to a 120-code rate)	PROCEED APPROACHING NEXT SIGNAL AT MEDIUM SPEED. (STANDARD CODE RULE 282.)	
APPROACH (corresponds to a 75-code rate)	PROCEED PREPARING TO STOP AT NEXT SIGNAL. TRAIN EXCEEDING MEDIUM SPEED MUST AT ONCE REDUCE TO THAT SPEED. (STANDARD CODE RULE 285.)	
RESTRICTING (corresponds to a 0-code rate)	PROCEED AT RESTRICTED SPEED. (STANDARD CODE RULE 290.)	

G-GREEN   Y-YELLOW   R-RED   W-LUNAR WHITE

Figure 3-7. CAB SIGNAL ASPECTS, TITLES AND INDICATIONS with the top half yellow and the bottom green. When lit it indicates that a reduction of speed is required. The third circular field contains a yellow light. When it is lit it indicates a speed restriction more severe than the yellow over green aspect. The fourth circular field is also a split with the top half red and the bottom yellow which when this is lit, it indicates that a stop is necessary or a very restricted speed is dictated.

As in wayside aspects, one cab signal aspect may have more than one indication as shown in Figure 3-7. The Engineer is responsible for the proper interpretation for the track territory in which the train is traveling.

3.4 Human Factors in Signaling

Appendix C is an accumulation of the wayside signal aspects used by only 20 U. S. railroads and may or may not represent the entire American railroad community. However, the variety of signal aspects shown there is almost overwhelming. It is almost certain that even an experienced locomotive engineer would be hard pressed to operate a train with any confidence through all of the territories represented by them. This lack of confidence stems from the fact that there are too many aspects to remember. One of the human factors to be considered in standardizing a signaling system involves the human inability to totally recall information. The recall of totally abstract information is more difficult than information which is arranged in some logical order. Signaling systems should be structured in an orderly fashion so as to be easily recognized. Most of the aspect systems surveyed in this study have a nucleus of orderly structure. However, they appear to have been distorted by arbitrary additions.

Human limitations of observation are prime factors to be considered in a wayside signaling system. In M. Mashour's treatment of "Human Factors in Signaling Systems", Document reference 306, Appendix A, it is well documented that the more complex the signal aspects, the more likely it is that human capability will be exceeded and misinterpretation will result. Misinterpretation is even more likely if the observer is subjected to stress or is required to concentrate on other problems. Human limitations of observations were demonstrated by G. Belforare Johansson and his collaborators in a test to determine the most desirable highway signs for new installations. The tests were conducted in Europe, involving five subjects who were driven in a specially equipped automobile over about one hundred miles of highway. The subjects' only responsibility was to press a button when the car passed the road sign. Under ideal conditions of good weather, daylight conditions and good visibility, at speeds of around 88 km/h (55 MPH) the number of signs registered by the participants ranged from 365 to 405 out of a total of 424 signs. The tests showed a miss-rate of from 5 to 14 percent. Such a statistic is not reassuring in considering that railroad wayside signals depend upon the human as an integral part of its operation. This is particularly true when the locomotive engineer responsible for detecting the signal is likely to be distracted by any number of other responsibilities.

Another aspect of human limitation in the observation of wayside signals is the effect of motion on the human eye. "Human Factors in Signaling," again, treated this effect in detail. The eye and nervous system are coupled together for the purpose of being attracted to an object in a field of view filled with numerous distracting influences by either abrupt changes in position or light intensity. The central portion of human vision is not as sensitive to detecting stimuli of this kind as the peripheral part of vision. Items of interest are more often detected in perpheral vision and brought into the central visual field by eye movement for more detailed observation. When the observer is moving and the central visual cone of the observer's eye is directed along the path of travel, the peripheral visual field is overstimulated by apparent movement of nearby objects passing to either side and the detecting capability is considerably impaired by this overload. In signal detecting, the peripheral field is relatively incapacitated by this effect and the central cone must act as detector, and that cone is not well suited for the task.

Speed, motion and the physiological limitations of the human eye certainly require a deeper look at signaling requirements for higher train speeds. The article, "High Speed Traffic Signalling", by O. Weber, Document reference 85, Appendix A, provides four basic principles for high speed signaling.

- Wayside signals should be abandoned because of the difficulty the operator has in observing them. The complexity of most wayside signals reduces operator reaction time and affects braking distances that are critical at high speeds.

- Cab signals are necessary for high speed operation. They should not be a repeat of wayside signals but should convey quantitative information that is easy to comprehend and act upon.

- The information provided to the operator should preferably be continuous. An intermittent data system is acceptable, but not a point-to-point system. The operator must be able to perceive restrictive indications in advance.

- Any system should provide the operator continuous speed restrictions with automatic braking or full automatic running control as preferred options.

In the book, Human Engineering Guide to Equipment Design (Sponsored by the joint Army-Navy-Air Force steering committee), human factors in signal and warning devices are dealt with in some detail. Several aspects are treated which are pertinent to cab signaling and to a lesser degree to wayside signaling. Among these is the research into attentiveness of operators in tasks requiring manual operation of devices which have feedback in the form of indicators that require control adjustments. This study verified formally the intuitively obvious fact that alertness diminishes with the passage of time and it also diminishes with boredom. An audible warning device is required. A good audible warning device should meet four requirements:

- Attract the attention of a busy or bored operator.

- Tell him what is wrong and what to do to correct it.

- Not interfere with his other duties.

- Be fail-safe and not give false warnings or fail to provide the correct warning. Failures if they do occur, should be easily detected.

In signal design, consideration should be given to the urgency of the warning being provided. Flashing lights have high attention value, but they are also more disturbing and may cause ill-advised snap judgements. Audible horns are also of high attention value, but they can interfere with verbal communications. Light intensity should be carefully evaluated for both night and day operations so that a warning light is intense enough to get the operator's attention but not be blinding or visually irritating. All signal and warning lights and other displays should be within a 30 degree visual cone of the operator's line of sight. If words are included in a warning display, the words should be black on a lighted background for the most effective attention value.

Red, green, yellow, and white color lights have the advantage over other colors in wayside signal applications because the colors can be produced from tungsten filament lamps through color filters. Blue and purple filters transmit only a fraction of the visible light produced by a tungsten filament. White and yellow should not be used together because they are easily confused by the human eye. If they are used together the white light should be of a high color temperature, often called "lunar white" or "bluish white." If yellow and green are used together, the green should be bluish green to minimize confusing it with yellow.

In distant application, color light signals should conform to the Illuminating Engineering Society Lighting Handbook (1966) formula:

$$D = 2000\sqrt{I}$$

where D = distance in feet and

I = intensity in candles for similar unit with a clear rather than colored lens

This applies to red or green signal lights which are steady rather than flashing. For yellow and white light, the distance is somewhat greater and for blue and purple light somewhat shorter. For all lights the recognition distance in clear weather is considerably greater than the formula indicates. Haze and fog reduce the distance considerably.

For flashing signals, the candle power value of the above formula may be reduced considerably from the steady state value as shown in Weslers formula (1960):

$$I_e = \frac{t \times I}{0.09+t}$$

where I_e = effective intensity in candles

I = intensity of steady light in candles, and

t = flash duration in seconds

The formula is effective for flash durations of 0.1 seconds or greater. Flashing lights should have a repetition rate of 4 flashes a second for maximum attention value with least visual nerve irritation.

In summation, human limitations are strong factors in favor of completely automatic train operation. Unfortunately, economic considerations make automatic operation of trains quite unlikely in the near future. Cab signals are not as vulnerable to human limitations and are the next choice as an ideal signal system. Again, economic factors have worked toward eliminating cab signals almost entirely from the American scene. As a distant third choice, there is a strong need for standardizing wayside signals, but even this step will probably not be undertaken in the near future.

While none of the three approaches toward improved signalization appears likely in the near future, goals should be established for alternative upgrading programs. Coupled to this should be a program of government incentives to encourage investment in improved signal systems.

SECTION 4.0

FOREIGN SIGNAL TECHNOLOGY

4.1 Foreign Wayside Signals

In the early stages of this study, as reported in the Task 1 final report, Document reference No. 394, a number of requests for information on foreign signal systems were initiated. The significant responses received from several countries have been supplemented by the literature search, reported under Table I, as well as by interviews with foreign techncial and management personnel.

Signal aspect, title and indication data are presented here for Britain, Germany and Russia. Some of the data is interpretive due to differences in applied meanings of technical terms that occur in translation. The "distant" signal, for instance, is functionally equivalent to our "approach" signal.

4.1.1 Signals in Great Britain

Representative wayside signal types of British railroads are shown in Appendix G. British signals may be classified as main signals, junction signals, and distant signals. Main signals compare to U. S. "home" or "block" signals and are used in open running between stations, yards, and sidings. Junction signals correspond roughly to U. S. interlocking signals. They are used to give route information. Distant signals are used in the same fashion as in the U. S. to provide information about conditions ahead.

In Britain some wayside signals are semaphore signals, but they are being phased out as much as economic conditions allow. British semaphores are much like U. S. semaphores except the signal blade is mounted on the left (or train side) of the supporting mast. Semaphore signals are used as main , distant and junction signals. The semaphore blade has only two positions, horizontal and 45° ascending to the left (upper quadrant). The position ascending to the right (lower quadrant) is seldom used. 45° denotes clear track ahead; horizontal means stop. When a caution aspect is needed to warn of the next signal a second semaphore arm is used. It also has two positions similar to the upper blade. The primary blade is red and the secondary one is yellow. Night lights for the upper blade are either red or green, and for the lower, either yellow or green. The detailed mechanism of semaphore blade operation and description of the power actuator were not available in the literature surveyed. Probably electric and pneumatic power are utilized as in the United States. The blades return to the horizontal when power fails.

Color light signals are much the same as those used in the United States. Searchlights, three-color lights and moveable colored lens lights are used in all types of signals. Some signals employ four lights; one red, one green, and two yellow. These are used mostly where distant signals may be required, in which case the two yellow lights are used. Two yellow lights denote caution at the next signal, and one or two flashing yellow lights denote that a diverging route is to be taken at, or just beyond, the next signal.

Junction signals on some British lines include a schematic representation of the diverging tracks ahead. For example, a single branch to the right will show two searchlight signals, one on top of the signal mast, the other on a branch mast to the right and slightly lower. If the switch is set for the main route, the light on top of the mast will be green and the light on the short mast to the right will be red. And if the right turnout is to be taken the reverse will be true. It appears that speed information is conveyed by yet another two-light signal at the lower part of the signal mast. However, the reference material is not specific in this regard. Junctions with as many as three turnouts have been signaled in this manner. The same schematic presentation is used with two-light and three-light signals.

In some signaling systems the lamps have two filaments and are so arranged that failure of the main filament will provide an alarm at the control center and automatically connect the second filament to power so that light is interrupted only for the time required for relay operation.

4.1.2 Signals in West Germany

The signal data accrued during this study are shown in Appendix H. German signals are classified into four categories, much like British signals. These categories are primary signals, distant signals, repeater signals, and switching signals.

Semaphore signals are still in use in West Germany, although they are also being phased out in favor of more easily maintained color light signals. Single arm semaphore signals are used as primary and switching signals but never as distant signals. Like semaphore signals in the United States, West German semaphore blades are mounted on the right side of the signal mast away from the train. All semaphore blades are white with a red border. The blade has a small disk at the end which also has a red border. Semaphore arms generally have only two positions. Three-position semaphores were introduced in 1940, but they never achieved wide usage. In the two-position semaphore the positions are horizontal for stop, and the upper quadrant 45^{o} (ascending to the right) for clear.

When a slow-travel (distant) aspect is required, a second semaphore arm is used. The ineffective position of this second semaphore arm, that is when it does not contribute to the aspect, is when it is vertically aligned with the signal mast. A slow-travel aspect is presented when both signal arms are at 45^{o} in the upper quadrant (ascending to the right).

When semaphore signals are used as switching signals they are always accompanied by a square display mounted on a separate mast usually on the right and in front of the semaphore mast. The square display has a moveable circular white field with a black bar in the center. As a switching signal the semaphore blade is always horizontal to denote danger. When the black bar of the secondary signal is horizontal, stopping and switching is prohibited. When the black bar is ascending to the right, stopping and switching is permitted.

Color light signals are used in all phases of signaling in West Germany. In some cases the position of the color lights is significant as to the kind of signal displayed. Primary signals may contain a field of four lights or six lights. In either case the background is a black vertical rectangle. In the four-light display the colors are the conventional red, yellow and green; the color of the fourth light is not known and its purpose was not revealed. The six-light signal is used at entrances to junctions where it serves as a junction signal as well. Color light distant signals and repeater signals are formed by a black rectangle tilted to ascend to the right. The yellow and green light displayed are form signals as well as color light signals in that they are displayed in pairs ascending to the right. Repeater signals are used in cases where the distant signal itself requires additional forewarning. Repeater signals are distinguished from distant signals by a lunar white light mounted in the center of the upper long side of the tilted rectangular display.

Distant signals include a type of signal which is not common outside of Germany. The signal is a moveable disk which is arranged to be either normal to the engineer's view or hinged up to be edgewise to the engineer's view. The disk is orange with a black inside border and white outer border.

When the disk is normal to the engineer's line of sight, the indication is that the primary signal is in the stop position. When the disk is edgewise to the engineer's line of sight the indication is that the primary signal is clear. An additional semaphore arm is added below the disk to indicate a primary signal set for slow travel. The added semaphore arm is shaped like an arrow pointed downward and pivoted in the center. This third aspect is in effect when the orange disk is "full" and the semaphore descending from left to right at 45^{o}.

These signals are augmented by secondary signals and markers, some lighted, others not. Signs spaced at intervals in front of a distant signal are called beacons. Three signs are generally used. The first one encountered will have three diagonal stripes ascending to the right. The second will have two stripes, and the third will have one stripe. These give notice that a distant signal is ahead. Speed restrictions are given in a triangular sign with the point down. If the speed restriction sign is at a junction where the speed restriction may vary, a lighted matrix is included which will display a number representing the speed limitation. Usually, the number presented is the speed in km/h minus the least significant digit.

Acceleration indicators are diamond shaped signs which may include a lighted matrix. The matrix can produce an arrow pointed up or down, signifying acceleration or deceleration.

Where multiple track switching is signaled at a station, a lighted matrix may be installed at the station home signal to show what track, by number, to which the interlocking is aligned. Where the junction is less complex, schematic lighted route displays are often used.

4.1.3 Signals in the Soviet Union

Russian signal aspects and indications are shown in Appendix I. Russian signals fall into four categories: home signals, route signals, starting signals, and intermediate block signals. Home signals are located at the entrance to stations. Route signals are used to regulate traffic within a station. Starting signals are located at the exits of a station to regulate traffic leaving the station. Intermediate block signals are used to regulate traffic on main lines between stations.

Semaphore signals are also still in use in the Soviet Union. They are almost identical to the German semaphore signals. The upper arm has two positions and a second arm is added when a distant aspect is required. They are also in all categories of signals.

Color light signals are used in various forms. Searchlight signals and two and three vertical rows of light displays are used. In each, a green light indicates a clear track, yellow some form of warning and red indicates stop. Some combinations of colors are also used, as well as flashing colors, to expand the aspects for certain conditions of speed and route indications. Lighted green horizontal stripes under the primary color light signals are also used as added aspects.

Permissive qualifying lights and signs are added below the primary signals in automatic block territory to allow freight trains to pass a red signal.

Route indicators are added to route signals and starting signals to indicate the track number for which the interlocking is set. These indicators may be lighted matrices on which a number may be displayed, or a lighted route indicator consisting of rows of light schematically representing the route to be taken. These indicators are usually mounted to the signal mast below the primary signal.

4.2 Foreign Cab Signals

Information obtained during field trips conducted during Tasks 1 and 2 of this study program includes vendor supplied information. A sample of a CATC cab signal display is included in Document reference 394, Appendix A and Section 6.4 of this report. It represents a cab control display utilizing scalar information rather than signal aspects. The system is in limited use in West Germany. A similar brochure was received for the Italian Rome-Florence Line, which utilizes a simplified four aspect cab signal display. The Italian system is used in conjunction with automatic train control and is briefly discussed in Document reference 394, Appendix A.

The Russian cab signal display consists of a vertical row of five circular lighted fields, very similar to the U. S. cab signals. Only one field is lighted at any time. The top field displays a green light. The second a yellow and the third a yellow over red. The function of the fourth circular field was not revealed in the Russian Rule Book. The fifth circular field is a white light which, when lighted, indicates that the onboard equipment is "on" but no signals are being received from the track, and wayside signals are to govern train movements. The aspects and indications of Russian cab signals is included in Appendix I.

SECTION 5.0

OPERATING RULES

U. S. railroads operate under rules developed by each company within the guidelines of the AAR Standard Code of Operating Rules, document reference 281, Appendix A, and the requirements of the Federal Railway Administration (FRA) Regulations 49 CFR 217 and 218. Each railroad's operating rules are required to be submitted to the FRA for review of compliance.

The AAR Standard Code is the basic document used in the development of each railroad's operating rules. However, the code was developed after most of the private railroad operating codes had been published. There has therefore been little standardization.

Government regulations were established to enhance safety. Most Federal regulations are administered by the FRA through the Signal Inspection Act and the Railway Safety Act.

5.1 Federal Rules, Standards and Instructions

Government safety regulations began in 1906 when the Interstate Commerece Commission (ICC) was vested with the responsibility for investigating and reporting on the necessity of block signal systems and appliances for the control of trains. This regulatory effort culminated in the Signal Inspection Act of 1937 which was a part of Section 26 of the Interstate Commerce Act. In 1967 the administration of the Signal Inspection Act was transferred to the Department of Transportation under the the Department of Transportation Act (49 U.S.C. 1651-9). The Federal Railroad Administration reissued the Rules, Standards and Instructions (RS&I) for Signal Systems as part of the Code of Federal Regulations (49 CFR 236). The RS&I, in consonance with the Signal Inspection Act and ICC orders, has become the principal instrument for Signal System safety regulations. The Signal Inspection Act assigns FRA the authority to:

- Order any carrier (railroad) to install a signaling system, device or appliance intended to promote the safety of railroad operation.

- Prohibit a carrier from discontinuing or materially modifying a signal system, device or appliances without approval.

- Inspect and test railroad signal systems, devices and appliances.

- Prohibit a carrier from using a signal system, device or appliance unless it is in proper working order.

- Require a carrier to report failures of signal systems, devices or appliances.

- Enforce compliance of related rules and instructions.

The goal of the government regulations was and remains the promotion of railroad safety by reducing train accidents and personal injury through the enforcement of the rules, standards and instructions for signal/control system installation and maintenance. The Railroad Safety Act of 1970 gave FRA authority over all domestic railroad operations including the requirements of the Signal Inspection Act (RS&I).

5.1.1 Interstate Commerce Commission Orders

In 1922 the ICC issued order 13413. This order established the specifications and requirements for the installation of automatic train stop or train control devices pursuant to Section 26 of The Interstate Commerece Act. However, after hearings conducted in 1928 the ICC decided that the installation of automatic train devices would no longer be required.

In 1947 ICC order 29543 was issued defining appliances, methods and systems intended to promote safety of railroad operations. This order established the requirement that automatic block signal systems (ABS) be installed on any railroad line where passenger trains were operated at 97 km/h (60 MPH) or more or any freight train was operated at 80 km/h (50 MPH) or more. The ABS was required to conform to the rules and standards established by the RS&I of 1939. The order further established requirements necessary where a manual block system was to be used in lieu of ABS.

The order also established the requirement that automatic train stop, train control systems, or continuous automatically controlled cab signal systems be installed on any railroad line or parts of lines where passenger or freight trains are operated 130 km/h (80 MPH) and above.

Authority for the enforcement of the ICC orders was transferred to the FRA in 1967. These orders are still in effect and enforced by the FRA along with the RS&I.

5.1.2 Rules, Standards and Instructions (RS&I)

The RS&I was developed under the Signal Inspection Act. The Act was originally enforced by the ICC, and authority for enforcement was transferred to the FRA in 1967 as 49 CFR Part 236. Part 236 of the Code of Federal Regulations provides rules, standards and instructions which railroads must observe during installation, inspection and maintenance of signal systems, devices and appliances.

The following general outline of Part 236 is provided to illustrate the organization and content of the RS&I.

Subpart A - Rules and Instructions; All Signals
General
Roadway Signals and Cab Signals
Track Circuits
Wires and Cables
Inspection and Tests; All Systems

Subpart B - Automatic Block Signal Systems

Subpart C - Interlocking
Rules and Instructions
Inspections and Tests

Subpart D - Traffic Control Systems
Standards
Rules and Instructions
Inspections and Tests

Subpart E - Automatic Train Stop, Train Control and Cab Signal Systems
Standards
Rules and Instructions; Roadway
Rules and Instructions; Locomotives
Inspection and Tests; Roadway
Inspection and Tests; Locomotives

Subpart F - Dragging Equipment, Slide Detectors and Other Similar Protective Devices

Subpart G - Definitions

5.1.3 Associated Federal Regulations

In accordance with 49 CFR Part 233, Signal System Reporting Requirements, each railroad must provide annual reports of the methods of train operations, interlocking and control points, automatic train stop, train control, and cab signal systems. Annual reports are due no later than 15 January of each year.

Part 234 requires each railroad to report within five days any occurrence of a "false proceed" signal failure. If a false proceed signal failure does not occur within a monthly period, then a report indicating that no failures occurred must be filed within ten days after the end of the month. In the event of an accident from failure of any signal device, a telegram must be sent immediately to the FRA Safety Office in Washington, D.C.

Part 235 requires each railroad to apply for approval of a discontinuance or material modification to installations of block signal system, interlocking traffic control system, automatic train stop, train control, or cab signal systems.

Part 220 promulgates the requirements for the use of radio in train operations. It prescribes the procedures for wayside-to-train, train-to-train and cab-to-caboose radio communications. Specific procedures are provided for transmission of train orders by radio communications to assure full understanding of the orders.

5.2 AAR Standard Code of Operating Rules

The Standard Code was adopted in 1889 by the AAR and has been revised through the years. The 1965 issue of the Code provided the modern standard for the operation of trains and signal systems under all forms of control, whether manual or automatic. The Standard Code was reissued in 1974 to revise specific rules and standards. The Standard Code was revised again in 1977 to cover radio operating procedures.

The AAR Standard Code is an effective document. It provides a complete base for safe train operations and conforms to the requirements of Federal Regulations.

The AAR Standard Code establishes eighteen signal aspects, titles and indications which should be sufficient for train operation under all conditions. Member railroads have agreed to--and basically use--the AAR Standard Code. However, many operating rules and signal aspects were established by the individual railroads prior to the adoption of the AAR Standard Code. Many railroads have retained their established procedures rather than incur the heavy expense of revising them and retraining their operating personnel. This prerogative is provided for by the AAR Standard Code. Figure 5-1 summarizes the standard aspects, titles and indications included in the AAR Standard Code.

5.3 Rules of Individual Railroads

Each railroad has developed its own operating rules which meet current Federal standards and basically conform to the AAR Standard Code. The AAR Standard Code includes provisions to allow the standards to be revised to respond to the operational needs of member railroads. Many railroads chose to retain standards, rules or other operational regulations that were in use before adoption of the Standard Code. The rules governing signal aspects, titles and indications are a good example of the lack of coordination between the operating codes of individual railroads and the Standard Code. Appendices C, D and E summarize the rules of individual railroads which define signal aspects, titles and indications. These appendices were developed from a review of fifteen operating rule books representing eighteen railroads. A comparison of the AAR rules and the rules used by these railroads shows that a large number of aspects, titles and indications in use. Many of them have resulted from changes found necessary by a specific situation of a property where physical changes to the signal system were not economical or practical.

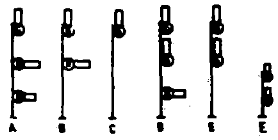
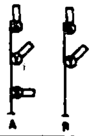
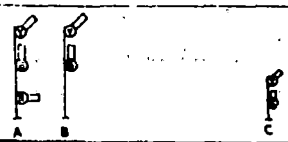
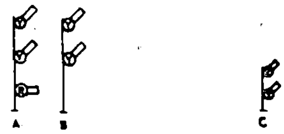
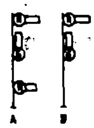
RULE	ASPECT	NAME	INDICATION	APPLICATION
281		Clear	Proceed	At entrance of normal speed route or block, to govern train movements at normal speed.
281A		Advance Approach Medium	Proceed approaching second signal at medium speed	
281B		Approach Limited	Proceed approaching next signal at limited speed	
281C		Limited-Clear	Proceed; limited speed within interlocking limits	
282		Approach Medium	Proceed approaching next signal at medium speed	At entrance of normal speed route or block, to govern the approach to Medium-Clear, Approach, Medium-Approach, or Approach Medium signals.
282A		Advance Approach	Proceed preparing to stop at second signal	
283		Medium-Clear	Proceed; medium speed within interlocking limits	At entrance of medium speed route or block, to govern train movements at not exceeding medium speed.
283A		Medium-Advance Approach	Proceed preparing to stop at second signal; medium speed within interlocking limits	
283B		Medium-Approach Slow	Proceed at medium speed approaching next signal at slow speed	

Figure 5-1. AAR STANDARD CODE SIGNAL ASPECTS, TITLES AND INDICATIONS (SHEET 1 OF 2)

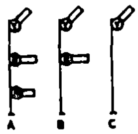
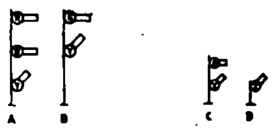
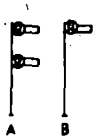
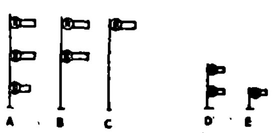
RULE	ASPECT	NAME	INDICATION	APPLICATION
284		Approach Slow	Proceed approaching next signal at slow speed. Train exceeding medium speed must at once reduce to that speed	At entrance of normal speed route or block, to govern the approach to Slow-Clear, or Slow-Approach signals.
285		Approach	Proceed preparing to stop at next signal. Train exceeding medium speed must at once reduce to that speed	At entrance of normal speed route or block, to govern the approach to Slow-Clear, Slow-Approach, Permissive, Restricting, Stop and Proceed, or Stop signals, red switch lamp and end of signaled territory
286		Medium-Approach	Proceed at medium speed preparing to stop at next signal	At entrance of medium speed route or block, to govern the approach to Slow-Clear, Slow-Approach, Permissive, Restricting, Stop and Proceed, or Stop signals and end of signaled territory.
287		Slow-Clear	Proceed, slow speed within interlocking limits	At entrance of slow speed route or block, to govern train movements at slow speed.
288		Slow-Approach	Proceed preparing to stop at next signal; slow speed within interlocking limits	At entrance of slow speed route or block, to govern the approach to Permissive, Restricting, Stop and Proceed, or Stop signals
289		Permissive	Block occupied, proceed prepared to stop short of train ahead Designate by 1 Letter plate, or 2 Marker light, or 3 Shape of arm, or 4 Combination of these distinguishing features	At entrance of a manual block to govern trains entering and using that block.
290		Restricting	Proceed at restricted speed	At entrance of normal speed, medium speed, or slow speed route or block, to permit trains to proceed prepared to stop short of train, obstruction, or anything that may require the speed of the train to be reduced
291		Stop and Proceed	Stop, then proceed at restricted speed Designate by 1. Number plate, or 2 Marker light, or 3 Pointed blade, or 4 Combination of these distinguishing features Note Railroads desiring to avoid stopping trains may arrange accordingly	At entrance of a route or an automatic block requiring trains to stop and after stopping, permitting them on two or more tracks to proceed at restricted speed and on single track in accordance with the rules.
292		Stop	Stop	At entrance of a route or block requiring trains to stop until authorized to proceed by train order, clearance card, more favorable indication than Stop, or in accordance with the rules.

Figure 5-1. AAR STANDARD CODE SIGNAL ASPECTS, TITLES AND INDICATIONS (SHEET 2 OF 2)

SECTION 6.0

STANDARD RULES AND REGULATIONS FOR SIGNAL SYSTEMS

As was stated earlier the purpose of the study is to analyze railroad signaling systems with the objective of recommending an overlay signal system for high speed passenger train operation which will not interfere with the existing signal systems now used for freight, commuter or conventional passenger train operations. The speeds involved for high speed passenger train operations will require the employment of a cab signaling system and, possibly, an associated train control system. In the following analyses and recommendations, the required elements of such a signaling system will be described as well as the manner in which the system must interface with existing cab and wayside signal systems. Attention has been given to the effects of such a system on operational standards and Federal regulations.

6.1 Signal Rules, Regulations and Indications Analyses

The primary consideration of any signal/control system should be safety. However, the evaluation of a signal system must also include the functions it will perform and services it will render. The application of the signal/control system will therefore determine the aspects needed for its proper operation. Each aspect must convey a particular indication to the engineer or operator, and the indication should be uniform and simple, yet provide for safety. Of primary consideration in establishment of a signal system is the braking distances of the trains involved. However, other factors affect the signal/control systems such as motive power, civil limitations, speeds of operation and traffic density.

6.1.1 Rules

A prerequisite for the development and installation of an overlay signal system is an understanding of the existing signal system and the interface with it. There are many configurations of existing signal systems to consider.

The lack of standardization among domestic railroads is evident in a comparison of the way in which several railroads have used the eighteen rules defined in the AAR Standard Code (reference appendices C, D and E). Rules 281 thru 292 are used in the AAR Standard Code to define the aspects, titles and indications. For the same purpose Union Pacific and Milwaukee number their rules 222, 240 (with alphabetical suffixes) and 501; Southern and Burlington Northern number their rules 301 thru 318; Seaboard Coast Line uses rule numbers 501 thru 518. Many of these are synonymous with the AAR Standard Code and differ only in the rule numbers. In some cases there are different titles or indications while in others different aspects.

6.1.2 Aspects, Titles and Indications

There is greater uniformity in signal titles used by domestic railroads. A comparison of titles in appendices C, D and E shows a modicum of standardization. Speed limits are specified by RESTRICTED; SLOW, MEDIUM, LIMITED AND CLEAR.

Prefixes and suffixes are used to modify the major speed classifications of the signal titles to convey additional indications to the locomotive engineer.

APPROACH and ADVANCE prefixes to a signal title are used when signal spacing and the tonnage of trains required more than one block length to stop. This signal indication provides the necessary warning to allow a reduction to the indicated speed. When used as suffixes in the title they provide the same advance warning of home restricting or stop signals.

APPROACH is used as a prefix to a speed indicator to denote that a reduction to the indicated speed is required by the next signal. For example; APPROACH MEDIUM indicates, "Proceed, approaching the next signal at Medium Speed." The addition of a second suffix such as ADVANCE, provides a new indication referring to the second signal in advance of a train. For example; ADVANCE APPROACH MEDIUM indicates, "Proceed, approaching second signal at medium speed."

A speed indicator title with a modifier suffix indicates a reduction in speed is required with a preparation to stop. For example, MEDIUM APPROACH indicates, "Proceed at medium speed, preparing to stop at the next signal." The addition of a second prefix, ADVANCE, indicates instructions for the second signal in advance of a train. For example, MEDIUM ADVANCE APPROACH indicates, "Proceed at medium speed, preparing to stop at second signal."

These rules for titles and indications are well established, and the wordage and intent are familiar to all domestic users. Therefore, the same terminology should be included in a standard system of titles to portray the intended meanings with clarity and conciseness. An analysis has been made of established speed limits among domestic railroads, and there appears to be only two examples where railroads differ in their definitions of MEDIUM and LIMITED speed ranges. MEDIUM is most often defined as 48 km/h (30 MPH) and LIMITED as 72 km/h (45 MPH). SLOW and LOW speeds are standard at 24 km/h (15 MPH) and 32 km/h (20 MPH) and seem to be close duplicates. LOW speed may well be eliminated and replaced with RESTRICTED speed at a standardized 24 km/h (15 MPH), while SLOW speed would indicate 32 km/h (20 MPH).

6.1.3 Adequacy of Government Regulations

The FRA conducted a public hearing on Railroad Safety in February of 1979. The principal topics of discussion were the Rules, Standards and Instructions (RS&I) and how they should be expanded or revised to increase safety and encompass all phases of Signaling and Train Control (S&TC) systems. Appendix J provides an agenda of the meeting and a summary of the proceedings.

The response of most participants included a concurrence that safety should be the ultimate goal of all S&TC systems. Operating railroads, in general, would like to operate without Federal regulations, but are realistic enough to recognize and understand the need of some regulations.

During the hearing, the RS&I topics most frequently discussed were:

- Rules which do not allow removal of a signal system when they are no longer beneficial to operations or economics. Most railroad representatives would like to make the removal determination themselves.

- Rules establishing spacing of signal blocks. Most railroads would prefer to space signals to suit the terrain and traffic conditions.

- Requirement for electric locks on switches in Traffic Control systems. Railroads in general contend this discourages competition with the trucking industry because of the cost of electric locks when adding spur lines to potential customers.

Additional topics referred to by participants included:

- The slow response of the FRA to requests by railroads to modify or delete signals or devices.

- Human error in repairing signals.

- Vandalism of signal equipment.

- Inadequate training of signal personnel.

- Lack of performance oriented requirements in the Federal regulations, although some felt a combination of performance and design requirements would be best.

- Signalmen felt the requirement to repair faulty equipment without "undue" delay should be more stringent and the term "undue" defined in terms of hours, minutes, etc. Railroad representation felt "undue" delay should mean before the next train operation.

The National Transportation Safety Board (NTSB) and Railway Labor Executive Association (RLEA) expressed concern about the FRA's failure to inspect and to enforce the requirements of the current regulations.

The Railway Progress Institute, which represents the railroad suppliers, stressed the need for a slow evaluation of signal system technology, citing the currently used fail-safe system as proven and reliable.

The NTSB recommended the use of more signal systems, especially cab signaling, for improved safety and reduction of accidents. The NTSB noted that the purpose of signal systems is safety of operation and that improved traffic density and more efficient operations are secondary benefits. They recommended elimination of the "stop and proceed" signal indication. The NTSB was in favor of simplified performance standards used in conjunction with design specifications for signal systems in general. They also stressed improved enforcement of regulations.

The Association of American Railroads (AAR) proposed that regulations for radio communications be changed to allow the railroads some flexibility in adapting radio to more efficient operation of trains. AAR submitted a proposed revision to the RS&I which was reviewed and is available in the reference library as Document reference 403, Appendix A.

6.1.4 RS&I and Signal System Compatibility

An overlay signaling system for high speed passenger train operation will require some form of cab signaling. The manner in which any such overlay system interfaces with the existing cab signals and wayside signals could conflict with current RS&I rules. Since the recommendation for a specific overlay signal/control system is not part of Task 3, some potential interface problems will be noted and recommendations made for changes which will be necessary for an overlay signal system. The following areas are in apparent conflict.

Speed Limits

The speed restrictions referred to in RS&I paragraph 236.501 as low-speed and medium-speed will require specific km/h (MPH) values to be assigned to be compatible with an overlay signal/control system. Freight and commuter trains will be assigned a standard speed while high speed passenger trains will operate under different assigned speeds unless negated by the failure of the overlay signal/control system.

Automatic Brake Application

The manner in which automatic brake application may be initiated for high speed passenger trains may not be directly interconnected to wayside signals as required in RS&I paragraph 236.504. For high speed trains, where the braking action may be initiated some distance ahead of the point where braking by a slower train would occur, the braking may not be initiated by main track signals as required by paragraph 504 of the RS&I but in progressive steps before reaching the wayside signal. Such braking would probably be initiated by the overlay cab signaling system.

Interconnection of Cab Signals and Wayside Signals

An overlay signal/control system for the purpose of controlling trains at speeds above 160 km/h (100 MPH) will not be compatible with wayside signals whose signals operate under separate and lower speed limits. Therefore, the requirements of RS&I paragraph 236.514 will be in conflict with the overlay signal/control system authorizing operation at speeds higher than wayside signals.

Radio Communications

It is anticipated that signal/control data may be required in radio communications. Regulations in CFR part 220 are only for normal voice communications and transmittal of train orders.

Signal Aspects, Titles and Indications

There is no apparent conflict between any of the candidate overlay signal/control systems and RS&I requirements for signal aspects and indications. However, standards should be set by the RS&I so that passenger trains such as AMTRAK would be responding to the same aspects and indications regardless of which railroad the train may be operating over or the type of signal system used in the local territory.

6.2 Recommended Revisions to the Rules, Standards and Instructions (RS&I)

The AAR has looked at the RS&I from a total viewpoint including appliances, equipment and regulations related to the problems of operating a revenue railroad. Since the AAR is an organization whose membership is composed of private railroads and suppliers, it represents the industry viewpoint. The AAR presented a proposal for revisions to the RS&I at the Inquiry of Signal and Train Control Safety by the FRA. Under the AAR proposal, revision of the RS&I was recommended to reflect appliances or equipments to include state-of-the-art or anticipated signal system technologies. The AAR proposed revisions to the RS&I have not been directly included in in this task because the depth of change includes many areas not addressed herein. However, the complete text of AAR's proposed revision of the RS&I is retained in the study library as Document reference 403, Appendix A.

The suggested areas of revision to the RS&I which follow are a result of analysis projecting the use of an overlay signal/control system for high speed passenger train service on normal train routes. The analysis was made of an accumulation of data inputs from a number of sources. Candidate overlay systems were identified and recommended for further study in Task 2. Although a specific overlay signal/control system has not been designated, candidate systems that reflect the latest available technologies are discussed and evaluated therein. A level or category of system implementation was outlined providing system configuration requirements. A combination of existing system technologies will most likely be the overlay signal/control system configuration that will be recommended in Task 6 of this program.

The following paragraphs of the RS&I (49 CFR 236) are recommended for revision based upon the anticipated overlay signal/control system.

Part 236.23 - Aspects and Indications. The safety of intercity passenger train service would be enhanced by the standardization of signal aspects, titles and indications for the signal types in use. RS&I paragraph 236.23 provides the conditions and requirements for aspects and indications but does not prescribe or define specific aspects, titles or indications. To be enforcible, this paragraph should be revised to include a standard.

Appendices C, D and E illustrate the wide variety of signal aspects, titles and indications that have developed under current regulations. The enforcement of the 18 rules in the AAR Standard Code could be the first step in the progressive establishment of standard signal aspects, titles and indications recommended in this report. A progressive or evolutionary approach to standardization would moderate the economic impact associated with such an undertaking.

Part 236.24 - Spacing of Roadway Signals. This paragraph should be revised to allow trains to utilize an overlay cab signal control system to govern speed control and/or brake application by the cab signal system independent of the roadway signal. The braking control commands initiated by the cab signal control system may or may not coincide with the roadway signals. Analysis of braking curves, presented in paragraph 6.3 herein, indicates there is a definite relationship of speed and braking distances between high speed passenger and freight trains. The block lengths in a signal/control system must be based on a standard length or spaced for the worst case braking distance. A signal spacing study analysis performed under the Northeast Corridor Improvement Project (NECIP), document reference 276, Appendix A, provides a comparative analysis between metroliner, normal passenger and freight train speed/braking curves.

Part 236.51 - Track Circuit Requirements. This paragraph should be revised to expand the term "track relay" to include other proven devices that may control home signals. This simple change does not affect the intent of the rule yet would allow the use of equipments employing track circuit control techniques other than relays. Computer controlled redundancy and/or programmed voting regimes are used in systems that have been identified as candidate overlay systems which achieve the same levels of highly secure operation without relays. The German continuous automatic train control (CATC) system uses a continuous inductive loop type instead of track circuits. The inductive conductor is laid between the rails independently of the existing track circuits.

Part 236.566 - Locomotive Operating in Cab Signal Territory; Equipped. This paragraph requires that all locomotives operating in cab signal, train control or automatic train stop territory shall be equipped with devices which are responsive to track or wayside activating devices. The operating principle for an overlay signal system for high speed passenger trains will directly conflict with this regulation. Operationally, freight and commuter passenger locomotives will operate with the currently installed signal system which may be wayside or cab signaling. High speed passenger locomotives will operate with an overlay to the existing signal system. In accordance with the subject paragraph, the freight and slower passenger locomotives must also be equipped with devices for the overlay signal/control system, which would negate the intent of the overlay system both operationally and economically. One important characteristic in the operation of an overlay signal/control system for high speed passenger trains is that it does not affect normal operations of the existing signal/control system or equipment. Therefore, this paragraph should be revised to state that moderate speed train traffic (not exceeding 130 km/h (80 MPH) must be capable of operating with the existing signal/controls and the applicable regulations, while the high speed passenger trains shall be capable of operating with both the existing signal/control system and the overlay signal/control system. The Task 2 final report establishes the requirement that existing signal/control systems must at least be ac coded automatic block. Candidate systems for an overlay system may utilize additional track circuits such as the overlay track circuits proposed for the NECIP, non-track circuit systems such as the German CATC inductive system or the British Columbian LIC interrogative system.

Part 236.568 - Different Speed Authorization Roadway/Cab Signal. This paragraph deals with the difference between speeds authorized by roadway signals and cab signals. Conditions of this paragraph should be changed to allow different speeds to be authorized between wayside and overlay cab signal control systems. The type of overlay signal system installed will determine the interface requirements and define the speed differentials.

Addition to the RS&I - ICC Order 28543, which is partially included now, should be totally incorporated within the RS&I to eliminate the need of interpretation between the two documents. The ICC orders are currently enforced in consonance with the RS&I and combining these regulations would be appropriate. The speed limits established by the ICC orders for operation of trains under certain required signal systems do not seem to pose an operational problem for most domestic railroads and are acceptable limits as established for current freight and commuter trains.

Part 220 - Radio Standards and Procedures. This part of Federal regulations defines the radio procedures to be used in conjunction with railroad operations. The regulation further establishes the criteria for transmission of train orders by radio. These regulations do not directly affect signal control systems. The inclusion of an overlay signal system with cab signaling and train control functions, in addition to the wayside signal systems, may require the use of radio communications for transmission of voice, data commands and system status. It is reasonable to expect that research will be undertaken to determine the feasibility of utilizing this medium to transmit commands for vital functions. In anticipation of this, Part 220 should be expanded to provide for communication at frequencies above current voice channels for use with signal control systems. Typical data would include:

Train-to-Wayside
- Train Identification
- Train Position
- Train Velocity

Train & System Status
Retained Command Signal

Wayside-to-Train
Speed Command
Enforcement Signals
Cab Signal Data

Voice Channel Available

6.3 Recommended Standard Wayside Signal Aspects, Titles and Indications.

This study specifically deals with the development of an overlay signal/control system that can be utilized with existing signal systems to control passenger trains operating at high speeds on lines which the passenger trains share with slower moving trains. The Task 2 final report defines the hardware and levels of implementation to meet these requirements. At a minimum the existing signal systems must be an automatic block system employing ac coded track circuits. Since a variety of signal/control systems are employed on domestic railroads and a final design of the overlay signal/control system is to be defined in Phase II of the Signal/ Control Development Program, any recommended standard signal aspects, titles and indications will be directed toward the requirements of overlay systems. In a broad sense the aspects of the proposed signal system can be compatible with present as well as proposed signal control systems, including the NECIP signal control system.

It may be that adoption of a standardized system of signals, aspects, titles and indictions is not economically justifiable at this time. However, consideration should be given to the adoption and implementation of a standard system for future signal control improvement projects such as the one under development for the NECIP. The use of an overlay system on the routes used by Amtrak would be another method for progressive implementation.

The current signal aspects, titles and indications have been analyzed with the proposed standard system in mind. Both domestic and foreign railroads, human engineering standards, and fail-safe requirements have been evaluated. The standards recommended are also within the existing AAR Standard Code.

These recommendations will address the requirements of cab signals and their applicability to passenger service at speeds in excess of 130 km/h (80 MPH). Wayside signals have also been considered since the proposed signal/control system must be compatible with existing systems and will require information exchange between locomotive and wayside to ensure safety. Figure 6-1 illustrates the recommended table of standard wayside signal aspects, titles and indications.

The recommended system employs a dual color light signal wherein each lens projects one color: green, yellow or red. Based on long established standards, green indicates go, clear or lack of danger; yellow indicates caution; and red indicates danger. It is with this reason that the current practice of green over red or green over red/red as a CLEAR indication will not be followed. Any aspect that indicates CLEAR or a condition of CLEAR will utilize green or green and yellow in combination only. Each principal aspect will denote a specific speed limit. Secondary aspects, that is, those with ADVANCE or APPROACH modifiers in their title, will still indicate a definite speed limit, but will convey advance instructions as well.

The proposed wayside signal aspects were selected on the basis of a logical progression using accepted human engineering principles. The basic aspects are: green/green the least restrictive (CLEAR); yellow/yellow caution or moderate (MEDIUM) speed; and red/red absolute STOP. Green/yellow indicates LIMITED and yellow/green the upper limit of caution (MEDIUM) with yellow/red the lower limit of caution. Red/yellow or red/red indicates

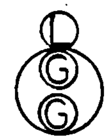
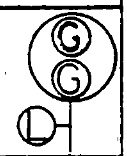
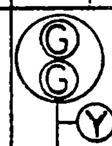
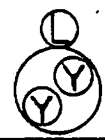
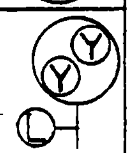
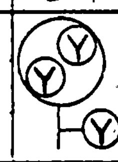
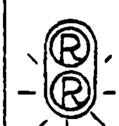
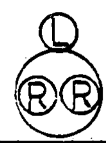
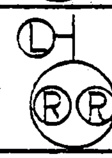
TITLE	INDICATION	COLOR LIGHT ASPECT	COLOR POSITION ASPECT
CLEAR	Proceed at 150 mph on cab signaling for passenger service only.		
CLEAR	Proceed at 120 mph on cab signaling for passenger service only.		
CLEAR	Proceed at maximum allowable speed. Trains exceeding 80 mph must include cab signaling.		
LIMITED	Proceed at limited speed.		
APPROACH MEDIUM	Proceed approaching next signal at medium speed. Train exceeding limited speed must at once reduce to that speed.		
MEDIUM	Proceed at medium speed.		
MEDIUM APPROACH	Approach at medium speed preparing to stop at next signal.		
SLOW	Proceed at slow speed.		
RESTRICTING	Proceed at restricted speed.		
STOP AND PROCEED	Stop and proceed at restricted speed. Proceed prepared to stop short of train or obstacle.		
STOP	Stop.		

FIGURE 6-1 RECOMMENDED STANDARD WAYSIDE SIGNAL ASPECTS, TITLES AND INDICATIONS

lowering levels of restricting speed or stop. The use of red/green as STOP AND PROCEED is self-indicating and easily distinguishable from absolute STOP red/red or RESTRICTED speed red/red flashing. Operating rules must include instructions that the loss of a lamp, damage or other failure will be interpreted as a more restrictive indication. It is proposed that the signals utilize two lights each containing two filaments with an automatic changeover when the active filament burns out. This arrangement provides redundancy and minimizes the occurrence of dark signals which may be overlooked or missed during night operations.

With a double light system, the displaying of a single light will indicate a signal system failure and a stop or slow speed indication would be established as a requirement in the operating rules. The rules must require a dark signal to be interpreted as red when the upper or lower color is discernable; the least restrictive signal would be SLOW. An interpretation of green over red is an exception, since this is not a valid aspect in the proposed system. Standard operating instructions under these conditions should include instructions to STOP until cleared by he dispatcher, or STOP AND PROCEED until the next valid signal is encountered. Figure 6-2 shows a matrix of aspects wherein lamp failure has occurred, and the operational aspects are designated for each lamp failure.

The use of a round speed limit marker, preferably illuminated, will indicate special or intermediate speeds for interlocking, diverging route or civil restrictions. Diamond shaped markers with the letters S, P, or G will be used for "take siding," "permissive" (with STOP AND PROCEED aspects) or "grade" (tonnage proceed), respectively, as required to define specific train operating limitations. Figure 6-3 illustrates these auxiliary markers.

	CLEAR	LIMITED	MEDIUM	SLOW	RESTRICTED OR STOP
NORMAL ASPECT	G G	G Y	Y Y Y G Y R	R Y	R R R R G R
FAILURE OF UPPER LAMP (ASSUMED RED)	R G	R Y	R R R G Y R	R Y	R R R R G R
FAILURE OF LOWER LAMP (ASSUMED RED)	G* R	G* R	Y Y Y R R R	R R	R R R R R R

*GREEN OVER RED IS NOT A VALID ASPECT. SUCH CONDITION WOULD BE ASSUMED TO BE YELLOW OVER RED OR RED OVER RED BY THE OPERATING STANDARD OR INSTRUCTION.

FIGURE 6-2 ASPECTS VS. LAMP FAILURE

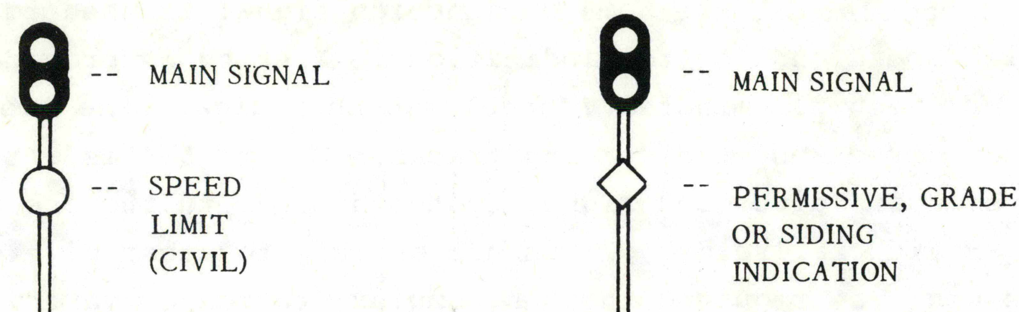


FIGURE 6-3 RECOMMENDED STANDARD AUXILIARY MARKERS

Appendices G, H, and I show the aspects, titles and indications for the British, German and Russian railroads respectively. All three illustrate the established human engineering principle using green, CLEAR; yellow, CAUTION and red, STOP. Yellow is used to designate degrees of caution in conjunction with green and red, but red and green are not used together for home signals.

There is a distinction between block (and approach) signals and interlocking signals on domestic railroads. Staggered signals, that is signals mounted on alternate sides of the signal mast, generally indicate block signals and vertically stacked signals designate interlocking signals. This practice appears to be directly contrary to human engineering principles. The British have a very graphic system for indicating divergent routes (appendix G). The home or junction signal is used to establish speed and control indications. Routing is provided by red or green illuminated roundels which indicate the clear route and direction of diverging tracks. Figure 6-4 is a recommended standard diverging signal system similar to the one used by the British railroads. It is not anticipated that diverging signals would be required through complex station or yard interlockings where speed through the interlocking limits has been established. The home/diverging signal would be utilized for home signals governing movements on or off main tracks only. The use of dwarf signals throughout the sidings and interlockings would remain in effect. Dwarf signals would use duplicate aspects of high mast signals.

Figure 6-5 extends the recommended standard signal system into 11 and 15-aspect systems. The latter two are proposed as alternative, interim standards. As will be described below, the 15-aspect system approximates a composite of existing signal systems. Its adoption would therefore require the least initial investment. It is, however, the least desirable from the standpoints of maintenance and locomotive engineer comprehension.

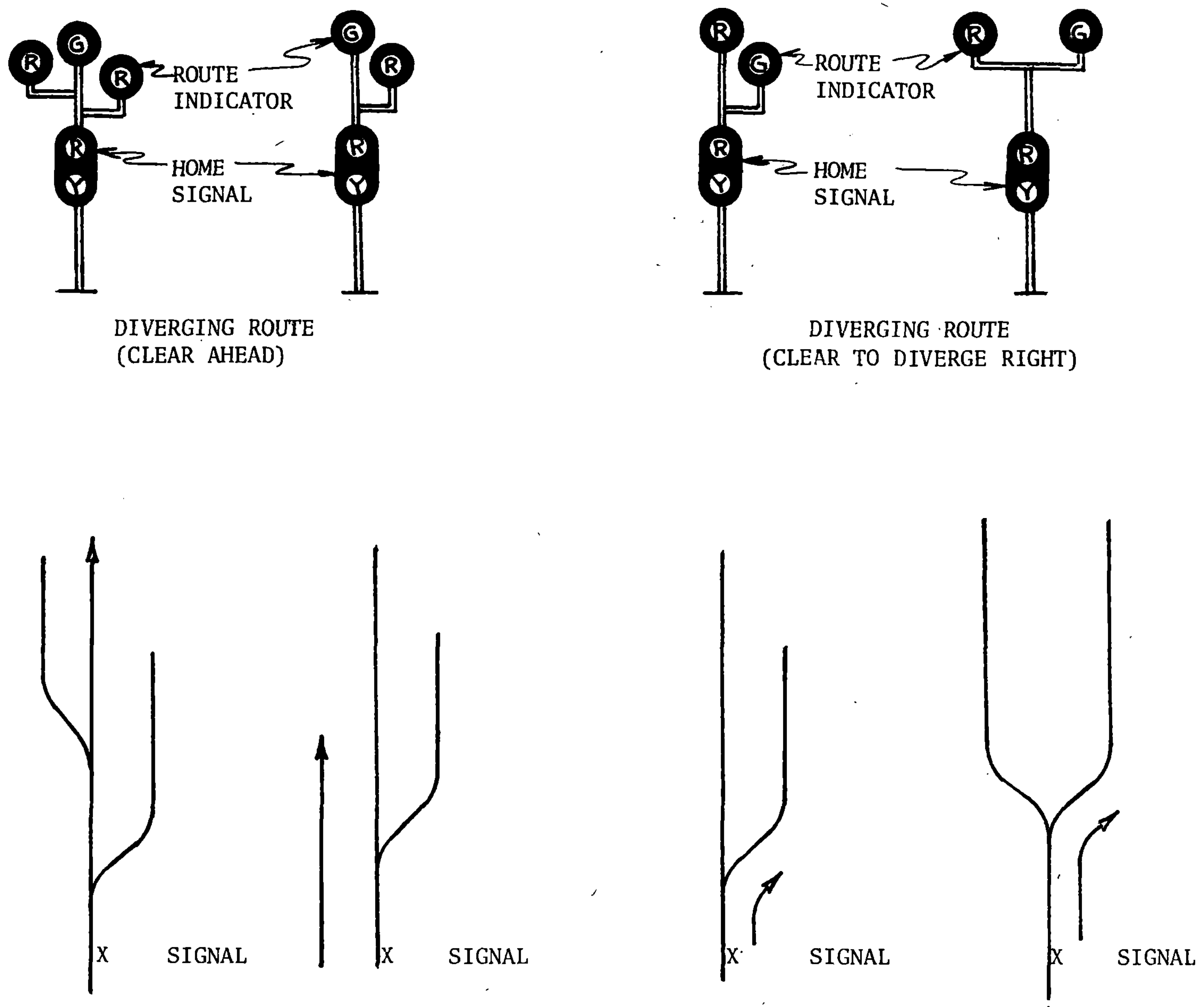


FIGURE 6-4 RECOMMENDED STANDARD WAYSIDE DIVERGING ROUTE SIGNALS

TITLE	INDICATION	3 ASPECT 2 BLOCK		9 ASPECT 3 BLOCK		11 ASPECT 4 BLOCK		15 ASPECT 4 OR 5 BLOCK	
CLEAR	PROCEED AT MAXIMUM ALLOWABLE SPEED (NOTE: ALL TRAINS EXCEEDING 80 MPH OR ABOVE MUST HAVE CAB SIGNALING).	G	L G G	G G	L G G	G G G	L G G	G G G	L G G
APPROACH LIMITED	PROCEED, APPROACHING NEXT SIGNAL AT LIMITED SPEED.	N/A	N/A	N/A	N/A	N/A	N/A	G G Y	L G G
LIMITED	PROCEED AT LIMITED SPEED.	N/A	N/A	G Y	G G L	G Y G	G G L	G Y G	G G L
LIMITED APPROACH	APPROACH AT LIMITED SPEED, PREPARING TO STOP AT THE NEXT SIGNAL.	N/A	N/A	N/A	N/A	G Y Y	G G	G Y Y	G G
ADVANCE APPROACH MEDIUM	PROCEED, APPROACHING SECOND SIGNAL AT MEDIUM SPEED.	N/A	N/A	N/A	N/A	N/A	N/A	Y G G	G G L
APPROACH MEDIUM	PROCEED, APPROACHING NEXT SIGNAL AT MEDIUM SPEED. TRAIN EXCEEDING LIMITED SPEED MUST AT ONCE REDUCE TO THAT SPEED.	N/A	N/A	Y G	G G Y	Y G Y	G G Y	Y G Y	G G Y
MEDIUM	PROCEED AT MEDIUM SPEED.	Y	L Y Y	Y Y	L Y Y	Y Y Y	L Y Y	Y Y Y	L Y Y
MEDIUM ADVANCE APPROACH	PROCEED AT MEDIUM SPEED, PREPARING TO STOP AT SECOND SIGNAL.	N/A	N/A	N/A	N/A	N/A	N/A	Y Y R	L Y Y
MEDIUM APPROACH	PROCEED AT MEDIUM SPEED, PREPARING TO STOP AT NEXT SIGNAL.	N/A	N/A	Y R	Y Y L	Y R Y	Y Y L	Y R Y	Y Y L
APPROACH SLOW	PROCEED, APPROACHING NEXT SIGNAL AT SLOW SPEED. TRAIN EXCEEDING MEDIUM SPEED MUST AT ONCE REDUCE TO THAT SPEED.	N/A	N/A	N/A	N/A	Y R R	Y Y	Y R R	Y Y L
SLOW	PROCEED AT SLOW SPEED.	N/A	N/A	R Y	Y Y Y	R Y Y	Y Y Y	R Y Y	Y Y Y
SLOW APPROACH	PROCEED AT SLOW SPEED, PREPARING TO STOP AT NEXT SIGNAL.	N/A	N/A	N/A	N/A	N/A	N/A	R Y R	Y Y
RESTRICTING	PROCEED AT RESTRICTED SPEED.	N/A	N/A	R R	L R R	R R Y	L R R	R R Y	L R R
STOP AND PROCEED (PERMISSIVE)	STOP AND PROCEED AT RESTRICTED SPEED. PROCEED PREPARING TO STOP SHORT OF TRAIN, OBSTACLE OR BROKEN RAIL.	N/A	N/A	R G	N/A	R R G	L R R	R R G	L R R
STOP	STOP.	R	R R	R R	R R	R R R	R R	R R R	R R

FIGURE 6-5 RECOMMENDED STANDARD WAYSIDE EXPANDED ASPECTS, TITLES AND INDICATIONS

The figure demonstrates that the 15-aspect system serves as a foundation for evolutionary development toward systems with fewer aspects and simpler hardware.

The 11-aspect standard is a logical step toward simplicity, but requires more hardware alterations. Adoption of this or the ultimate 9-aspect standard could be carried out on a segment-by-segment basis as worn-out or obsolete hardware is replaced. The three aspect, two-block system is suggested for light density lines that will never see high speed passenger train operations.

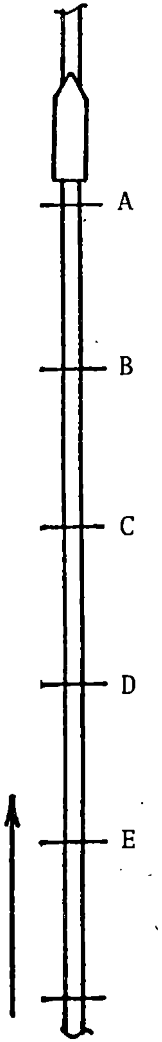
The number of signal aspects adopted by the survey railroads varies considerably:

RAILROAD	NUMBER OF ASPECTS
ATSF	11
B&O	17
BN	15
CN	17
C&O	15
CR; AMTRAK	23
D&H	12
D&RGW	9
ICG	13
L&N	8
MILW	15
N&W	12
RF&P	8
RI; MOPAC	11
SCL	17
SOU	18
SP	15
UP	11

The fifteen-aspect proposal was developed by noting all possible alternatives found in the survey and by combining identical or similar indications. The 18 rules and aspects provided by the AAR Standard Code are obviously the bases for most railroads' aspects, titles and indications. This factor was also relevant in formulating the system of standard aspects.

The titles have not been changed, but rather reflect familiar terms having meanings common to current usage. However, the signal title, CLEAR, following a specific speed, has been eliminated; for example MEDIUM-CLEAR now reads MEDIUM. Also eliminated were titles such as LOW and PERMISSIVE which appear to be closely synonymous with SLOW and STOP AND PROCEED, respectively. A signal title, in which APPROACH precedes a speed indicator word such as CLEAR, LIMITED or MEDIUM, will correspond to an indication requiring the engineer to reduce to the indicated speed by the next signal. The word, APPROACH, in a signal title after a speed indicator will require an immediate reduction to the indicated speed, and preparation to stop at the next signal. In a signal title either a prefix or a suffix modified by the word ADVANCE corresponds to an indication requiring the action to be completed at the second signal. ADVANCE signal indications are not included in the proposed standard system. This is based on the assumption that advance instructions will not be required with a properly designed signal aspect system with block lengths based on speed/braking curves. However, it is recognized that there are block systems in use today that require advance signal information especially for heavy tonnage freight trains in a passenger/commuter intermix or where civil limits, such as on grades and curves, require adding braking distances.

Figure 6-6 provides an illustration of speed correlations between freight and passenger trains for two, three and four-block signal systems. The speed braking curve shown in Inset 2,



MATRIX

SIGNAL (a)	2 BLOCK SYSTEM				3 BLOCK SYSTEM				4 BLOCK SYSTEM			
	FREIGHT		PASSENGER		FREIGHT		PASSENGER		FREIGHT		PASSENGER	
	SPEED	ASPECT	SPEED	ASPECT	SPEED	ASPECT	SPEED	ASPECT	SPEED	ASPECT	SPEED	ASPECT
A	0	R R	0		0	R R	0		0	R R	0	
B	30	Y R	45		30	Y R	45		30	Y R	45	
C	79	G G	150		45	G Y	60		45	G Y	60	
D	↓	G G	↓	↓	79	G G	150		45	G Y	60	
E	↓	G G	↓	↓	↓	G G	↓	↓	79	G G	150	

GRADE	MINIMUM BLOCK LENGTH PASSENGER / FREIGHT		
	2	3	4
+ 1%	4350 / 3800	2900 / 2533	2175 / 1900
0	5000 / 6000	3333 / 4000	2500 / 3000
- 1%	6000 / 14,500	4000 / 9666	3000 / 7250

INSET 1

INSET 2

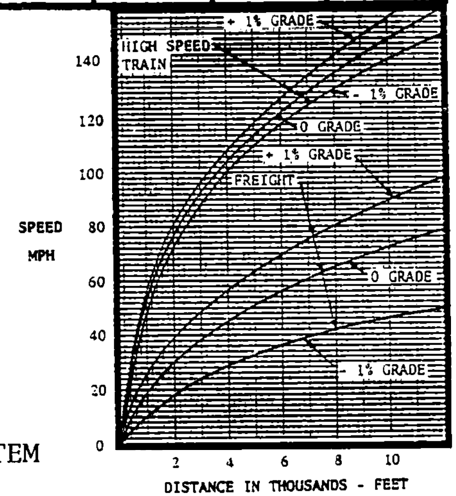


FIGURE 6-6 SPEED BRAKING CURVE WITH BLOCK SYSTEM

is summarized from Signal Spacing Analysis, Document reference 276, Appendix A, and provides the comparative braking distance requirements for a level grade, 1% ascending grade and 1% descending grade. This braking curve was used to develop the minimum block length shown in Inset 1, from which correlating speed limits were established for freight and passenger trains as shown in the matrix. The minimum block length distances shown in Inset 1 are based on a maximum speed of 240 km/h (150 MPH) for passenger trains and 130 km/h (80 MPH) for freight trains. The matrix provides the signal aspects and associated speed limits for a trailing train overtaking the preceding train for varying block systems. The matrix indicates aspects of the recommended nine-aspect signal system and considers that the excluded aspects are used to provide operational integrity in special requirements. An example is that all signals for the occupied block are shown as red/red or absolute STOP. However, operating conditions may require that the aspect be red/green for STOP AND PROCEED allowing a train to enter the occupied block at a restricted speed with visual alertness for the train ahead. The analysis of freight and passenger train speeds and braking curves verified that different speeds can be maintained safely by each train in blocks established for the worst case stopping distance.

Figure 6-7 is a correlation of the proposed wayside signals, cab signals and the corresponding speeds and indications for each aspect. The code rates for the existing wayside/cab signal system (100 Hz carrier) and the proposed overlay cab signal system (26- Hz carrier) are also correlated with the signal aspects. It is assumed that freight train traffic will operate over existing signal control systems while passenger trains will operate by utilizing the existing signal systems in conjunction with the added overlay signal control system. The passenger system will

TITLE	INDICATION	COLOR LIGHT ASPECT	COLOR POSITION ASPECT	CAB SIGNAL ASPECTS WAYSIDE REPEATER	CAB SIGNAL ASPECTS CAB DISPLAY	STANDARD SPEEDS FREIGHT	STANDARD SPEEDS PASSENG.	CODE RATES FREIGHT 100Hz	CODE RATES PASSENG. 260Hz
CLEAR	Proceed at 150 mph on cab signaling only.	G G	L G G	G G		N/A	150	180	180
CLEAR	Proceed at 120 mph on cab signaling only.	G G	L G G	G G		N/A	120	180	120
CLEAR	Proceed at maximum allowable speed. Trains exceeding 80 mph must include cab signaling.	G G	L G G	G G		79	80	180	75
LIMITED	Proceed at limited speed.	G Y	G G L	G Y		45	60	120	75
APPROACH MEDIUM	Proceed approaching next signal at medium speed. Train exceeding limited speed must at once reduce to that speed.	Y G	G G Y	Y G	↓				
MEDIUM	Proceed at medium speed.	Y Y	L Y Y	Y Y		30	45	75	75
MEDIUM APPROACH	Approach at medium speed preparing to stop at next signal.	Y R	Y Y L	Y R	↓				
SLOW	Proceed at slow speed.	R Y	Y Y Y	R Y		20	30	0	75
RESTRICTING	Proceed at restricted speed.	R R	L R R	R R		15	15	0	0
STOP AND PROCEED	Stop and proceed at restricted speed. Proceed prepared to stop short of train or obstacle.	R G	L R R	R G		0	0	-	-
STOP	Stop.	R R	R R	R R	↓	0	0	-	-

FIGURE 6-7 RECOMMENDED STANDARD WAYSIDE SIGNAL SYSTEM, SPEED LIMITS AND CONTROL CODES

utilize a cab signaling display and rely on wayside signals in case of failure of the overlay system. The signal/control system overlay interface requirements will be specified in Task 6 of the Phase I study program.

6.4 Recommended Standard Cab Signal Aspects, Titles and Indications.

The cab signal aspects described herein include only those associated with the overlay system and the recommended standard aspects. These titles and indications are included in Figure 6-7. Aspects are shown in two ways. The primary system is a quantitative display providing speed and control data in a numeric format similar to that shown in Figure 6-9. The secondary system is a repeat of the standard wayside signal. This is in effect if a numeric display is not operative because of the absence of the second ac carrier (260 Hz) or other overlay system for passenger service. A cost analysis will be made during Task 5 to establish the economic benefits available for each type of system. If a Continuous Automatic Train Control (CATC) system proves economically feasible, the primary cab signal indicator should be a quantitative display, providing the train operator with data in a direct reading, digital format. Figure 6-8 provides a typical CATC cab signal display currently in use in one European CATC system.

Figure 6-9 depicts a possible cab signal display for standard application. The display will provide the train operator with direct digital readout information for the target or allowable speed, actual speed and distance to next speed change assuming the data is available in the system. A wayside signal repeater will be incorporated into the display to be used in case of failure of the CATC or other overlay signal/control system. A white light will indicate the operation of the overlay signal/control system. An unlighted white indicator denotes failure

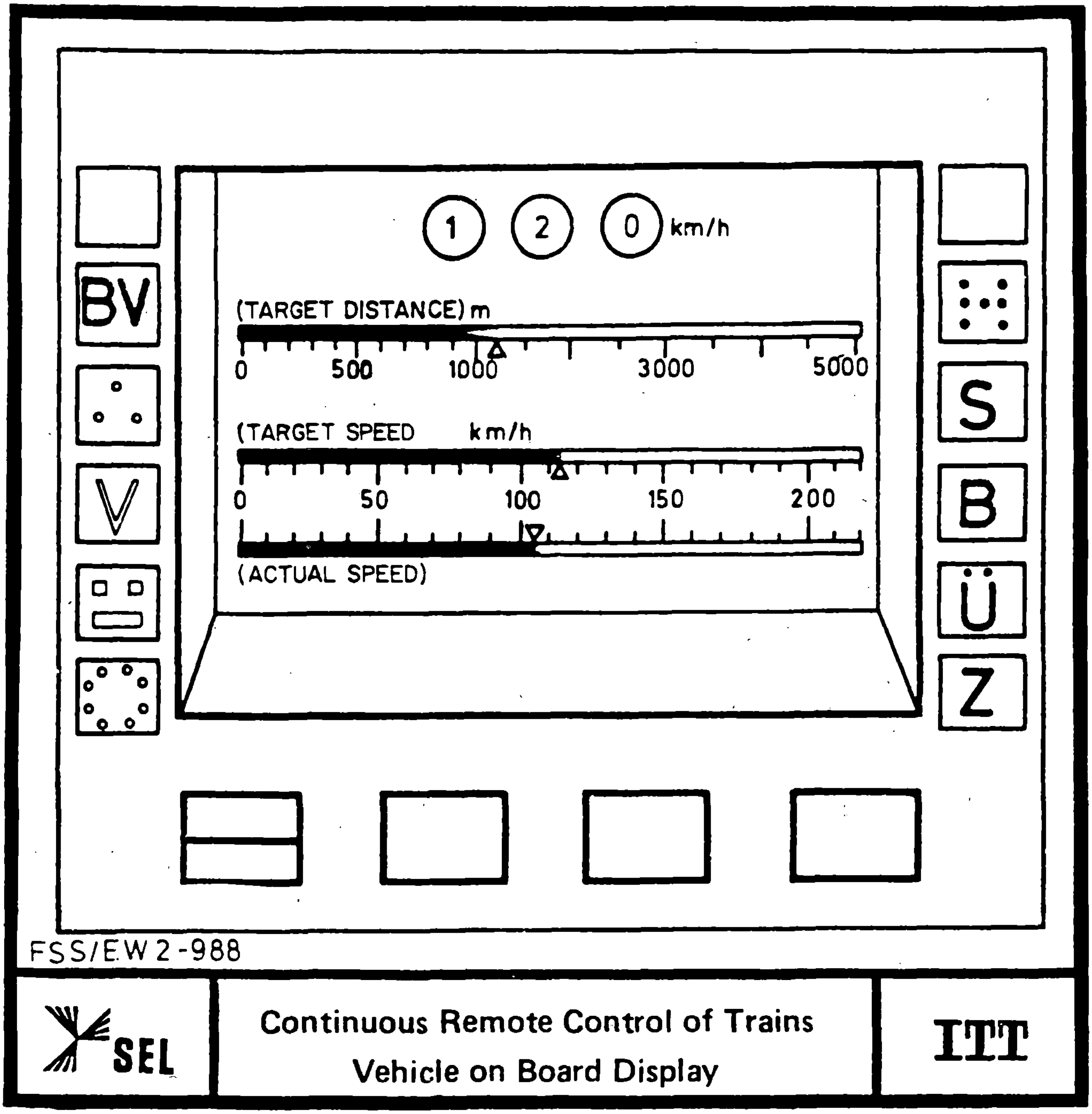


Figure 6-8. CATC CAB SIGNAL DISPLAY

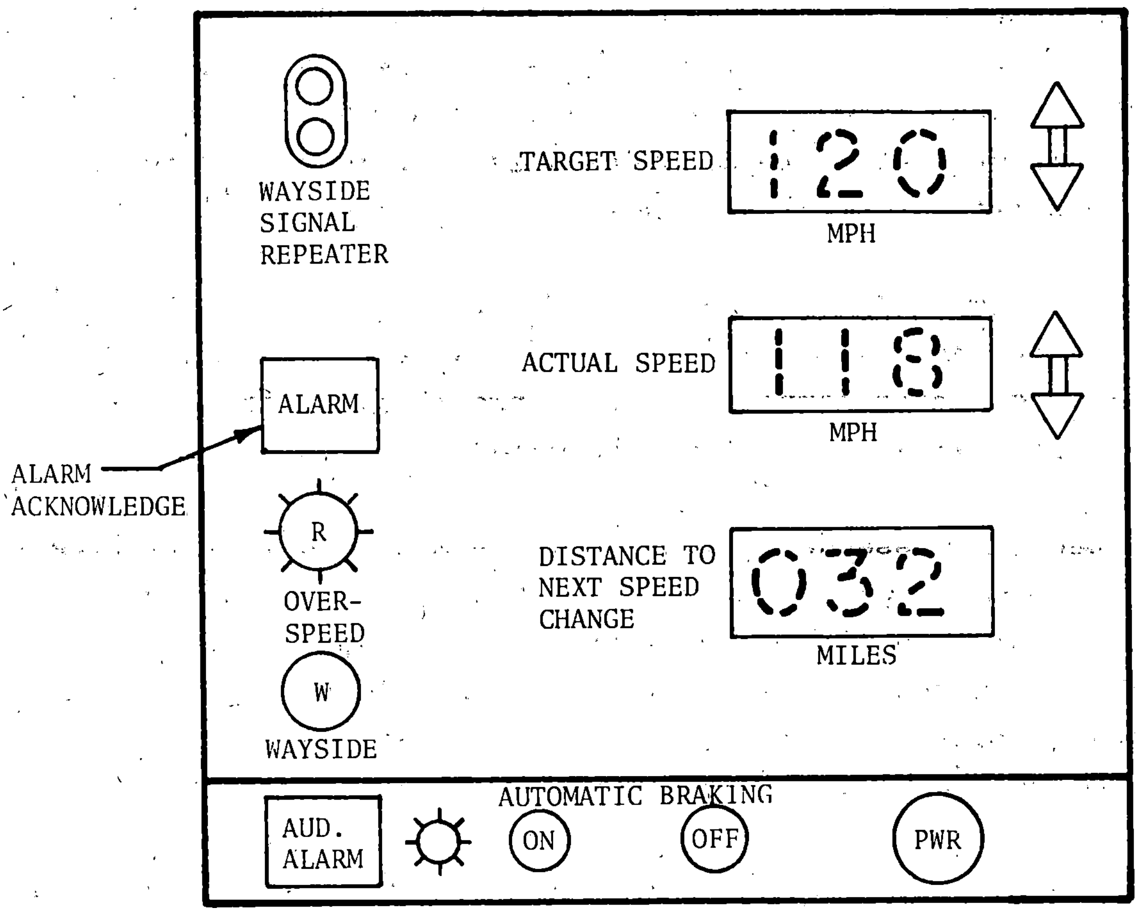


FIGURE 6-9 RECOMMENDED CAB SIGNALING CONTROL DISPLAY

of the overlay signal/control system, requiring operation governed by wayside signals at reduced speeds. This is a safety feature to accommodate failure of the overlay signal/control system. The system allows the passenger train to operate from the wayside (100 Hz) signals at speeds of 130 km/h (80 MPH) and below until the overlay system or system component is restored to working order.

The cab signal/control display may also include status information for automatic train control (ATC) in the overlay signal/control system. Indications will be provided for automatic brake controls, including a flashing indicator when the operator control is automatically overridden. Automatic brake application indications are also included.

An alarm will be provided to notify the operator of a lower speed restriction. An acknowledge switch will allow him to make speed corrections in a preset time period before automatic braking control is activated.

Because passenger trains will operate at different speeds for identical signal aspects, a method will be required to identify and provide finite speed limits for civil restrictions such as curves, turnouts, switches and track conditions. The recommended standard aspects, titles and indications provided a means of showing speed limitations with wayside auxiliary markers.

Two APPROACH aspects have been defined in the standard system of aspects to provide advance warning for a divergence or civil limitation requiring a severe speed reduction. This subject is discussed in articles "Signaling for High Speed" document reference No. 219, Appendix A and "High Speed Trafic Signaling" document reference No. 85, Appendix A. One note of interest arising from these articles is the statement that signals for high speed operation should be limited to four aspects, otherwise the operator's task becomes too complicated. It may seem contradictory to accept this statement when the proposed standard is an nine-aspect signal system. However, it should be noted that only three aspects are utilized for operation above 130 km/h (80 MPH). This is responsive to the guidelines established in the referenced articles. Except to establish reasonable operating speeds, signal aspects used at 130 km/h (80 MPH), and below, provide safe interface with slower freight/commuter train traffic and are not necessarily required for higher speed train operations.

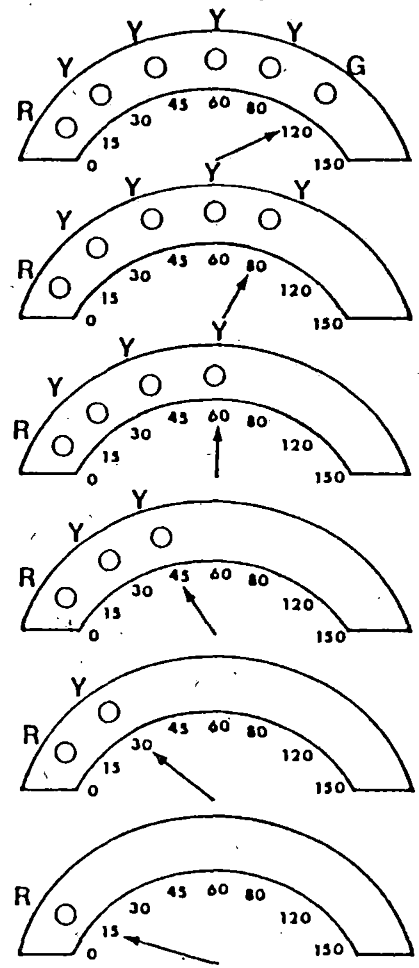
Similar consideration must be given to the overlay signal/control system with regard to the need for activating fixed speed restrictions at all operating speeds. When an added carrier frequency (260 Hz) is provided for passenger trains, this carrier frequency may be eliminated in the track block involving a restriction. This forces the operator to use wayside signals (or a repeat of wayside signals in the cab) thereby enforcing a required civil speed limit. If a CATC or other type of overlay system is utilized, a track profile, stored in the processor equipment, will be required to define and adjust speeds to civil restrictions. These target speeds in this case will be projected on the digital speed control indicator to enforce action by the locomotive engineer.

Figure 6-10 illustrates the cab signal speed aspects proposed for the NECIP. These are included for their comparative value with the cab signaling system proposed herein for high speed passenger train service.

FIGURE 6-10 NORTHEAST CORRIDOR IMPROVEMENT PROJECT

CAB SIGNAL SYSTEM SPEED ASPECTS

TRACK CIRCUIT CODE (PULSES PER MINUTE) 100 Hz	260 Hz	AUTHORIZED SPEED (MPH)	CAB SIGNAL SPEED ASPECT DISPLAYED: 4-ASPECT SYSTEM CAB LIGHT SIGNALS	7-ASPECT SYSTEM: METROLINER AND AEM 7 SPEEDOMETER SIGNALS	7-ASPECT SYSTEM: DIGITAL SIGNALS
180	180			FUTURE	
180	–	NORMAL (MAS FOR EQUIPMENT AND TRACK)			N
120	120	80			80
75	75	60			60
120	–	45 (LIMITED)			45
75	–	30 (MEDIUM)			30
0 (OR 0 CURRENT)	–	15 (RESTRICTED)			R



SECTION 7.0

CONCLUSION

Completion of this task in conjunction with tasks 1 and 2 provides an overview of signal/control systems, signal types and signal aspects, titles and indications. The findings indicate a need for classification of certain rules and the broad standardization of wayside signals. It also appears that signal/control technology should be augmented and improved by state-of-the-art advancements that have successfully taken place on a limited scale.

There are existing signal systems which incorporate hardware that was developed early in this century. The longevity of such equipment attests to its reliability and ruggedness. However, much equipment has remained in use beyond a normal life cycle because of the vast capital investment required to replace it. Many technological advances have been made in signal/control systems over the years. However, the mixing of old and new systems and equipment has created a variety of systems with some equipment serving beyond its normal service life. Many signal systems currently in use are composed of an assortment of equipment and circuits in which the only commonality is the basic fail-safe design concept. The extreme incongruity may be seen in semaphore signals, which were developed a century ago, used as part of a computer augmented train control system with state-of-the-art components and techniques.

Railroad mergers, bankruptcies, technological advances, equipment development, and changing transportation trends have affected private railroads which comprise a capital intensive, equipment oriented and fixed plant industry. The ultimate effect has been that many technical decisions have been influenced more by economic conditions than by technical need.

The trend of the railroad industry has resulted in situations where signaling systems are removed not because they are obsolete but because they are not required for safety of operation or because falling train desities have negated the need for their existence. Intercity passenger train service has become the responsibility of the federally support National Railroad Passenger Corporation (Amtrak), which is having difficulty maintaining cost-effective train operations over a nationally interconnected system which is dependent on the use of freight-oriented trackage. Amtrak, operating trains over eighteen private railroads, first felt the need for standardization of operating rules including standard signal aspects, titles and indications. The standardization of operating rules would enable an Amtrak passenger train to operate over several rail properties without having to change crews at each corporate boundary and also eliminate the requirement for composite cab signal equipment. This should reduce equipment and labor costs and effect a reasonable increase in operating schedules.

The addition of an overlay signal/control system dedicated to high speed passenger service would likewise increase operating efficiencies. The use of a dedicated signal system would allow Amtrak trains to operate at higher speeds with shorter headways in mixed frieght and commuter traffic with added safety. This would increase efficiency and dependability of schedules, thereby increasing revenue through increased ridership.

Industry standardization of operating rules, including signal aspects, titles and indications, is provided by the AAR Standard Code of Operating Rules. This document is the basis for most private railroad operating rules and is an acceptable regulatory document, if it is enforced. The key word is enforcement. Operating rules developed to individual railroad needs, an accumulation of signal types and a myriad of operating situations have produced many exceptions to the AAR Standard Code.

Such exceptions are permitted by current regulations thereby reducing the effectiveness of industry standards. This study report contains recommended standard signal aspects, titles and indications which, if incorporated into enforceable Federal standards and regulations, would simplify railroad operations and thereby enhance safety.

The FRA held a public hearing in February 1979 to hear all pertinent testimony on signal and train control systems, current regulations and the enforcement of these regulations toward the ultimate goal of increased safety. The FRA apparently recognizes the condition of the railroad industry. Regulatory action taken by the FRA that would require extensive outlays of capital for equipment or system improvements could further burden an already troubled industry. Railroads have provided a vital link in the development of our nation and are expected to make a significant contribution in the future. On the other hand the industry is confronted with an increasing frequency of accidents. Therefore, changes regulatory documents must meet the two-fold purpose of providing the minimum regulation yet achieving maximum safety with an ultimate goal of near accident-free operation. The findings of this study emphasize the encouragement of cost effective use of state-of-the-art technology and sensible regulation toward effecting a solution.

The summary conclusions of this report are:

- An overlay or secondary signal/control signal system is required for high speed passenger train operations to improve schedule performance and enhance safety in a mixed traffic environment.

- Standard operating rules including signal aspects, titles and indications are required as a foundation for the development of an overlay signal/control system.

- Current regulations are basically adequate for railroad operations. However, revisions or modifications are needed to enhance the development and incorporation of state-of-the-art signal/control systems, to support operational improvements and to up-date equipment maintenance requirements.

APPENDIX A

DOCUMENT REFERENCE LIST

This report has 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 the report the appropriate acknowledgement was made in the text; however, the report could not have been completed without the general background information which was obtained from the documents in this appendix. The authors acknowledge these sources by including them in this appendix. The numbers in the left column of the appendix listing are document numbers assigned for filing puropses. The numbers are not sequential since only those documents applicable to this report have been included here, out of the documents accumulated for the general study including tasks 1 and 2. These documents have been accumulated as a library and are available for reference. It may be noted that some documents were requested for this study task and were not recieved; however, they are listed here for their topical value and the fact that they may be received after the report is published.

DOCUMENT REFERENCE LIST

	Title	Source	Date
34	USE OF ELECTRONIC COMPONENTS IN SIGNALING, DEFINITION OF TERMS CONCERNING ELECTRONIC SAFETY SIGNALING SYSTEMS (21Pg.)	UIC/ORE A118/RP7/E	APRIL 75
38	TRAIN SAFETY CONTROL SYSTEM FOR SHINKANSEN-CPU SYSTEM WITH PRIORITY ON SAFETY (ASME JOURNAL OF DYNAMIC SYSTEMS, MEAS. AND CONTROL-VOL.97 NO. 2 SERIES G)	ASME	JUNE 75
47	USE OF A COMPUTER IN THE DESIGN OF RAILWAY SAFETY SIGNALING CIRCUITS	IEE, LONDON,RRB	1974
50	NEW YORK CITY TRANSIT AUTHORITY DESIGN GUIDELINES SIGNALS AND COMMUNICATION (UMTA-IT-09-0014-75-5)	UMTA	1975
71	A118/RP 3/E (31p.) USE OF ELECTRONIC COMPONENTS IN SIGNALING. FAULTS AND SAFETY IN RAILWAY SAFETY SYSTEMS	UIC/ORE	OCT. 72
72	A/118/RP 5/E (16p.) USE OF ELECTRONIC COMPONENTS IN SIGNALING. SYSTEM STRUCTURES FOR ACHIEVING SAFETY IN THE SIGNALING TECHNIQUE-INTRODUCTION	UIC/ORE	OCT. 75
73	118/RP 6/E (45p.) USE OF ELECTRONIC COMPONENTS IN SIGNALING. METHODS FOR CALCULATING THE PERFORMANCE OF SAFETY SYSTEMS	UIC/ORE	OCT. 75
80	IAN Allan Limited (07110 05710) (136 p.) 1978 BRITISH RAILWAY SIGNALING FOURTH EDITION by Kithenside & Williams	IAN ALLAN LTD.	1978
81	PROGRESS IN SIGNALING FOR TRACK GUIDED SYSTEMS (ASCE JOURNAL OF TRANSPORTATION ENGINEERING VOL. 101, NO. TE 4,11695)	ASCE	NOV. 75
82	SIGNALING THE NEW LYON LINE OF THE PARIS/SUB-EST NETWORK FOR 260 KM/H AND MORE	RAIL ENG. INT.	NOV. 75
	SAFE TRAIN SEPARATION IN MODERN RAPID TRANSIT SYSTEMS (75-ICT-11) (NOT RECEIVED)	ASME	JULY 76

Appendix A

DOCUMENT REFERENCE LIST

	Title	Source	Date
85	HIGH SPEED TRAFFIC SIGNALING	IME LONDON	SEP. 75
93	RAILROAD OPERATION AND RAILWAY SIGNALING (BOOK)	SIMMONS-BOARDMAN	1942
95	DOT-TSC-OST-74-4 (ATA/RT-74/1,2,3,1974) SAFETY AND AUTOMATIC TRAIN CONTROL FOR RAIL RAPID TRANSIT SYSTEM	DOT, ATA	JULY 74
112	SAFETY BOARD MAKES SUGGESTIONS FOR SIGNAL SYSTEMS AND RULES	RY.SYS.CONT	MAR. 72
114	RAILWAY SIGNALING DEVELOPMENT	RY.EN.JOUR.	MAY 73
115	SAFETY BOARD ASKS FRA TO WRITE RADIO RULES	RY.SYS.CONT	JUNE 72
138	THE SAFETY OF ELECTRONICS IN RAILROAD CONTROLS SYSTEMS	FRA	JULY 77
141	ANATOMY OF A TRAIN CRASH	MASS TRANS.	JUNE 76
	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)	UIC	APRIL 76
	NORTHEAST CORRIDOR HIGH SPEED RAIL PASSENGER SERVICE IMPROVEMENT PROJECT. TASK 16: ELECTRIFICATION SYSTEMS AND STANDARDS (NOT RECEIVED)	ELECTRACK INC.	DEC. 76
	CONSIDERATIONS IN THE DESIGN OF H.V. A.C. ELECTRIFICATION FOR THE SOUTH AFRICAN RAILWAYS (NOT RECEIVED)	QUAIL, JB S. AFR. RW	1974

Appendix A

DOCUMENT REFERENCE LIST

	Title	Source	Date
148	SIGNALING TECHNOLOGY FOR NEW OPERATING DEMANDS (ITALY)	IRJ	DEC. 76
155	RAILROAD ACCIDENT REPORT: COLLISION OF TWO CONSOLIDATED RAILROAD CORPORATION COMMUTER TRAINS, NEW CANAAN, CONN., JULY 13, 1976	NAT'L. TRANS. SAFT. BRD.	MAY 77
156	RAILROAD ELECTROMAGNETIC COMPATIBILITY: A SURVEY AND ASSESSMENT	ELEC. COMPT. ANAL. CENTER	AUG. 77
	RAILROAD CAR PRESENCE DETECTION DEVICES (NOT RECEIVED)	FRA	
	MICROPROCESSOR CONTROLLED RAILWAY SIGNALING INTERLOCK (NOT RECEIVED)	IEEE	1977
	COMMUNICATION SYSTEM CUSTOM DESIGNED FOR THE MONTREAL METRO-RAPID TRANSIT SUBWAY (NOT RECEIVED)	IEEE	1977
219	SIGNALING FOR HIGH SPEED	MOD. RYS.	
223	ROLE OF THE SIGNAL ENGINEER	RY. ENG.	JAN./FEB. 1977
251	SIGNALING --- WITHOUT POLE LINES?	PROG. RR	JAN. 78
261	NEW DEVELOPMENTS IN THE FIELD OF COMMUNICATION SYSTEMS PROTECTION ON ELECTRIFIED RAILROADS (TRANSLATED FROM RUSSIAN)	FRA	1972
264	HANDBOOK FOR SIGNALING ON SOVIET RAILRAODS (TRANSLATED FROM RUSSIAN)	FRA	1872
271	MAINTAINING ALERTNESS IN RAILROAD LOCOMOTIVE CREWS	FRA	MARCH 77
276	SIGNAL SPACING ANALYSIS (SIGNEL) DOT-FR-76048	FRA	DEC. 77
277	AN EVALUATION OF RAILROAD SAFETY	OTA	MAY 78

Appendix A

DOCUMENT REFERENCE LIST

	Title	Source	Date
281	THE STANDARD CODE OF OPERATION RULES (JAN. 1965) AAR WITH RULE CHANGES	AAR	1965
299	SUMMARY REPORT ON VANDALISM AND PASSENGER SECURITY IN THE TRANSIT INDUSTRY (TRANSPORTATION RESEARCH RECORD NO. 487, 1974)	ATA	1974
300	SCOPE OF CRIME AND VANDALISM ON URBAN TRANSIT SYSTEMS (TRANSPORTATION RESEARCH RECORD NO. 487, 1974)	ATA	1974
306	HUMAN FACTORS IN SIGNALLING SYSTEMS M. MASHOUR (BOOK)	JOHN WILEY & SONS	1974
313	SIGNALS PLUS (COMPUTERIZATION)	MOD. RR	SEP. 78
315	THE SIGNALS OF THE GERMAN RAILROADS (BOOK - TRANSLATED FROM GERMAN)	ALBA BUCHVERLAG DUSSELDORF	1974
316	FRA WILL WORK WITH RAILROADS	RSC	AUG. 69
324	ALL ABOUT SIGNALS JOHN ARMSTRONG	TRAINS	1957
346	RESIGNALLING ON THE SCOTTISH SECTION OF THE WEST COAST MAIN LINE	IRSE LONDON	MAR. 74
349	VICTORIA LINE SIGNALLING PRINCIPLES	IRSE	NOV. 66
355	RAILROAD SAFETY IN PERSPECTIVE	PROG. RR	MAY 78
360	AN EVALUATION OF RAILROAD SAFETY (216 p.)	OTA	MAY 78
362	49 CFR - TRANSPORTATION PARTS 200 to 999 (CODE OF FEDERAL REGULATIONS)	FED. RGSTR.	JULY 78
371	NEW SIGNAL ASPECTS FOR THE GERMAN RAILROADS	SIGNAL + DRAHT, VOL. 67, NO. 7/8	1975

Appendix A

DOCUMENT REFERENCE LIST

	Title	Source	Date
375	THE PRICE OF SAFETY	IME	JAN. 77
383	REAR END COLLISION OF THREE MBTA TRAINS, BOSTON, MASSACHUSETTS, AUGUST, 1975 (PB-253-360)	NTSB	APRIL 76
384	PROCEED, PREPARED TO STOP - THE ABC'S OF PROTOTYPE SIGNALING BY GORDON ODEGARD	MODEL RR	SEP. 76
385	THE COMPENDIUM OF SIGNALS - BY ROGER F.R. KARL (BOOK)	BOYNTON Y ASSOC.	1971
391	PROPOSED SIGNAL SYSTEM FOR THE NORTHEST CORRIDOR	DeLEUW, CATHER/ PARSONS	FEB. 79
392	RIGHTS OF TRAINS BY PETER JOSSERAND (BOOK)	SIMMONS - BOARDMAN	1957
394	EVALUATION OF SIGNAL/CONTROL SYSTEM EQUIPMENT AND TECHNOLOGY. TASK 1 - ASSESSMENT OF SIGNAL/CONTROL TECHNOLOGY AND LITERATURE REVIEW	FRA	DEC. 78
395	EVALUATION OF SIGNAL/CONTROL SYSTEM EQUIPMENT AND TECHNOLOGY. TASK 2 - STATUS OF PRESENT SIGNAL/CONTROL EQUIPMENT	FRA	JAN. 79
396	PRACTICAL ELECTRONIC PROJECTS FOR MODEL RAILROADERS BY PETER J. THORNE	KALMBACH	1974
397	MOTOR SECTION CAR SIGNAL SYSTEM	MODEL RAILROADER	OCT. 78
402	TRANSCRIBED PROCEEDINGS OF FRA GENERAL SAFETY INQUIRY FEB. 1979 PUBLIC HEARING ON RAILROAD SIGNALS AND TRAIN CONTROL REGULATIONS AND ORDERS. DOCKET NO. RSSI-28-5 NOTICE NO. 6	KENTRON INTERNATIONAL	FEB. 79
403	RECOMMENDED REVISION TO RULES, STANDARDS AND INSTRUCTIONS FOR FRA GENERAL SAFETY INQUIRY OF FEB. 1979	AAR	FEB. 79

APPENDIX B

CHRONOLOGICAL LISTING OF SIGNIFICANT EVENTS OF SIGNALING EQUIPMENT AND SYSTEM DEVELOPMENT

The chronology of technological development presented here utilized OTA's report "Automatic Train Control in Rail Rapid Transit" and "American Railway Signaling Principles and Practices", Chapter 1: "History and Development of Railroads", Signal sction, dated 1954, as primary source material.

Other data sources included "Railroad Operation and Railway Signalling" by E. J. Phillips, Jr., dated 1942, "History of the Brotherhood of Railway Signalmen 1901-1976" by A. E. Lyon, dated 1976, "British Railway Signaling" by O. S. Nock, dated 1969 and "The Railway Signal Association Signal Dictionary" 1911 Edition.

It should also be noted that the chronological development of signaling systems in some countries are not included in this listing because the information was not available in the literature surveyed. It is apparent that considerable progress has been made in signaling systems in Italy and France since the end of World War II when the railroads were in such a disrupted state; however, these developments are not included because they are not known.

DATE	COUNTRY	EVENTS
1832	United States	The first fixed signal system in America was installed on the New Castle and Frenchtown Railroad. The signals were ball-shaped objects mounted on 30 foot masts at 3-mile intervals. The signals were raised and lowered by a signalman to indicate permissible speed; low meaning stop and stay and high meaning proceed at full speed. The latter indication gave rise to the expression "highballing".

DATE	COUNTRY	EVENTS
1839	England	The block system of controlling train movement dates from 1839 on the Great Western Railway of England. A magnetic needle indicator was used to telegraph the arrival and departure of trains from station-to-station for a short distance near London. An instrument and control was provided at each station. The indicating instrument was a galvanometer with two deflecting coils which were under the control of the next station. The two positions indicated whether or not the block in between the stations contained a train.
1843	England	The first centralized plant for the operation of switches and signals was installed at Bricklayer's Arms Junction in England. It was a simple machine operated by a signalman who worked the switches with his hands and the signals with his feet.
1843	United States	The movements of trains by signal indication only was demonstrated on the Eastern Railroad through the Salem, Mass. tunnel. The signals used were a ball signal on the eastern end and a dial indicator on each entrance to the tunnel. The dials were manually operated from the opposite end of the tunnel by signalmen stationed there.
1843	Germany	Electric telegraphs were first used on the Rhine Railway to signal train arrivals between Aachen and Ronheide with a five needle telegraph.

DATE	COUNTRY	EVENTS
1851	United States	The Morse code electric telegraph was first used in train operation for sending train orders on the New York and Erie Railroad.
1853	United States	The Philadelphia and Reading Railroad installed signal towers for providing information to approaching trains on the occupancy of the track in advance.
1853	England	Records indicate that the first patent concerning the use of tracks as conductors to communicate between trains and between trains and stations was granted in England. However, there is no evidence that the patent idea was ever tried on a railway.
1853	Germany	The Saxony-Bavaria State Railroad operated its first signals by remote control through a wire line.
1860	United States	Gate signals were initiated in America. A stop indication was displayed by placing a red banner or disc on top of the gate during the day. A red light was displayed at night.
1863	United States	The first manual block signal system was placed in service on the United New Jersey Canal and Railroad. The system used the space interval of controlling train movement.

DATE	COUNTRY	EVENTS
1865	Germany	The Berlin-Gorlitz Railroad introduced station (platform) signals.
1866	United States	The first automatic electric block system was installed on the New York, New Haven and Hartfort Railroad at Meriden, Connecticut. The disc signals were operated from open-circuit track circuits using wheel actuated treadles as circuit initiators.
1868	Germany	The Baunschweig Railroad installed the first mechnical switch controlled from a signal cabin. The switch controls had two-way bolt locking.
1868	United States	The Pennsylvania Railroad used a type of train order signal which was under the control of the train dispatcher who could set the signal in the stop-danger aspect at any remote station by means of a selective device operated over the regular Morse telegraph circuit.
1870	United States	The first interlocking machine in America was installed at Top-of-the-Hill, a junction at Trenton, New Jersey, on the Camden and Amboy Division of the Pennsylvania Railroad.
1871	United States	The first automatic electric block system comparable with those presently used (using open track circuits) was installed on the New York and Harlem Railroad and the Eastern Railroad.

DATE	COUNTRY	EVENTS
1872	United States	The first automatic electric block system using fail-safe closed DC track circuits was installed on the Philadelphia and Erie Railroad in Kinzua, Pennsylvania.
1872	Germany	Block signaling was introduced on the Herlasgrun-Reichenbach route.
1873	Germany	The Prussian railroad introduced the predecessor to today's distant signal.
1873	United States	A closed DC track circuit block utilizing switch position as an active element was installed on the Philadelphia and Erie Railroad. The track circuit included controllers which used the position of three switches to control the signal displays at the entrance to the block.
1876	United States	The first pneumatic power interlocking system was put in use on the Pennsylvania Railroad at the Mantua "Y" in West Philadelphia. Compressed air was used to operate the switches.
1880	United States	The first Automatic-Train Stop trial was conducted on the Middle Division of the Pennsylvania Railroad. A glass tube located under the car near the rails was broken by a track device which bled the air pressure in the car brake lines and set the car brakes.

DATE	COUNTRY	EVENTS
1881	United States	The first hydraulic interlocking system was installed at Wellington, Ohio at the crossing of the Wheeling and Lake Erie Railroad and the Cleveland, Cincinnati Chicago and St. Louis Railroad.
1885	United States	The "Dutch Clock" device for establishing time intervals (headways) between trains was in use on the New York, New Haven and Hartford Railroad and the New York Central and Hudson River Railroad. The device was operated automatically by a treadle device on the rail. The passing train released a pointer on a wayside dial which started to move around the dial. The dial was divided into three segments each representing 5 minutes. The pointer movement was controlled by an escapement so that it moved across the dial in a period of 15 minutes. Headway for the train ahead was thus indicated up to 15 minutes.
1885	United States	The first electric occupancy detector locking system used in interlocked track switches was installed by the Pennsylvania Railroad at the Pittsburgh, Pennsylvania terminal. The system prevented the movement of track switches when a train was in track territory near the switches.

DATE	COUNTRY	EVENTS
1889	United States	The first electric interlocking system employing dynamic indication was installed at East Norwood, Ohio at the crossing of the Baltimore and Ohio Southwestern Railroad by the Cincinnati and Northern Railroad. The indication was a feedback which denoted the accomplishment of the selected switch movement and was employed as an active element in the interlocking system.
1891	United States	The Polarized track circuit relay was patented. The Polarized relay was developed to be used in track circuits where the rails were also used as direct current returns in electric propulsion.
1892	Germany	Night signals of Green, for clear, were introduced.
1893	United States	The first low-voltage, direct-current, motor-operated automatic semaphore block signals were installed on the Central Railroad of New Jersey at Black Dan's Cut, east of Phillipsburg, New Jersey. They were two-position lower quandrant signals with the motor and driving chain outside the mast.

DATE	COUNTRY	EVENTS
1897	United States	Semaphore block signals operated by an electric motor were installed on the Pennsylvania, Michigan Central, Cincinnati, New Orleans, and Texas and Pacific Railroads. The motors operated on direct current and were unique in that they operated push rods inside the signal mast which in turn moved the semaphore signal arms.
1900	United States	The first three-block indication was installed on the Pennsylvania Railroad between Altoona and Cresson, Pennsylvania. The signals were two-position, lower-quadrant, two arm automatic semaphores. This signal system informed a trainman of the status of the next three blocks using 4 signal aspects.
1900	England	In Acton Town, England, an illuminated track diagram was first used in connection with resignaling on the District Railroad due to electrification. It dispensed with separate track indicators and brought together all track occupany information on the plan of tracks and signals, thereby facilitating the work of the signalman handling traffic.
1901	United States	The Boston Elevated installed special polarized DC track relays. This was the first attempt to operate track circuits on a railroad where propulsion power was supplied by electricity and the rails were used as the medium for current return.

DATE	COUNTRY	EVENTS
1901	United States	The Boston Elevated made the first permanent installation of an automatic train stop system, which consisted of mechanical wayside trips engaging brake control apparatus on the moving car.
1903	United States	The North Shore Railroad of California made the first installation of AC track circuits for automatic block signals. The system used a single rail track circuit and utilized a DC propulsion system.
1904	United States	Double track AC track circuits were installed in the East Boston Tunnel territory of the Boston Elevated. The track circuits were the first to utilize impedance bonds at the rail joints. Short range colored light signals were also installed. The lights were automatically operated by the AC track circuits.
1904	United States	The first approach locking system with automatic release was installed on the Pennsylvania Railroad at Lou Garden, Philadelphia, Pennsylvania.
1906	United States	The first large scale installation of double rail track circuits, using impedance bonds and polyphase track relays, was completed on the New York Central Railroad electric zone. This was the first system where power was taken from a single alternating current transmission line.

DATE	COUNTRY	EVENTS
1906	United States	The first signal system with AC track circuits on a road using AC propulsion power was installed on the New York, New Haven and Hartford Railroad. The track circuits were the two-rail type, 60 Hz, with impedance bonds. Propulsion current was 25 Hz.
1907	United States	The first automatic interlocking for the protection of a railroad crossing was installed at Chester, Virginia, at a crossing of the Tidewater and Western Railroad with the Virginia Railway, Power & Light Company. An approaching train automatically set the signals on the railroad being intersected to a restricitve aspect.
1908	United States	The first color specification for railway signal lights was approved by the Railway Signal Association.
1909	United States	The Erie Railroad installed automatic signaling for train operation by signal indication on a two-track division, 139.7 miles in length, which directed trains to: (1) stop and hold main track, (2) take siding, (3) proceed on main track regardless of trains which by time table would take precedance.
1909	United States	The first electro-mechanical interlocking machine with small levers for electric control mounted separately above the large mechanical levers was installed at Gap, Pennsylvania on the Pennsylvania Railroad.

DATE	COUNTRY	EVENTS
1911	Canada	The absolute permissive block system was first installed on the Toronto, Hamilton and Buffalo Railroad, between Kinnear and Vinemount, Ontario, using direct-current semaphore signals.
1912	United States	Cab signals were first used on an electric railway by the Indianpolis and Cincinnati Traction Co.
1914	United States	The first signaling system utilizing long range colored lights was installed on the New York, New Haven and Hartford Railroad.
1914	United States	The cam controller for control of power application to DC propulsion motors was first used in the Chicago Rapid Transit Company.
1915	United States	The American Railway Association adopted rules which permitted train operation on a single track by controlled manual block signal indications, superseding timetable and train orders.
1919	United States	The Buffalo, Rochester and Pittsburg Railroad made a trial installation of an intermittent inductive train stop system. The system used magnetic induction to transfer signals from wayside to the train.

DATE	COUNTRY	EVENTS
1920	United States	The first installation of automatic speed control was made on the Chicago, Rock Island and Pacific Railroad between Blue Island and Joliet, Illinois. The system used an intermittent electrical contact ramp. The tain brakes were activated by a combination of mechanical and electrical action. The mechanical action consisted of a wayside ramp activating a train mounted shoe. The mechanical action occurred each time the train passed a ramp. The electrical circuit was the determining factor in whether or not the train braking valve was activated. The electrical circuit was powered and energized through wayside signal relays and included equipment aboard the train which was connected via brushes on the ramp. As a fail-safe measure the system was designed to apply the brakes only if the electrical circuit was not energized.
1923	United States	The Pennsylvania Railroad placed in service, experimentally, the first installation of a continuous inductive cab signal and train control system covering 43.5 miles of single track and 3.4 miles of two-track, between Lewistown and Sunbury, Pa. It was the first use of vacuum tubes for purposes other than in communication circuits. This installation also was the first time that cab signals were used in lieu of wayside signals for operating trains by signal indication.

DATE	COUNTRY	EVENTS
1923	United States	The first commercial installation of an intermittent inductive train stop system was made on the Chicago and North Western Railraod between West Chicago and Elgin, Illinois.
1924	United States	The first installation of car retarders was made at Northbound Yard, Gibson, Indiana on the Harbor Belt Railroad. The retarders were pneumatically operated and electrically controlled.
1925	United States	The first permanent installation of cab signals without wayside block signals was made on the Atchison, Topeka & Santa Fe Railroad between Chillicothe, Illinois and Ft. Madison, Iowa. The equipment displayed three-speed signals and was received by the train equipment via a continuous inductive device.
1926	United States	The Illinois Central Railroad was the first to equip an operating division with automatic train stops and two-indication continuous cab signals without wayside automatic block signals.
1927	United States	The first centralized traffic control system was installed on the Ohio division of the New York Central Railroad between Stanley and Derwick, Ohio. This installation also introduced the first dual-control electric switch machines which made possible both local and remote operation of selected switches installed in this system.

DATE	COUNTRY	EVENTS
1928	Canada	Centralized traffic control was first installed in Canada on the Canadian Pacific Railroad.
1929	United States	The first interlocked system which used only relays in logic sequence instead of mechanically locked levers was installed on the Chicago, Rock Island & Pacific Railroad at Blue Island, Illinois.
1930	Germany	The first automatic train stop in Germany used a permanent magnet on both the train and track structure as activating elements of the brakes on the train. Both permanent magnets had electro-magnetic cancelling coils which deactivated the braking sequence. The system was fail-safe because a failure in the electrical circuit of the way-side system or train system would activate the brakes on the train.
1931	United States	The New York Central Railroad installed a system of four-block indication signals on a line equipped with automatic block signals in heavy suburban traffic. The four-block system accommodated faster passenger train speed while maintaining efficient operation of slower trains.
1932	United States	The Philadelphia subways installed a modified type of the three-wire circuit code scheme of centralized traffic control.

DATE	COUNTRY	EVENTS
1933	United States	Coded track circuits were first installed on the Pennsylvania Railroad between Zoo and Arsenal, Phildelphia, Pennsylvania. The coded track circuits were used for control of both wayside and cab signals. The installation operated on 100 Hertz AC power.
1933	United States	The Pennsylvania Railroad was granted permission by the ICC to convert all its locomotives equipped with the coded continuous train stop system to the coded continuous cab signal system with whistle and acknowledger. This was with the understanding that the Pennsylvania Railroad would voluntarily extend cab signal territory to include most of its main line trackage.
1937	United States	The New York Central railroad installed the first relay interlocked system with push-buttons to control automatically selected routes, switches and signals.
1937	England	The first installation of an all-relay interlocked system with pushbutton selection of routes installed in Brunswick England on the Cheshire Lines. The pushbuttons positioned switches and signals of a route automatically.
1939	United States	The first application of coded detector track circuits in an interlocked system was made by the Norfolk & Western Railroad.

DATE	COUNTRY	EVENTS
1939	United States	A four-aspect, four-speed, coded continuous train control system was installed on suburban cars of the Key System, Southern Pacific and Sacremento Northern Railroads operating over the San Francisco-Oakland Bay Bridge, California. The system was designed to handle 10-car multiple-unit trains operating on a 1-minute headway. The installation included a route (NX) interlocking system with a train describer and automatic operation of a single switch.
1940	United States	The first application of approach-energized, tuned alternators as the power source for cab signals was made on the coded track circuit installation of the Pennsylvania Railroad between Conpit and Keskiminetas Junction, Pennsylvania.
1940	United States	The Pennsylvania Railroad installed a centralized traffic control system between Harmony and Effingham, Illinois, which was unique in that it used a two wire code line circuit in which all field equipment was connected in multiple across the line wires. The two wire system used a 35 station time code for control and also served for communication.

DATE	COUNTRY	COUNTRY
1940	United States	The first installation of reversible code track circuits in single-track territory with centralized traffic control was made between Machias and Hubbard, New York on the Pennsylvania Railroad.
1940	United States	The first installation of absolute permissive block (APB) signaling with three and four indications with coded track circuits was made on the Norfolk & Western Railway, between Peterburg and Evergreen, Virginia.
1941	Canada	The Canadian National Railroad installed centralized traffic control between Catamount and West End (Moncton) New Brunswich. The system used a two-wire polar control simplex system (series line) with provisions for super-imposing telephone on the code line wires.
1941	United States	The first installation of speed control using car retarders was made on the Norfolk & Western Railroad at Roanoake, Virginia. Electro-pneumatic retarders were used.
1941	United States	The first normally de-energized coded track circuits were placed in service through the Moffat Tunnel on the Denver & Salt Lake Railroad.
1943	United States	The first installation of coded track circuits using polar reverse codes with three-indication signaling for either direction operation was made on the St. Louis Southwestern Railroad.

DATE	COUNTRY	EVENTS
1944	United States	The first installation of normally deengergized coded track circuits for centralized traffic control on single track was placed in service between Laredo and Polo, Missouri, on the Chicago, Milwaukee, St. Paul & Pacific Railroad.
1945	United States	The Atchison Topeka & Santa Fe Railroad successfully demonstrated the feasibility of centralized traffic control operation over long distances on existing railroad communication lines. The test was made over 2,200 miles of telegraph circuit.
1946	Germany	The first German push-button controlled track-diagram interlocked system display was installed at The Dasseldorf-Dorendorf Station. The system had a control desk and switching equipment that consisted of modular relay groups. Routes were controlled by start-destination (NX in US terms) buttons in the track diagram.
1946	United States	The Pennsylvania Railroad demonstrated the feasibility of centralized traffic control operation over commercial communication circuits, including beamed radio. The test was made over approximately 1,130 miles of Western Union carrier telegraph circuit including about 90 miles of beamed radio. This was the first time beamed radio was used for this purpose.

DATE	COUNTRY	EVENTS
1948	United States	Automatic Train Dispatching was first used in rapid transit by the Philadelphia Rapid Transit, now (SEPTA). The system employed a perforated opaque tape driven by a clock-like mechanism. A beam of light scanning the tape triggered a photo-electric cell which initiated starting lights at terminals.
1949	United States	The first installation of a coded route (NX) inter-locked system was installed on the Missouri Pacific Railroad at Kansas City, Missouri.
1949	United States	The Rochester and Pittsburg Railroad installed automatic block signaling between Rochester and Scottsville New York which was unique in that the signals were normally dark, being activated only by approaching traffic. The installation included both forward and reverse track coding which was initiated by traffic.
1950	Canada	The Canadian Pacific Railway installed the first car retarder system to be completely operated by auto-matic switching. The system was installed at St. Lac Yard in Montreal, Quebec and included speed control of movements through the retarders located ahead of the scales.
1951	Germany	The first train number identification system was installed for automated train-run supervision at the Cologne Central Station.

DATE	COUNTRY	EVENTS
1951	Germany	The first automatic block continuous train control was introduced on the German Federal Railway (DB) main line between Bebra and Cornberg. The system detected the train number which was transmitted to the control center by pulse code.
1951	United States	The Pennsylvania Railraod installed a three-speed inductive train control system which limited speed to 20 mph when the track carried no code, 30 mph when the track carried a 75 code, 45 mph at 120 code, and no limit with 180 code.
1951	United States	The Chicago Transit Authority began the use of automatic dispatching with remote override from central locations. The system employed a mechanical clock, pen graph recorder of train movements and line supervision.
1951	United States	Portable radios were first used by yard switchmen on the Southern Railway in connection with coupling cars in the classification yard and transferring them to the departure yard.
1952	United States	An automatic train identification system was placed in service by the Erie Railroad at Waterloo, New York, in connection with a remotely controlled interlocking system. The system identified the direction of movement and the number of the train as it cleared a manual block on a branch line. The passing time (OS) was automatically transmitted to the dispatchers office which was over 20 miles away.

DATE	COUNTRY	EVENTS
1952	Germany	A continuous train control system was placed in operation from Regensburg to Nurnberg. The system used pulse-code rotary selector controls at the central office in Nurnberg.
1953	United States	Transistors were introduced into cab signaling equipment in lieu of vacuum tubes on the New York, New Haven & Hartford Railroad.
1953	United States	Transistors were used in safety (vital) carrier equipment on the Pennsylvania Railroad.
1953	United States	Automatic retarders controlled by an Analog Computer was installed at Kirk Yard on the Elgin Joliet & Eastern Railroad.
1955	United States	A crewless remote-controlled passenger train was demonstrated on the New York, New Haven & Hartford Railroad.
1959	United States	The inductive train phone was first used in rail rapid transit by the Chicago Transit Authority.
1961	United States	A completely automatic subway train was placed in service on the shuttle run between Times Square and Grand Central Station in New York. A motorman was on board for emergencies, but he was not involved in normal operation of the train and often spent his time reading the newspaper.
1962	Canada	A crewless freight train operating system was tested on the Canadian National Railroad.

DATE	COUNTRY	EVENTS
1962	Germany	A three-phase magnetic core transistor circuit system with logic elements operating on the fail-safe principal were first used on German Railroads.
1964	United States	Automatic Train Operation, (ATO) equipment, intended for use in the BART system, was operationally tested at Thorndale on the Chicago Transit Authority North-South route.
1964	Japan	The Japanese National Railroad inaugurated a transistorized Central Train Control system from Tokyo to Shin-Osaka.
1964	Germany	The interlocking system at Munich main station was resignaled using self checking modular relay groups. At the same time, continuous train control was also implemented using pulse code communications and automatic block installations for automatic train routing.

DATE	COUNTRY	EVENTS
1966	United States	Four automatic train control systems for BART were demonstrated at the Diablo test track - one using the moving block concept, two using coded track circuits, and the other using a "trackwire" communications link and wayside control equipment. The moving block system utilized a form of radar transceiver on each train, coupled to a waveguide mounted between or alongside the track. A signal was propagated in the forward direction only, being reflected by a target on a leading train, thereby producing an indication of the separation of the two trains. The purpose of the system was to provide a means of maintaining a fixed distance between trains.
1966	United States	Fully automated vehicle operation and innovative methods of train control were demonstrated for the Transit Expressway (Skybus) system at South Park, Pennsylvania, by the Port Authority Allegheny County (Pittsburg).
1966	Germany	A system was placed in service at Kassel on the U-Strassbahn using inductive transmission of data between trains and fixed track devices for control of routes, signals, train destination platform indicators, etc.

DATE	COUNTRY	EVENTS
1967	United States	Audio-frequency track circuits in a rail rapid transit application were first placed in regular service by the Chicago Transit Authority.
1968	Germany	An experimental Microwave system was implemented in the Munich area for reading a 12-digital vehicle number.
1969	United States	Revenue service was begun on the PATCO Lindenwold Line. After a manually initiated start, train operation is completely automatic until the doors are opened at the next station.
1970	Germany	An experimental train control system using track conductors (called "wiggle wires") was installed between Munich and Ausburg.
1970	Germany	The first "super express" locomotive was run under fully automatic control.
1971	United States	An automatic people-mover system was placed in operation at the Tampa Airport. This system incorporates one of the ATC elements originally demonstrated at South Park.
1972	United States	Four automatic people-mover systems were demonstrated at TRANSPO '72, Washington, D.C., under the auspices of the U. S. Department of Transportation.
1972	England	The final section of the Victoria line of the London underground was opened for service. The system utilizes automatic train operation as well as ticket issue and control. Closed circuit television is included in the communication system.

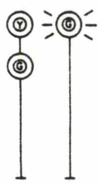
DATE	COUNTRY	EVENTS
1972	Finland	Trials began on a six car test train as a part of the Helsinki Subway system. The train is completely automated.
1972	Japan	The Shinkansen Railroad was extended from Shin-Osaka to Okayama. This extension included the addition of computer control of routes at all stations, adjustments of traffic and transmitting of turn around and employment of rolling stock.
1972	United States	Revenue service was initiated on the Fremont-MacArthur portion of the BART system. Train operation, including start, berthing, and door operation, is entirely automatic but under the supervision of an onboard operator.
1973	United States	The Satellite Transit System, featuring automatic crewless vehicle operation, was placed in service for passengers at the Seattle-Tacoma (Sea-Tac) Airport.
1974	United States	The AIRTRANS system at Dallas/Ft. Worth Airport opened for service. Operating on 17 interconnected routes, AIRTRANS has automatic crewless trains to carry passengers, baggage, freight, mail and refuse within the airport complex.
1974	United States	Demonstration of the Morgantown, W. Virginia, Personal Rapid Transit (PRT) system was conducted. Small vehicles, operating on a fixed guideway, circulate under automatic control and without onboard operators.

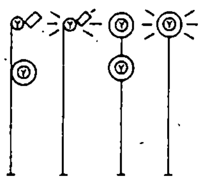
DATE	COUNTRY	EVENTS
1974	Germany	A computer controlled system called CORECT (Continuous Remote Control of Train) was placed in operation on the railway between Hamburg and Bremen. The system used track conductors (wiggle wires) instead of the tracks for communication with trains and for train position monitoring. The track conductors were positioned between the tracks and crossed over each other every 100 meters to provide points of reference for passing trains.
1975	Canada	The Canadian National Railroad completed a Coast to Coast system of centralized traffic control. In 3,800 miles of track, there are 12 Control Centers.
1975	United Kingdom	A computer system was placed on the line which introduced nation wide monitoring of freight vehicles in 155 freight centers. The system is designated TOPS (Total Operations Processing System) and has proved to be of significant value in enabling freight managers to plan freights movements and vehicle utilization in a more efficient manner.

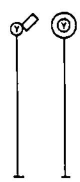
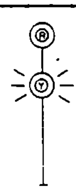
APPENDIX C

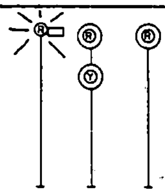
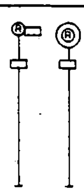
RAILROAD SIGNAL ASPECTS, TITLES AND INDICATIONS

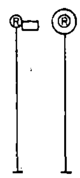
The information included in this appendix is an accumulation of data taken from the official rule books from 18 railroads who carry AMTRAK passenger trains. The rules are arranged in the appendix in alphabetical order by the railroad name.

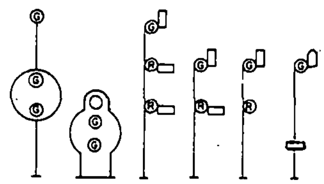
RULE NO.	ATCHISON, TOPEKA AND SANTA FE		
	SIGNAL	NAME	INDICATION
280			
281		CLEAR	PROCEED
281-A		APPROACH LIMITED	PROCEED; APPROACH NEXT SIGNAL NOT EXCEEDING MEDIUM SPEED, AND BE PREPARED TO ENTER DIVERGING ROUTE AT PRESCRIBED SPEED.
281-B			
281-C			
281-D			

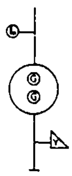
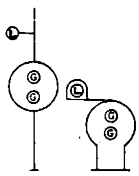
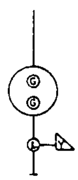
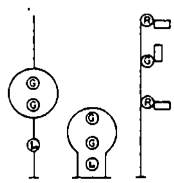
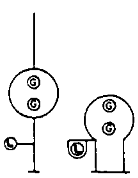
RULE NO.	ATCHISON, TOPEKA AND SANTA FE SIGNAL	NAME	INDICATION
281-E			
282		APPROACH MEDIUM	PROCEED; APPROACH NEXT SIGNAL NOT EXCEEDING MEDIUM SPEED, AND BE PREPARED TO ENTER DIVERGING ROUTE AT PRESCRIBED SPEED.
282-A			
283		DIVERGING CLEAR	PROCEED THROUGH DIVERGING ROUTE; PRESCRIBED SPEED THROUGH TURNOUT.
283-A			
283-B			

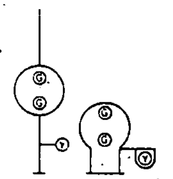
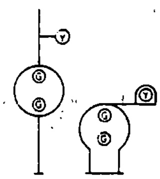
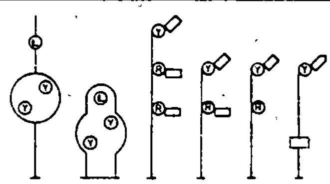
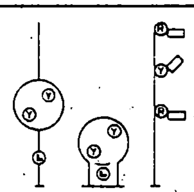
RULE NO.	ATCHISON, TOPEKA AND SANTA FE		
	SIGNAL	NAME	INDICATION
283-C			
284		APPROACH RESTRICTED	PROCEED; PREPARED TO PASS NEXT SIGNAL AT RESTRICTED SPEED, AND TO ENTER DIVERGING ROUT AT PRESCRIBED SPEED; IF EXCEEDING MEDIUM SPEED, IMMEDIATELY REDUCE TO MEDIUM SPEED.
285		APPROACH	PROCEED PREPARING TO STOP AT NEXT SIGNAL; IF EXCEEDING MEDIUM SPEED IMMEDIATELY REDUCE TO MEDIUM SPEED.
285-A			
285-B			
286		DIVERGING APPROACH	PROCEED THROUGH DIVERGING ROUTE; PRESCRIBED SPEED THROUGH TURNOUT; APPROACH NEXT SIGNAL PREPARING TO STOP, IF EXCEEDING MEDIUM SPEED IMMEDIATELY REDUCE TO MEDIUM SPEED.

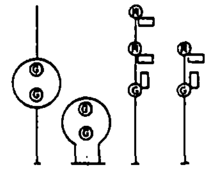
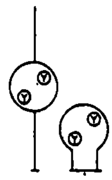
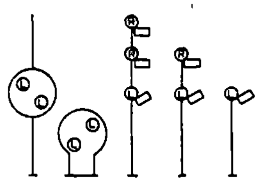
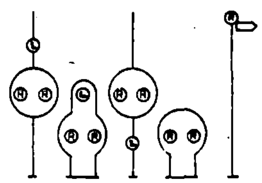
RULE NO.	ATCHISON, TOPEKA AND SANTA FE		
	SIGNAL	NAME	INDICATION
287			
288			
289			
290		RESTRICTING	PROCEED AT RESTRICTED SPEED
290-A		PERMISSIVE	PROCEED AT RESTRICTED SPEED
291		STOP AND PROCEED	STOP; THEN PROCEED AS PRESCRIBED BY RULE 320. (ALTERNATIVE CONDITIONS; 1. SINGLE TRACK W/O TCS 2. ANY TRACK WITH TCS 3. FACING POINT SWITCH IMMEDIATELY BEYOND SIGNAL 4. TRAIN OR CARS IMMEDIATELY BEYOND SIGNAL)

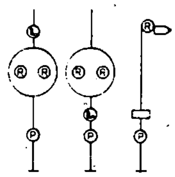
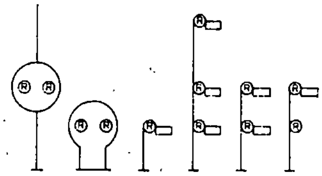
RULE NO.	ATCHISON, TOPEKA AND SANTA FE		
	SIGNAL	NAME	INDICATION
291-A			
292		STOP	STOP
293			
293-A			
294			
295			

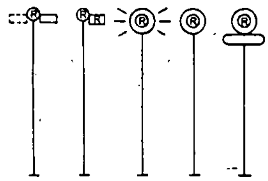
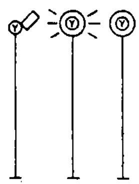
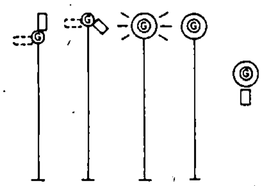
RULE NO.	BALTIMORE AND OHIO		
	SIGNAL	NAME	INDICATION
280			
B281		CLEAR	PROCEED
281-A			
281-B			
281-C			
281-D			

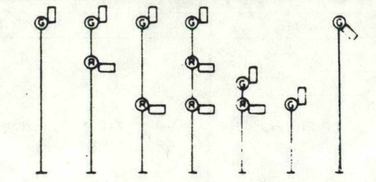
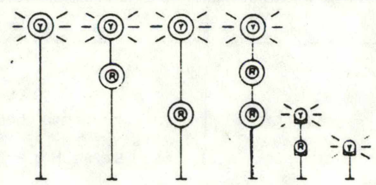
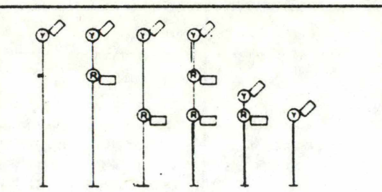
RULE NO.	BALTIMORE AND OHIO		
	SIGNAL	NAME	INDICATION
281-E			
282		APPROACH LIMITED	PROCEED APPROACHING NEXT SIGNAL AT NOT EXCEEDING LIMITED SPEED
282-A		APPROACH MEDIUM	PROCEED APPROACHING NEXT SIGNAL AT NOT EXCEEDING MEDIUM SPEED
283		LIMITED CLEAR	LIMITED SPEED THROUGH CROSSOVERS TURNOUTS, SIDINGS, INTERLOCKING LIMITS AND OVER POWER SWITCHES; THEN PROCEED AT MAXIMUM AUTHORIZED SPEED
283-A		MEDIUM CLEAR	MEDIUM SPEED THROUGH CROSSOVERS TURNOUTS, SIDINGS, INTERLOCKING LIMITS AND OVER POWER SWITCHES; THEN PROCEED AT MAXIMUM AUTHORIZED SPEED
283-B		MEDIUM APPROACH MEDIUM	PROCEED AT NOT EXCEEDING MEDIUM SPEED APPROACHING NEXT SIGNAL AT NOT EXCEEDING MEDIUM SPEED

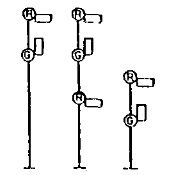
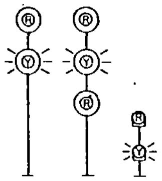
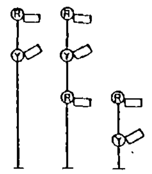
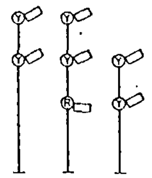
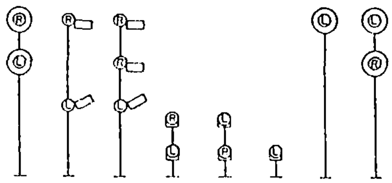
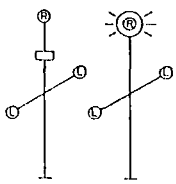
RULE NO.	BALTIMORE AND OHIO		
	SIGNAL	NAME	INDICATION
283-C		MEDIUM APPROACH SLOW	PROCEED AT NOT EXCEEDING MEDIUM SPEED APPROACHING NEXT SIGNAL AT NOT EXCEEDING SLOW SPEED.
284		APPROACH SLOW	PROCEED APPROACHING NEXT SIGNAL AT SLOW SPEED. TRAIN OR ENGINE EXCEEDING MEDIUM SPEED WHEN INDICATION IS SEEN MUST TAKE ACTION AT ONCE TO REDUCE TO MEDIUM SPEED OR SLOWER, IF NECESSARY.
B285		APPROACH	PROCEED PREPARED TO STOP AT NEXT SIGNAL. TRAIN OR ENGINE EXCEEDING MEDIUM SPEED WHEN INDICATION IS SEEN MUST TAKE ACTION AT ONCE TO REDUCE TO MEDIUM SPEED OR SLOWER IF NECESSARY.
B285-A		DISTANT SIGNAL	APPROACH NEXT SIGNAL PREPARED TO STOP.
285-B			
286		MEDIUM APPROACH	PROCEED AT NOT EXCEEDING MEDIUM SPEED PREPARED TO STOP AT NEXT SIGNAL.

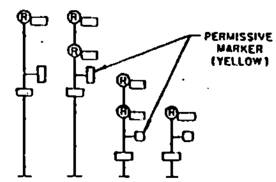
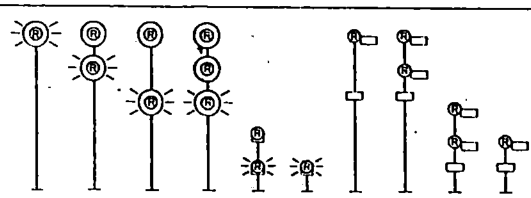
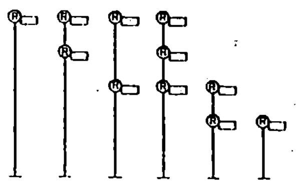
RULE NO.	BALTIMORE AND OHIO		
	SIGNAL	NAME	INDICATION
287		SLOW-APPROACH SLOW	SLOW SPEED THROUGH CROSSOVERS, TURNOUTS, SIDINGS, INTERLOCKING LIMITS, AND OVER POWER SWITCHES. TRAIN OR ENGINE MAY THEN PROCEED AT MAXIMUM AUTHORIZED SPEED, IF CONDITIONS PERMIT, BUT MUST APPROACH THE NEXT SIGNAL AT NOT EXCEEDING SLOW SPEED
288		SLOW-APPROACH	SLOW SPEED THROUGH CROSSOVERS, TURNOUTS, SIDINGS, INTERLOCKING LIMITS, AND OVER POWER SWITCHES; THEN PROCEED AT NOT EXCEEDING MEDIUM SPEED PREPARED TO STOP AT NEXT SIGNAL
289			
290		RESTRICTING	PROCEED AT RESTRICTED SPEED
290-A			
B291		STOP AND PROCEED	STOP; THEN PROCEED AT RESTRICTED SPEED

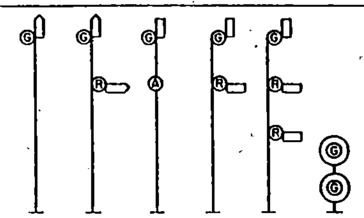
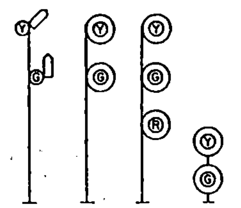
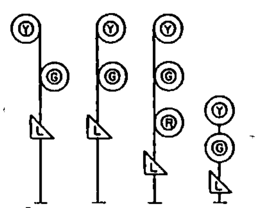
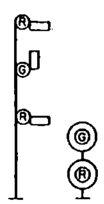
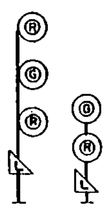
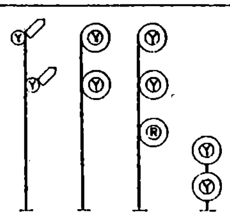
RULE NO.	BALTIMORE AND OHIO		
	SIGNAL	NAME	INDICATION
291-A		GRADE SIGNAL	PROCEED AT RESTRICTED SPEED WITHOUT STOPPING
B292		STOP	STOP
293		DRAGGING EQUIPMENT SIGNAL	WHEN ILLUMINATED, STOP AND EXAMINE TRAIN FOR DRAGGING EQUIPMENT
293-A			
294		TAKE SIDING SIGNAL	WHEN ILLUMINATED, TAKE SIDING
295		END OF TRACK CIRCUIT SIGN	END OF TRACK CIRCUIT

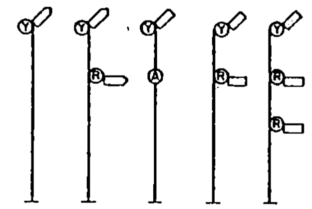
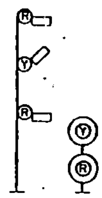
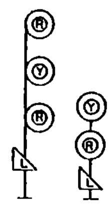
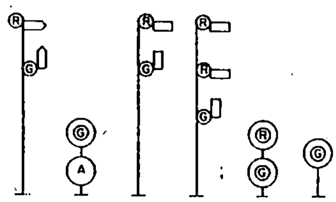
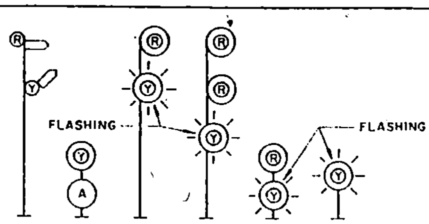
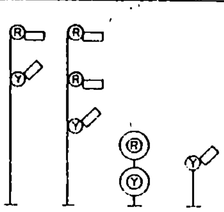
RULE NO.	BURLINGTON NORTHERN		
	SIGNAL	NAME	INDICATION
222-A		STOP	STOP UNLESS CLEARANCE RECEIVED.
222-B		19 ORDER	PROCEED IF CLEARANCE RECEIVED.
222-C		CLEAR	PROCEED
240-A			
240-B			
240-C			

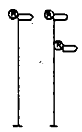
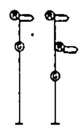
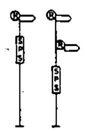
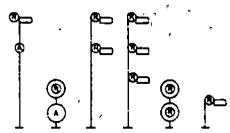
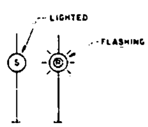
RULE NO.	BURLINGTON NORTHERN		
	SIGNAL	NAME	INDICATION
501		CLEAR	PROCEED
501-A		APPROACH MEDIUM	PROCEED APPROACHING NEXT SIGNAL NOT EXCEEDING 30 MPH.
501-B		APPROACH	PROCEED PREPARED TO STOP BEFORE ANY PART OF TRAIN OR ENGINE PASSES THE NEXT SIGNAL.

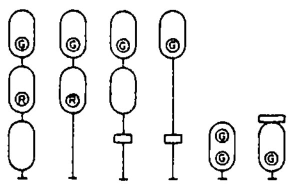
AAR RULE NO.	BURLINGTON NORTHERN		
	SIGNAL	NAME	INDICATION
501-C		DIVERGING CLEAR	PROCEED ON DIVERGING ROUTE AT PRESCRIBED SPEED.
501-D		DIVERGING APPROACH MEDIUM	PROCEED ON DIVERGING ROUTE AT PRESCRIBED SPEED AND APPROACH NEXT SIGNAL NOT EXCEEDING 30 MPH.
501-E		DIVERGING APPROACH	PROCEED ON DIVERGING ROUTE AT PRESCRIBED SPEED PREPARED TO STOP BEFORE ANY PART OF TRAIN OR ENGINE PASSES THE NEXT SIGNAL.
501-F		APPROACH RESTRICTING	PROCEED APPROACHING NEXT SIGNAL NOT EXCEEDING RESTRICTED SPEED.
501-G		RESTRICTING	PROCEED AT RESTRICTED SPEED.
501-H		TAKE SIDING INDICATOR FOR HAND OPERATION OF SWITCH	PROCEED AT RESTRICTED SPEED. HAND OPERATE SWITCH AND ENTER SIDING.

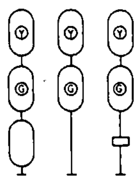
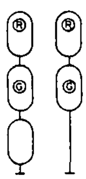
AAR RULE NO.	BURLINGTON NORTHERN		
	SIGNAL	NAME	INDICATION
501-I		PERMISSIVE	PROCEED AT RESTRICTED SPEED THROUGH ENTIRE BLOCK.
501-J		STOP AND PROCEED	STOP BEFORE ANY PART OF TRAIN OR ENGINE PASSES THE SIGNAL THEN PROCEED AT RESTRICTED SPEED THROUGH ENTIRE BLOCK.
501-K		STOP	STOP BEFORE ANY PART OF TRAIN OR ENGINE PASSES THE SIGNAL.

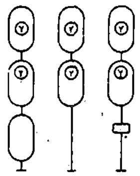
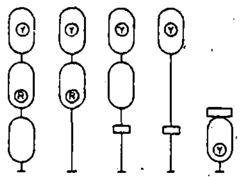
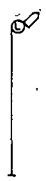
RULE NO.	CANADIAN NATIONAL		
	SIGNAL	NAME	INDICATION
281		CLEAR SIGNAL	PROCEED
282		APPROACH MEDIUM SIGNAL	PROCEED, APPROACHING NEXT SIGNAL AT MEDIUM SPEED.
282-A		APPROACH LIMITED SIGNAL	PROCEED, APPROACHING NEXT SIGNAL AT LIMITED SPEED.
283		MEDIUM CLEAR SIGNAL	PROCEED, MEDIUM SPEED WITHIN INTERLOCKING LIMITS OR THROUGH TURNOUTS.
283-A		LIMITED CLEAR SIGNAL	PROCEED, LIMITED SPEED WITHIN INTERLOCKING LIMITS OR THROUGH TURNOUTS.
284		APPROACH SLOW SIGNAL	PROCEED, APPROACHING NEXT SIGNAL AT SLOW SPEED. TRAINS EXCEEDING MEDIUM SPEED MUST AT ONCE REDUCE TO THAT SPEED.

RULE NO.	CANADIAN NATIONAL		
	SIGNAL	NAME	INDICATION
285		APPROACH SIGNAL	PROCEED, PREPARING TO STOP AT NEXT SIGNAL. TRAINS EXCEEDING MEDIUM SPEED MUST AT ONCE REDUCE TO THAT SPEED. REDUCTION TO MEDIUM SPEED MUST COMMENCE BEFORE PASSING SIGNAL.
286		MEDIUM APPROACH SIGNAL	PROCEED AT MEDIUM SPEED PREPARING TO STOP AT NEXT SIGNAL.
286-A		LIMITED APPROACH SIGNAL	PROCEED AT LIMITED SPEED PREPARING TO STOP AT NEXT SIGNAL.
287		SLOW CLEAR SIGNAL	PROCEED, SLOW SPEED WITHIN INTERLOCKING LIMITS OR THROUGH TURNOUTS.
288		SLOW APPROACH SIGNAL	PROCEED, PREPARING TO STOP AT NEXT SIGNAL. SLOW SPEED WITHIN INTERLOCKING LIMITS OR THROUGH TURNOUTS, MEDIUM SPEED MUST THEN NOT BE EXCEEDED UNTIL A MORE FAVORABLE INDICATION HAS BEEN ACCEPTED.
290		RESTRICTING SIGNAL	PROCEED AT RESTRICTED SPEED.

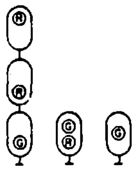
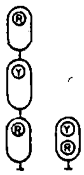
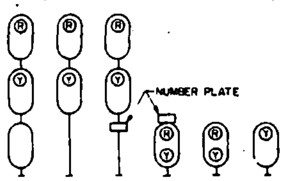
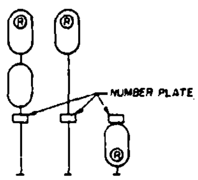
RULE NO.	CANADIAN NATIONAL SIGNAL	NAME	INDICATION
291		STOP AND PROCEED SIGNAL	STOP, THEN PROCEED AT RESTRICTED SPEED.
291-A		GRADE SIGNAL	TRAINS HANDLING FIFTY PER CENT OR MORE OF RULING GRADE TONNAGE APPROACHING A GRADE SIGNAL INDICATING "STOP, THEN PROCEED AT RESTRICTED SPEED" MAY PASS IT WITHOUT STOPPING AND PROCEED AT RESTRICTED SPEED.
291-B		STATION PROTECTION SIGNAL	STOP, THEN PROCEED AT RESTRICTED SPEED AND PRECEDED BY A FLAGMAN WHEN NECESSARY TO ENSURE FULL PROTECTION.
292		STOP SIGNAL	STOP
293		TAKE (OR LEAVE) SIDING SIGNAL	BE GOVERNED BY SIGNAL INDICATION. TAKE (OR LEAVE) SIDING WHEN "S" LIGHTED OR LIGHT FLASHING. NOTE: LIGHTED "S" OR FLASHING LIGHT IS USED IN CONJUNCTION WITH A BLOCK OR INTERLOCKING SIGNAL.

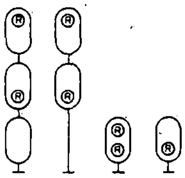
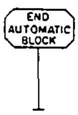
RULE NO.	CHESAPEAKE AND OHIO		
	SIGNAL	NAME	INDICATION
280			
281		CLEAR	PROCEED
281-A			
281-B			
281-C			
281-D			

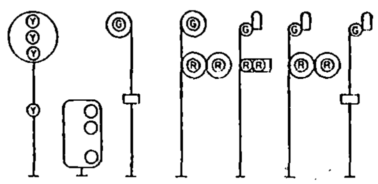
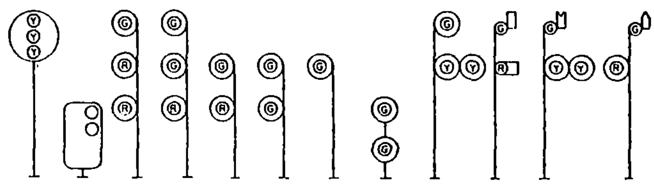
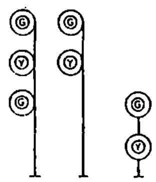
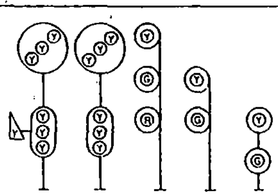
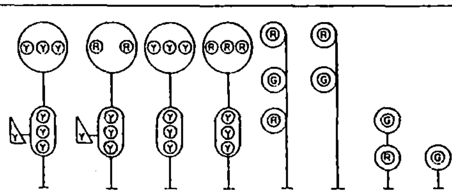
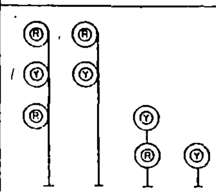
RULE NO.	CHESAPEAKE AND OHIO		
	SIGNAL	NAME	INDICATION
281-E			
282		APPROACH MEDIUM	PROCEED APPROACHING NEXT SIGNAL AT NOT EXCEEDING MEDIUM SPEED
282-A			
283		MEDIUM CLEAR	MEDIUM SPEED THROUGH CROSSOVERS TURNOUTS, SIDINGS, INTERLOCKING LIMITS AND OVER POWER SWITCHES; THEN PROCEED AT MAXIMUM AUTHORIZED SPEED
283-A		MEDIUM APPROACH SLOW	PROCEED AT NOT EXCEEDING MEDIUM SPEED APPROACHING NEXT SIGNAL AT NOT EXCEEDING SLOW SPEED
283-B			

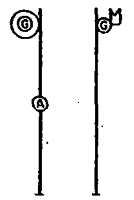
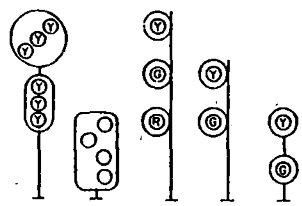
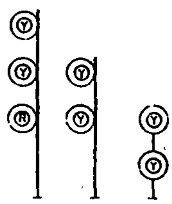
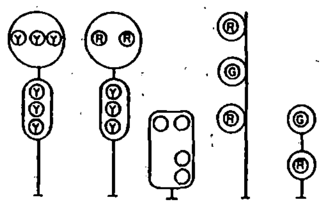
RULE NO.	CHESAPEAKE AND OHIO		
	SIGNAL	NAME	INDICATION
283-C			
284		APPROACH SLOW	PROCEED APPROACHING NEXT SIGNAL AT NOT EXCEEDING SLOW SPEED; TRAIN OR ENGINE EXCEEDING MEDIUM SPEED MUST TAKE ACTION AT OR BEFORE REACHING APPROACH SLOW INDICATION TO REDUCE TO THAT SPEED.
285		APPROACH	PROCEED PREPARED TO STOP AT NEXT SIGNAL. TRAIN OR ENGINE EXCEEDING MEDIUM SPEED MUST TAKE ACTION AT OR BEFORE REACHING APPROACH INDICATION TO REDUCE TO THAT SPEED.
285-A		DISTANT SIGNAL	APPROACH NEXT SIGNAL PREPARED TO STOP.
285-B			
286		MEDIUM APPROACH	PROCEED AT NOT EXCEEDING MEDIUM SPEED PREPARED TO STOP AT NEXT SIGNAL.

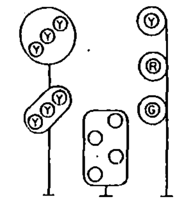
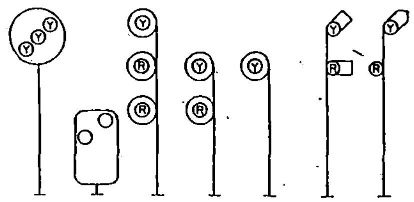
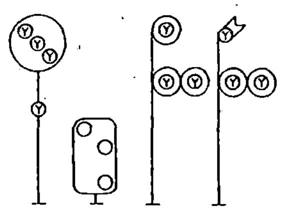
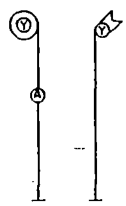
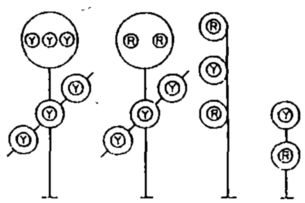
CHESAPEAKE AND OHIO

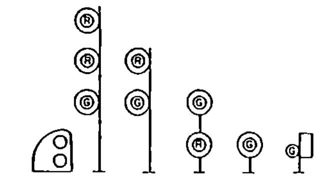
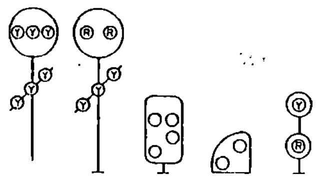
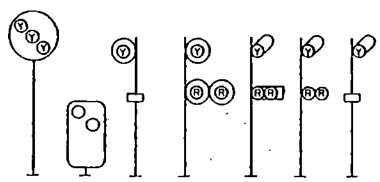
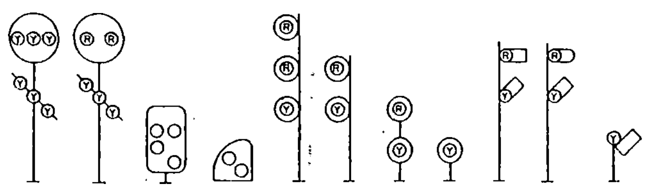
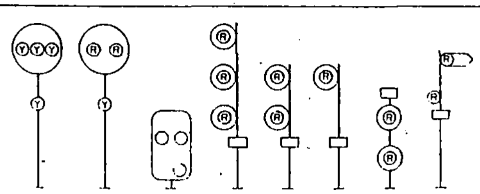
RULE NO.	SIGNAL	NAME	INDICATION
287		SLOW CLEAR	SLOW SPEED THROUGH CROSSOVERS, TURNOUTS, SIDINGS, INTERLOCKING LIMITS, AND OVER POWER SWITCHES; THEN PROCEED AT MAXIMUM AUTHORIZED SPEED
288		SLOW-APPROACH	SLOW SPEED THROUGH CROSSOVERS, TURNOUTS, SIDINGS, INTERLOCKING LIMITS, AND OVER POWER SWITCHES; THEN PROCEED AT NOT EXCEEDING MEDIUM SPEED PREPARED TO STOP AT NEXT SIGNAL
289			
290		RESTRICTING	PROCEED AT RESTRICTED SPEED
290-A			
291		STOP AND PROCEED	STOP; THEN PROCEED AT RESTRICTED SPEED

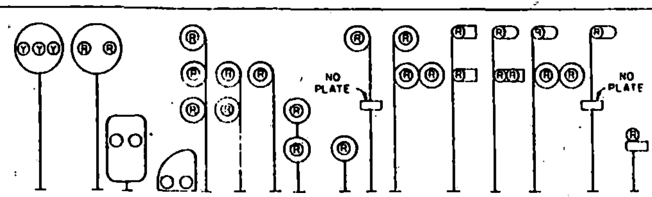
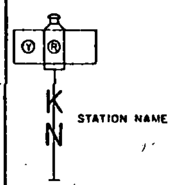
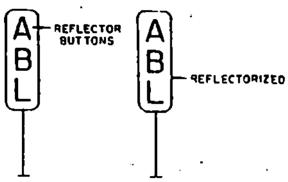
RULE NO.	CHESAPEAKE AND OHIO		
	SIGNAL	NAME	INDICATION
291-A			
292		STOP	STOP
293			
293-A			
294		TAKE SIDING	TRAIN TAKE SIDING
295		BLOCK SIGN	END OF TRACK CIRCUIT

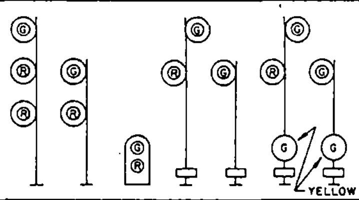
RULE NO.	CONRAIL , AMTRAK		
	SIGNAL	NAME	INDICATION
280		CLEAR - BLOCK	PROCEED; FOR PASSENGER TRAINS, MANUAL BLOCK CLEAR; FOR TRAINS OTHER THAN PASSENGER TRAINS, MANUAL BLOCK CLEAR OUTSIDE YARD LIMITS.
281		CLEAR	PROCEED
281-A		ADVANCE APPROACH MEDIUM	PROCEED APPROACHING SECOND SIGNAL AT MEDIUM SPEED.
281-B		APPROACH LIMITED	PROCEED APPROACHING NEXT SIGNAL AT LIMITED SPEED.
281-C		LIMITED CLEAR	PROCEED: LIMITED SPEED WITHIN INTERLOCKING LIMITS. NOTE - IN CAB SIGNAL TERRITORY WITH FIXED AUTOMATIC BLOCK SIGNAL, TRAINS WITH CAB SIGNALS NOT IN OPERATIVE CONDITION, OR NOT EQUIPPED WITH CAB SIGNALS, MUST NOT EXCEED MEDIUM SPEED TO NEXT SIGNAL.
281-D		LIMITED APPROACH	PROCEED AT LIMITED SPEED PREPARING TO STOP AT NEXT SIGNAL.

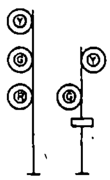
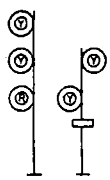
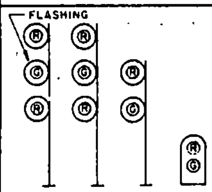
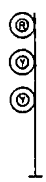
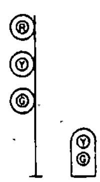
RULE NO.	CONRAIL, AMTRAK SIGNAL	NAME	INDICATION
281-E		APPROACH CLEAR	PROCEED. NOTE—DOES NOT CONVEY CONDITION OF TRACK BETWEEN APPROACH SIGNAL AND INTERLOCKING SIGNAL.
282		APPROACH MEDIUM	PROCEED APPROACHING NEXT SIGNAL AT MEDIUM SPEED.
282-A		ADVANCE APPROACH	PROCEED PREPARING TO STOP AT SECOND SIGNAL. TRAIN EXCEEDING LIMITED SPEED MUST AT ONCE REDUCE TO THAT SPEED.
283		MEDIUM CLEAR	PROCEED; MEDIUM SPEED WITHIN INTERLOCKING LIMITS. NOTE—IN CAB SIGNAL TERRITORY WITH FIXED AUTOMATIC BLOCK SIGNALS, TRAINS WITH CAB SIGNALS NOT IN OPERATIVE CONDITION, OR NOT EQUIPPED WITH CAB SIGNALS, MUST NOT EXCEED MEDIUM SPEED TO NEXT SIGNAL.
283-A		MEDIUM ADVANCE APPROACH	PROCEED PREPARING TO STOP AT SECOND SIGNAL; MEDIUM SPEED WITHIN INTERLOCKING LIMITS.
283-B		MEDIUM APPROACH SLOW	PROCEED AT MEDIUM SPEED APPROACHING NEXT SIGNAL AT SLOW SPEED.

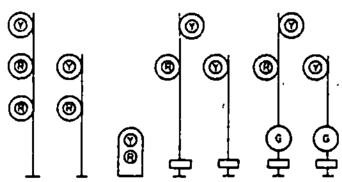
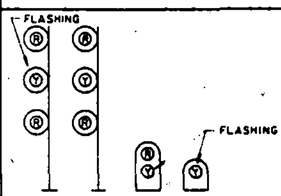
RULE NO.	CONRAIL , AMTRAK		
	SIGNAL	NAME	INDICATION
283-C			
284		APPROACH SLOW	PROCEED APPROACHING NEXT SIGNAL AT SLOW SPEED TRAIN EXCEEDING MEDIUM SPEED MUST AT ONCE REDUCE TO THAT SPEED
285		APPROACH	PROCEED PREPARED TO STOP AT NEXT SIGNAL. TRAIN EXCEEDING MEDIUM SPEED MUST AT ONCE REDUCE TO THAT SPEED
285-A		CAUTION	TRAIN EXCEEDING MEDIUM SPEED MUST AT ONCE REDUCE TO THAT SPEED. WHERE A FACING SWITCH IS CONNECTED WITH THE SIGNAL, APPROACH THAT SWITCH PREPARED TO STOP. APPROACH NEXT SIGNAL PREPARED TO STOP.
285-B		APPROACH RESTRICTING	PROCEED PREPARED TO STOP AT NEXT SIGNAL. TRAINS EXCEEDING MEDIUM SPEED MUST AT ONCE REDUCE TO THAT SPEED. NOTE - DOES NOT CONVEY CONDITION OF TRACK BETWEEN APPROACH SIGNAL AND INTERLOCKING SIGNAL
286		MEDIUM APPROACH	PROCEED AT MEDIUM SPEED PREPARED TO STOP AT NEXT SIGNAL

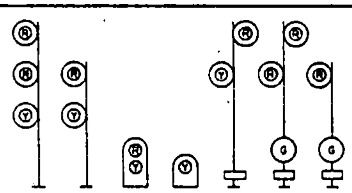
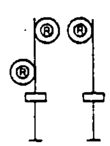
RULE NO.	CONRAIL , AMTRAK		
	SIGNAL	NAME	INDICATION
287		SLOW-CLEAR	PROCEED; SLOW SPEED WITHIN INTERLOCKING LIMITS.
288		SLOW APPROACH	PROCEED PREPARING TO STOP AT NEXT SIGNAL; SLOW SPEED WITHIN INTERLOCKING LIMITS.
289		PERMISSIVE BLOCK	BLOCK OCCUPIED: FOR PASSENGER TRAINS, STOP: FOR TRAINS OTHER THAN PASSENGER TRAINS PROCEED PREPARED TO STOP SHORT OF A TRAIN OR OBSTRUCTION, BUT NOT EXCEEDING 15 MILES PER HOUR.
290		RESTRICTING	PROCEED AT RESTRICTED SPEED
290-A			
291		STOP AND PROCEED	STOP, THEN PROCEED AT RESTRICTED SPEED. NOTE—WHERE, IN ADDITION TO THE NUMBER PLATE, A LETTER G, GRADE MARKER, IS DISPLAYED AS PART OF THESE ASPECTS, RULE 290 APPLIES.

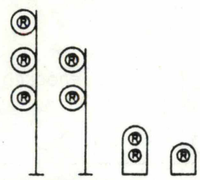
RULE NO.	CONRAIL , AMTRAK		
	SIGNAL	NAME	INDICATION
291-A			
292		STOP SIGNAL	STOP
293		BLOCK-LIMIT	LIMIT OF THE BLOCK NOTE - YELLOW LIGHT TO BE PLACED NEXT TO TRACK GOVERNED
293-A		APPROACH BLOCK-LIMIT	PROCEED PREPARED TO STOP AT NEXT BLOCK-LIMIT SIGNAL. TRAIN EXCEEDING MEDIUM SPEED MUST AT ONCE REDUCE TO THAT SPEED. NOTE - WILL NOT APPLY TO TRAINS AUTHORIZED TO PASS THE BLOCK-LIMIT STATION AS THOUGH CLEAR BLOCK SIGNAL WERE DISPLAYED.
294			
295			

RULE NO.	DELAWARE AND HUDSON		
	SIGNAL	NAME	INDICATION
280			
281		CLEAR	PROCEED
281-A			
281-B			
281-C			
281-D			

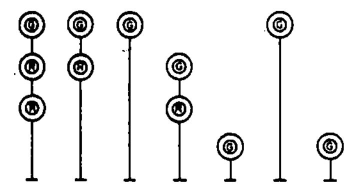
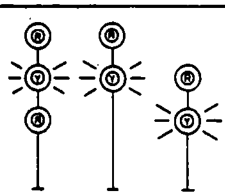
RULE NO.	DELAWARE AND HUDSON — SIGNAL	NAME	INDICATION
281-E			
282		APPROACH MEDIUM	PROCEED APPROACHING NEXT SIGNAL AT MEDIUM SPEED
282-A		ADVANCE APPROACH	PROCEED PREPARING TO STOP AT SECOND SIGNAL
283		MEDIUM CLEAR	PROCEED MEDIUM SPEED WITHIN INTERLOCKING LIMITS
283-A		MEDIUM ADVANCE APPROACH	PROCEED PREPARING TO STOP AT SECOND SIGNAL ; MEDIUM SPEED WITHIN INTERLOCKING LIMITS
283-B		MEDIUM APPROACH MEDIUM	PROCEED AT MEDIUM SPEED APPROACHING NEXT SIGNAL AT MEDIUM SPEED

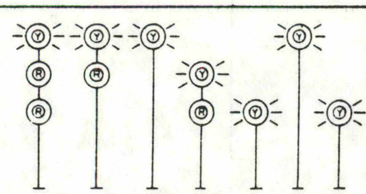
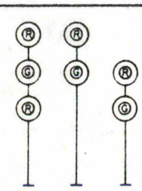
RULE NO.	DELAWARE AND HUDSON		
	SIGNAL	NAME	INDICATION
283-C			
284			
285		APPROACH	PROCEED PREPARING TO STOP AT NEXT SIGNAL. TRAINS EXCEEDING MEDIUM SPEED MUST AT ONCE REDUCE TO THAT SPEED
285-A			
285-B			
286		MEDIUM APPROACH	PROCEED AT MEDIUM SPEED PREPARING TO STOP AT NEXT SIGNAL

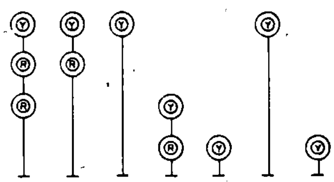
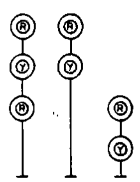
RULE NO.	DELAWARE AND HUDSON		
	SIGNAL	NAME	INDICATION
287			
288			
289			
290		RESTRICTING	PROCEED AT RESTRICTED SPEED
290-A			
291		STOP AND PROCEED	STOP THEN PROCEED AT RESTRICTED SPEED

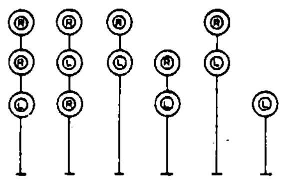
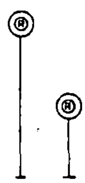
RULE NO.	DELAWARE AND HUDSON		
	SIGNAL	NAME	INDICATION
291-A		RESTRICTING	PROCEED AT RESTRICTED SPEED PREPARING TO ENTER SIDING
292		STOP	STOP
293			
293-A			
294			
295			

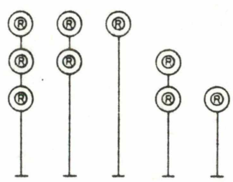
DENVER AND RIO GRANDE WESTERN

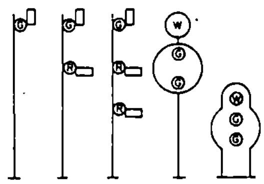
RULE NO.	SIGNAL	NAME	INDICATION
280			
281		CLEAR	PROCEED
281-A			
281-B		DIVERGING APPROACH MEDIUM	PROCEED AUTHORIZED SPEED UNTIL ENTIRE TRAIN IS THROUGH TURNOUT APPROACHING NEXT SIGNAL MEDIUM SPEED.
281-C			
281-D			

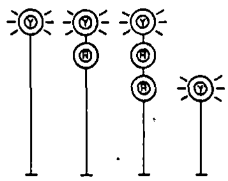
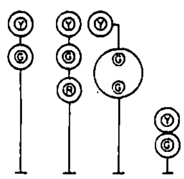
RULE NO.	DENVER AND RIO GRANDE WESTERN		
	SIGNAL	NAME	INDICATION
281-E			
282		APPROACH MEDIUM	PROCEED APPROACHING NEXT SIGNAL MEDIUM SPEED.
282-A			
283		DIVERGING CLEAR	PROCEED AUTHORIZED SPEED UNTIL ENTIRE TRAIN IS THROUGH TURNOUT.
283-A			
283-B			

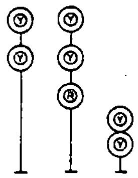
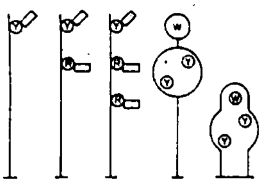
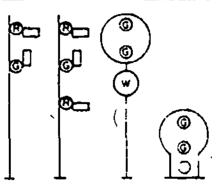
RULE NO.	DENVER AND RIO GRANDE WESTERN		
	SIGNAL	NAME	INDICATION
283-C			
284			
285		APPROACH	PROCEED, PREPARED TO STOP AT NEXT SIGNAL. TRAIN EXCEEDING MEDIUM SPEED MUST AT ONCE REDUCE TO THAT SPEED.
285-A			
285-B			
286		DIVERGING APPROACH	PROCEED MEDIUM SPEED THROUGH TURNOUT, PREPARED TO STOP AT NEXT SIGNAL, EXCEPT WHEN LEAVING MAIN TRACK, BE GOVERNED BY RULE 105.

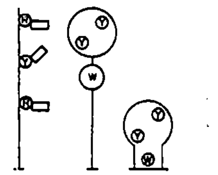
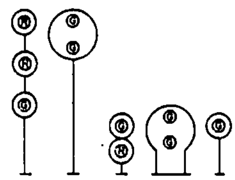
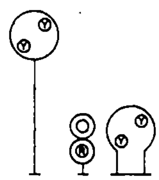
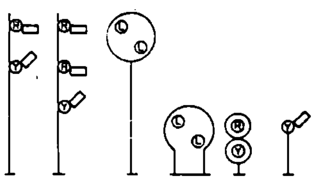
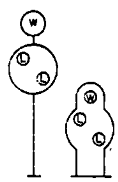
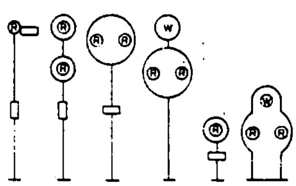
RULE NO.	DENVER AND RIO GRANDE WESTERN		
	SIGNAL	NAME	INDICATION
287			
288			
289			
290		RESTRICTING	PROCEED AT RESTRICTED SPEED; (1) WITHIN ABS TO NEXT SIGNAL GOVERNING IN SAME DIRECTION. (2) AT INTERLOCKING OUTSIDE ABS THROUGH INTERLOCKING LIMITS (3) ONTO NON-SIGNALED TRACK UNTIL ENTIRE TRAIN IS THROUGH TURNOUT; IF THERE IS NO TURNOUT, UNTIL HEAD END OF TRAIN HAS PASSED THE SIGNAL.
291		STOP AND PROCEED	STOP THEN PROCEED, SEE RULE 509. (RULE 509 SAYS THAT AFTER A TRAIN OR LOCOMOTIVE HAS STOPPED IT MAY PROCEED AT RESTRICTED SPEED PREPARED TO FIND ONE OF A NUMBER OF DESCRIBED OBSTACLES.)

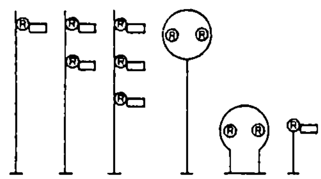
RULE NO.	DENVER AND RIO GRANDE WESTERN		
	SIGNAL	NAME	INDICATION
291-A			
292		STOP	STOP
293			
293-A			
294			
295			

RULE NO.	ILLINOIS CENTRAL GULF		
	SIGNAL	NAME	INDICATION
280			
281		CLEAR	PROCEED
281-A			
281-B			
281-C			
281-D			

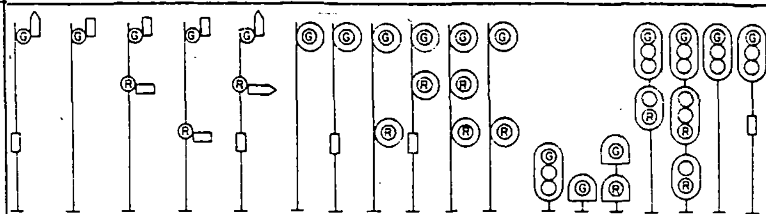
RULE NO.	ILLINOIS CENTRAL GULF		
	SIGNAL	NAME	INDICATION
281-E			
282		ADVANCE APPROACH	PROCEED; PREPARED TO STOP AT SECOND SIGNAL. TRAIN EXCEEDING 30 MPH MUST AT ONCE REDUCE TO THAT SPEED
282-A			
283		APPROACH LIMITED	PROCEED; APPROACHING NEXT SIGNAL PREPARED TO ENTER TURNOUT AT PRESCRIBED SPEED, BUT NOT EXCEEDING 40 MPH
283-A			
283-B			

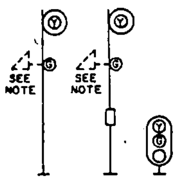
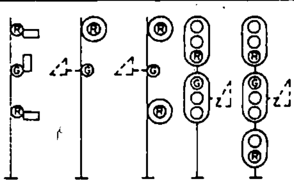
RULE NO.	ILLINOIS CENTRAL GULF		
	SIGNAL	NAME	INDICATION
283-C			
284		MEDIUM APPROACH	PROCEED; APPROACHING NEXT SIGNAL PREPARED TO ENTER TURNOUT AT PRESCRIBED SPEED, BUT NOT EXCEEDING 30 MPH
285		APPROACH	PROCEED; PREPARED TO STOP AT NEXT SIGNAL. TRAIN EXCEEDING 30 MPH MUST AT ONCE REDUCE TO THAT SPEED.
285-A			
285-B			
286		DIVERGING CLEAR	PROCEED ON DIVERGING ROUTE; NOT EXCEEDING PRESCRIBED SPEED THROUGH TURNOUT.

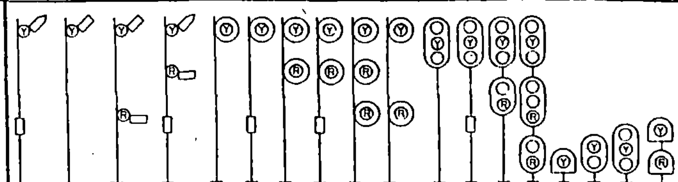
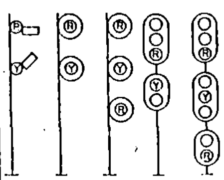
RULE NO.	ILLINOIS CENTRAL GULF		
	SIGNAL	NAME	INDICATION
287		DIVERGING APPROACH	PROCEED ON DIVERGING ROUTE ; THROUGH TURNOUT AT PRESCRIBED SPEED ; PREPARED TO STOP AT NEXT SIGNAL, BUT NOT EXCEEDING 30 MPH
288		SLOW CLEAR	PROCEED ; AT PRESCRIBED SPEED WITHIN INTERLOCKING LIMITS, OR THROUGH TURNOUT
289		SLOW APPROACH	PROCEED ; AT PRESCRIBED SPEED THROUGH TURNOUT OR WITHIN INTERLOCKING LIMITS PREPARED TO STOP AT NEXT SIGNAL, BUT NOT EXCEEDING 30 MPH
290		RESTRICTING	PROCEED AT RESTRICTED SPEED
290-A		RESTRICTING MAIN ROUTE	PROCEED AT RESTRICTED SPEED
291		RESTRICTED PROCEED	PROCEED AT RESTRICTED SPEED

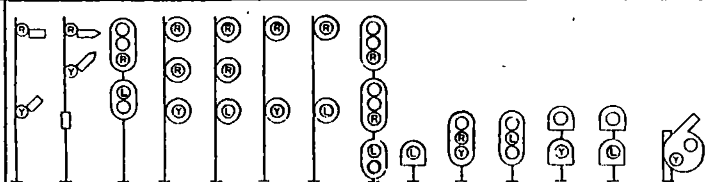
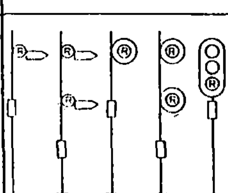
RULE NO.	ILLINOIS CENTRAL GULF		
	SIGNAL	NAME	INDICATION
291-A			
292		STOP	STOP
293			
293-A			
294			
295			

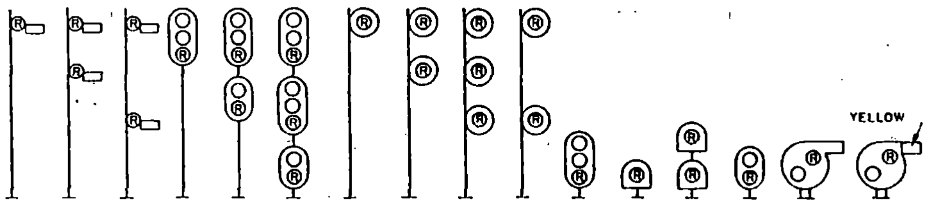
LOUISVILLE AND NASHVILLE

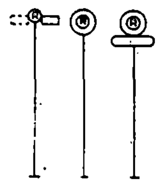
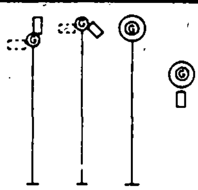
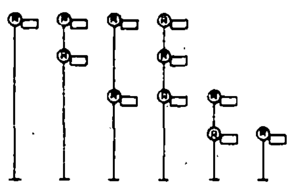
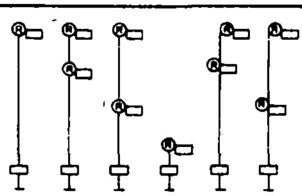
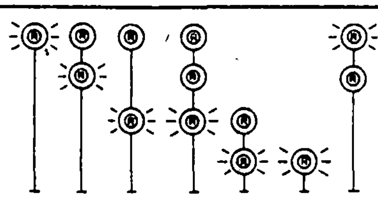
RULE NO.	SIGNAL	NAME	INDICATION
280			
281		CLEAR	PROCEED
281-A			
281-B			
281-C			
281-D			

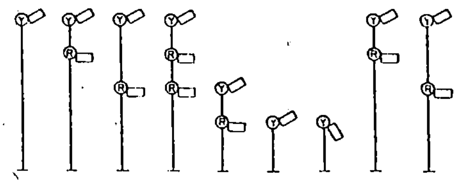
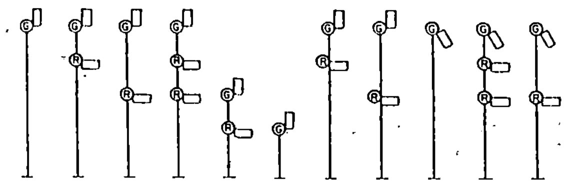
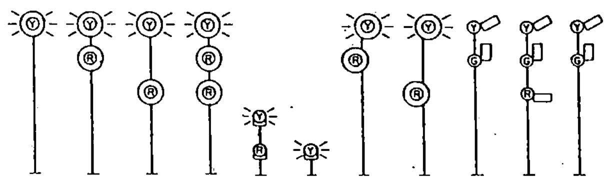
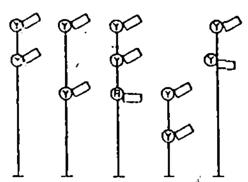
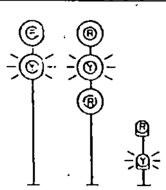
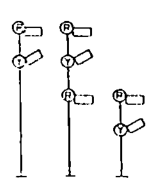
RULE NO.	LOUISVILLE AND NASHVILLE		
	SIGNAL	NAME	INDICATION
281-E			
282		APPROACH MEDIUM	PROCEED APPROACHING NEXT SIGNAL AT MEDIUM SPEED NOTE: AT ANY OF THE SIGNALS DISPLAYING A YELLOW TRIANGLE OUTLINED IN BLACK, TRAIN MAY PROCEED APPROACHING NEXT SIGNAL AT NOT EXCEEDING LIMITED SPEED
282-A			
283		MEDIUM CLEAR	PROCEED AT NOT EXCEEDING MEDIUM SPEED. NOTE: AT ANY OF THE SIGNALS DISPLAYING A YELLOW TRIANGLE OUTLINED IN BLACK, TRAIN MAY PROCEED AT NOT EXCEEDING LIMITED SPEED. NOTE A: IF FLASHING GREEN LIGHT, RESUME NORMAL SPEED AFTER TURNOUT OR CROSSOVER IS CLEARED.
283-A			
283-B			

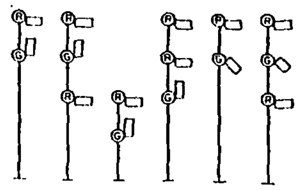
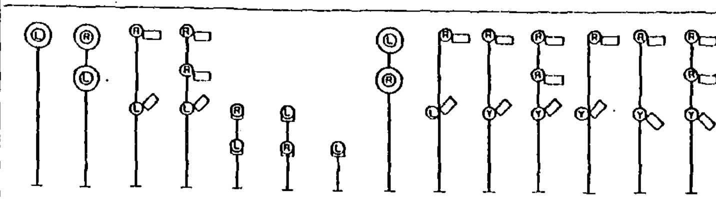
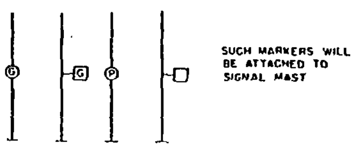
RULE NO.	LOUISVILLE AND NASHVILLE SIGNAL	NAME	INDICATION
283-C			
284			
285		APPROACH	PREPARE TO STOP AT NEXT SIGNAL. TRAIN EXCEEDING MEDIUM SPEED MUST AT ONCE REDUCE TO THAT SPEED.
285-A			
285-B			
286		MEDIUM APPROACH	PROCEED AT NOT EXCEEDING MEDIUM SPEED PREPARED TO STOP AT NEXT SIGNAL.

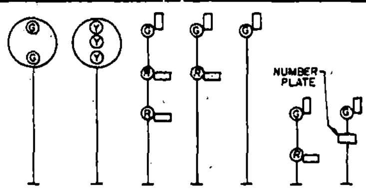
RULE NO.	LOUISVILLE AND NASHVILLE		
	SIGNAL	NAME	INDICATION
287			
288			
289			
290		RESTRICTING	PROCEED AT RESTRICTED SPEED. NOTE-A: IF FLASHING LUNAR LIGHT, RESUME NORMAL SPEED AFTER TURNOUT OR CROSSOVER IS CLEARED.
290-A			
291		RESTRICTED PROCEED	PROCEED AT RESTRICTED SPEED

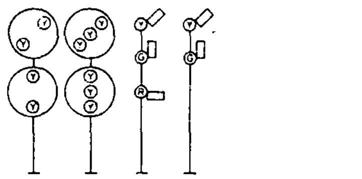
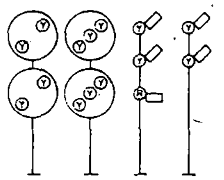
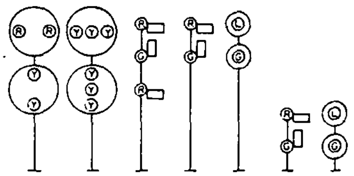
RULE NO.	LOUISVILLE AND NASHVILLE		
	SIGNAL	NAME	INDICATION
291-A			
292		STOP	STOP.
293			
293-A			
294			
295			

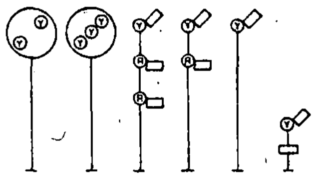
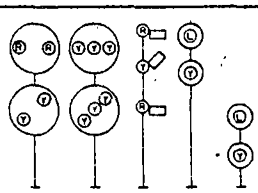
RULE NO.	MILWAUKEE ROAD SIGNAL	NAME	INDICATION
222-A		STOP	STOP FOR ORDERS.
222-B		19 ORDER	PROCEED UNDER CLEARANCE OR TRAIN ORDER AND CLEARANCE.
222-C		CLEAR	PROCEED
240-A		STOP	STOP BEFORE ANY PART OF TRAIN OR ENGINE PASSES THE SIGNAL.
240-B		STOP AND PROCEED	STOP BEFORE ANY PART OF TRAIN OR ENGINE PASSES THE SIGNAL THEN PROCEED AT RESTRICTED SPEED THROUGH ENTIRE BLOCK.
240-C		FLASHING STOP & PROCEED	STOP. BLOCK OCCUPIED. PROCEED AT RESTRICTED SPEED.

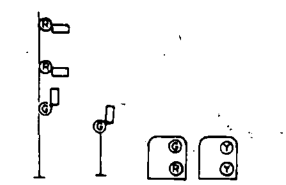
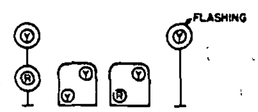
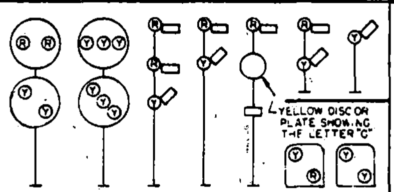
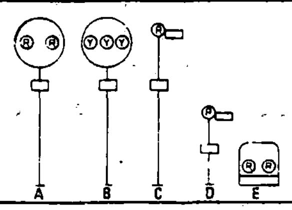
RULE NO.	MILWAUKEE ROAD		
	SIGNAL	NAME	INDICATION
240-D		APPROACH	PROCEED PREPARED TO STOP BEFORE ANY PART OF TRAIN OR ENGINE PASSES THE NEXT SIGNAL. TRAINS EXCEEDING 40 MPH MUST IMMEDIATELY REDUCE TO THAT SPEED.
240-E		CLEAR	PROCEED
240-F		ADVANCE APPROACH	PROCEED PREPARED TO PASS NEXT SIGNAL AT NOT EXCEEDING 40 MILES PER HOUR.
240-G		APPROACH DIVERGING	APPROACH NEXT SIGNAL PREPARED TO PROCEED ON DIVERGING ROUTE AT PRESCRIBED SPEED.
240-K		DIVERGING ADVANCE APPROACH	PROCEED ON DIVERGING ROUTE AT PRESCRIBED SPEED PREPARED TO PASS NEXT SIGNAL AT NOT EXCEEDING 40 MPH.
240-L		DIVERGING APPROACH	PROCEED ON DIVERGING ROUTE AT PRESCRIBED SPEED PREPARED TO STOP BEFORE ANY PART OF TRAIN OR ENGINE PASSES THE NEXT SIGNAL

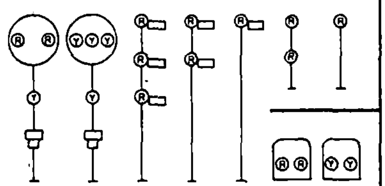
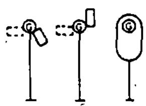
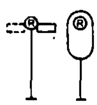
RULE NO.	MILWAUKEE ROAD SIGNAL	NAME	INDICATION
240-M		DIVERGING CLEAR	PROCEED ON DIVERGING ROUTE AT PRESCRIBED SPEED.
240-N		RESTRICTING	PROCEED AT RESTRICTED SPEED
240-P		PERMISSIVE	PROCEED AT RESTRICTED SPEED WITHOUT STOPPING.
501			
501-A			
501-B			

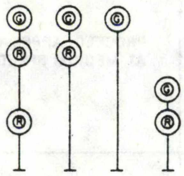
RULE NO.	NORFOLK AND WESTERN		
	SIGNAL	NAME	INDICATION
280			
281		CLEAR	PROCEED AT PRESCRIBED SPEED
281-A			
281-B			
281-C			
281-D			

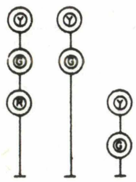
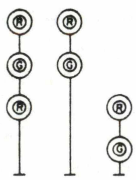
RULE NO.	NORFOLK AND WESTERN		
	SIGNAL	NAME	INDICATION
281-E			
282		APPROACH DIVERGING	PROCEED PREPARING TO TAKE DIVERGING ROUTE BEYOND NEXT SIGNAL AT PRESCRIBED SPEED.
282-A		ADVANCE APPROACH	PROCEED PREPARING TO STOP AT SECOND SIGNAL.
283		DIVERGING CLEAR	PROCEED THROUGH TURNOUT OR TURNOUTS AT PRESCRIBED SPEED.
283-A			
283-B			

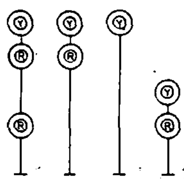
RULE NO.	NORFOLK AND WESTERN		
	SIGNAL	NAME	INDICATION
283-C			
284			
285		APPROACH	PROCEED PREPARING TO STOP AT NEXT SIGNAL. IF EXCEEDING MEDIUM SPEED IMMEDIATELY TAKE ACTION TO REDUCE TO THAT SPEED.
285-A			
285-B			
286		DIVERGING APPROACH	PROCEED THROUGH TURNOUT OR TURNOUTS AT PRESCRIBED SPEED PREPARING TO STOP AT NEXT SIGNAL. IF EXCEEDING MEDIUM SPEED IMMEDIATELY TAKE ACTION TO REDUCE TO THAT SPEED.

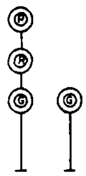
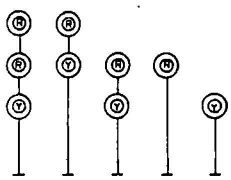
RULE NO.	NORFOLK AND WESTERN		
	SIGNAL	NAME	INDICATION
287		SLOW CLEAR	PROCEED ; SLOW SPEED WITHIN INTERLOCKING LIMITS.
288		SLOW APPROACH	PROCEED PREPARING TO STOP AT NEXT SIGNAL; SLOW SPEED WITHIN INTERLOCKING LIMITS.
289			
290		RESTRICTING	PROCEED AT RESTRICTED SPEED.
290-A			
291		STOP AND PROCEED	STOP; THEN PROCEED AT RESTRICTED SPEED. NOTE TO ASPECT "E"— IF SIGNAL GOVERNS MOVEMENT TO A MAIN TRACK, PROTECTION MUST BE AFFORDED AGAINST TRAINS AND ENGINES APPROACHING WITH THE CURRENT OF TRAFFIC.

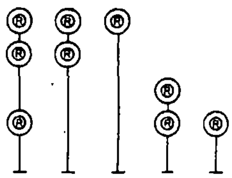
RULE NO.	NORFOLK AND WESTERN		
	SIGNAL	NAME	INDICATION
291-A			
292		STOP AND STAY	STOP AND STAY
293		CLEAR TRAIN ORDER SIGNAL	PROCEED, NO ORDERS
293-A			
294		STOP TRAIN ORDER SIGNAL	STOP, UNLESS CLEARANCE CARD IS RECEIVED
295			

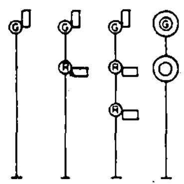
RULE NO.	RICHMOND, FREDERICKSBURG AND POTOMAC		
	SIGNAL	NAME	INDICATION
280			
281		CLEAR	PROCEED
281-A			
281-B			
281-C			
281-D			

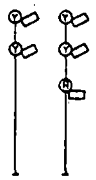
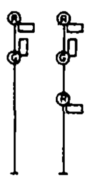
RULE NO.	RICHMOND, FREDERICKSBURG AND POTOMAC		
	SIGNAL	NAME	INDICATION
281-E			
282		APPROACH MEDIUM	PROCEED APPROACHING NEXT SIGNAL AT MEDIUM SPEED.
282-A			
283		MEDIUM CLEAR	PROCEED: MEDIUM SPEED WITHIN INTERLOCKING LIMITS.
283-A			
283-B			

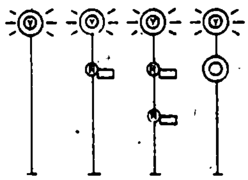
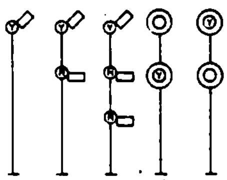
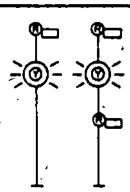
RULE NO.	RICHMOND, FREDERICKSBURG AND POTOMAC		
	SIGNAL	NAME	INDICATION
283-C			
284			
285		APPROACH	PROCEED PREPARED TO STOP AT NEXT SIGNAL. TRAIN EXCEEDING MEDIUM SPEED MUST AT ONCE REDUCE TO THAT SPEED.
285-A			
285-B			
286		MEDIUM APPROACH	PROCEED AT MEDIUM SPEED PREPARED TO STOP AT NEXT SIGNAL.

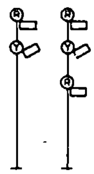
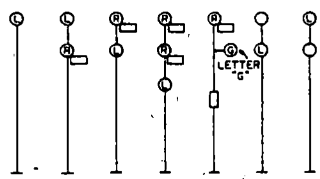
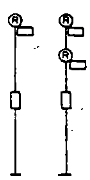
RULE NO.	RICHMOND, FREDERICKSBURG AND POTOMAC		
	SIGNAL	NAME	INDICATION
287		SLOW CLEAR	PROCEED SLOW SPEED THROUGH CROSSOVERS AND TURNOUTS AND THEN PROCEED AT AUTHORIZED SPEED.
288			
289			
290		RESTRICTING	PROCEED AT RESTRICTED SPEED
290-A			
291			

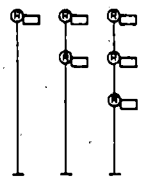
RULE NO.	RICHMOND, FREDERICKSBURG AND POTOMAC		
	SIGNAL	NAME	INDICATION
291-A			
292		STOP SIGNAL	STOP
293			
293-A			
294			
295			

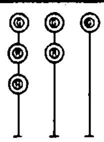
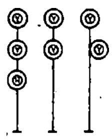
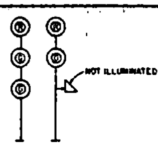
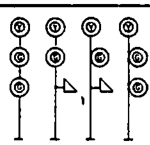
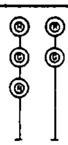
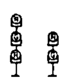
RULE NO.	ROCK ISLAND — MISSOURI PACIFIC		
	SIGNAL	NAME	INDICATION
280			
281		CLEAR	PROCEED
281-A			
281-B			
281-C			
281-D			

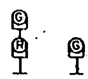
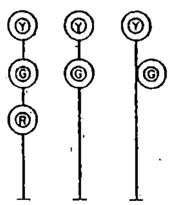
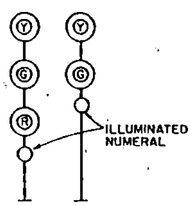
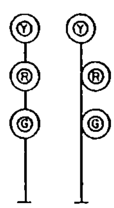
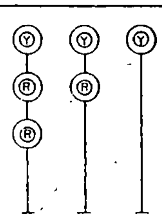
RULE NO.	ROCK ISLAND , MISSOURI PACIFIC		
	SIGNAL	NAME	INDICATION
281-E			
282		ADVANCE APPROACH	PROCEED, REDUCING TO 50 MPH BEFORE REACHING NEXT SIGNAL.
282-A			
283		DIVERGING CLEAR	PROCEED ON DIVERGING ROUTE, NOT EXCEEDING PRESCRIBED SPEED THROUGH TURNOUT.
283-A			
283-B			

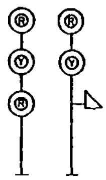
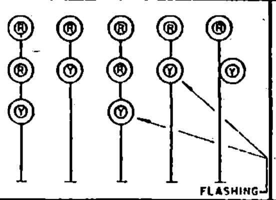
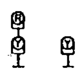
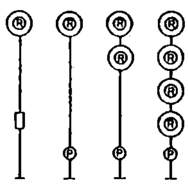
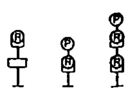
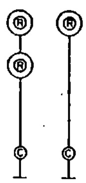
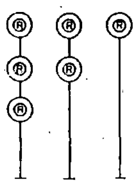
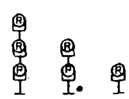
RULE NO.	ROCK ISLAND , MISSOURI PACIFIC		
	SIGNAL	NAME	INDICATION
283-C			
284		APPROACH MEDIUM	PROCEED, REDUCING TO 35 MPH BEFORE REACHING NEXT SIGNAL.
285		APPROACH	PROCEED, IMMEDIATELY REDUCING TO 40 MPH OR SLOWER IF NECESSARY, PREPARED TO STOP BEFORE REACHING NEXT SIGNAL.
285-A			
285-B			
286		DIVERGING APPROACH MEDIUM	PROCEED ON DIVERGING ROUTE, NOT EXCEEDING PRESCRIBED SPEED THROUGH TURNOUT, REDUCING TO 35 MPH BEFORE REACHING NEXT SIGNAL

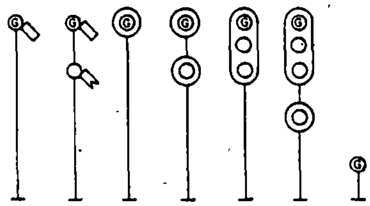
RULE NO.	ROCK ISLAND, MISSOURI PACIFIC		
	SIGNAL	NAME	INDICATION
287		APPROACH DIVERGING	PROCEED, PREPARED TO ADVANCE ON DIVERGING ROUTE AT THE NEXT SIGNAL AT PRESCRIBED SPEED THROUGH TURNOUT.
288		DIVERGING APPROACH	PROCEED ON DIVERGING ROUTE AT PRESCRIBED SPEED THROUGH TURNOUT, PREPARED TO STOP BEFORE REACHING NEXT SIGNAL.
289			
290		LOW	PROCEED AT LOW SPEED: (1) WITHIN ABS—TO NEXT SIGNAL GOVERNING IN SAME DIRECTION. (2) AT INTERLOCKINGS OUTSIDE ABS—THROUGH INTERLOCKING LIMITS. (3) WHERE THIS SIGNAL GOVERNS MOVEMENT ONTO NON-SIGNALED TRACK—UNTIL ENTIRE TRAIN IS THROUGH TURNOUT.
290-A			
291		STOP AND PROCEED	STOP, THEN PROCEED AT LOW SPEED THROUGH THE ENTIRE BLOCK.

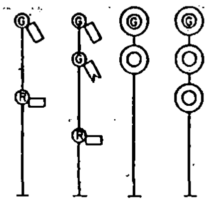
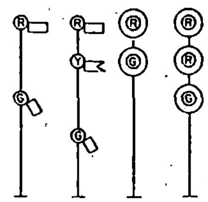
RULE NO.	ROCK ISLAND, MISSOURI PACIFIC		
	SIGNAL	NAME	INDICATION
291-A			
292		STOP	STOP
293			
293-A			
294			
295			

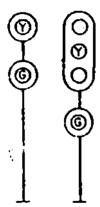
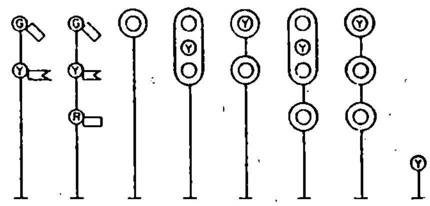
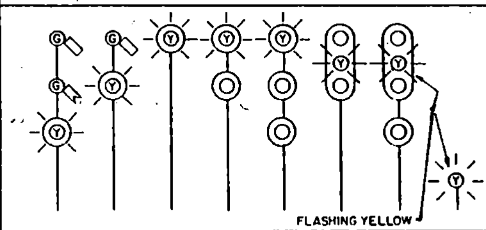
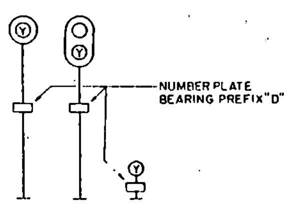
RULE NO.	SEABOARD COAST LINE			
	HIGH SIGNAL	DWARF SIGNAL	NAME	INDICATION
501			CLEAR	PROCEED
502			ADVANCE APPROACH	PROCEED PREPARING TO STOP AT NEXT SIGNAL.
503			LIMITED CLEAR	PROCEED, LIMITED SPEED THROUGH TURNOUTS.
504			APPROACH LIMITED	PROCEED APPROACH NEXT SIGNAL AT LIMITED SPEED; LIMITED SPEED THROUGH TURNOUTS.
505			MEDIUM CLEAR	PROCEED MEDIUM SPEED THROUGH TURNOUTS.
506			MEDIUM ADVANCE APPROACH	PROCEED PREPARING TO STOP AT SECOND SIGNAL; MEDIUM SPEED THROUGH TURNOUTS.

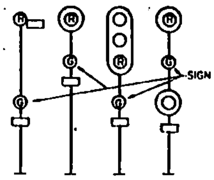
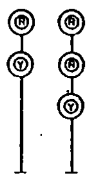
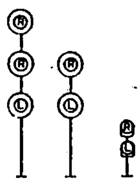
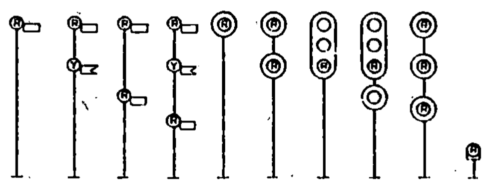
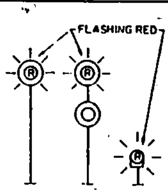
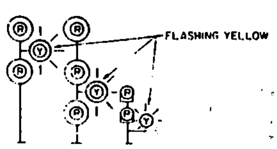
RULE NO.	SEABOARD COAST LINE			
	HIGH SIGNAL	DWARF SIGNAL	NAME	INDICATION
507			CLEAR CONVERGING	PROCEED, AUTHORIZED SPEED THROUGH TURNOUTS.
508			APPROACH MEDIUM	PROCEED APPROACHING NEXT SIGNAL AT MEDIUM SPEED.
509			SPEED APPROACH	PROCEED APPROACHING NEXT SIGNAL AT SPEED DESIGNATED BY ILLUMINATED NUMERAL
510			APPROACH SLOW	PROCEED APPROACHING NEXT SIGNAL AT SLOW SPEED. TRAIN EXCEEDING 40 MPH MUST AT ONCE REDUCE TO THAT SPEED.
511			MEDIUM APPROACH SLOW	PROCEED AT MEDIUM SPEED APPROACHING NEXT SIGNAL AT SLOW SPEED.
512			APPROACH	PROCEED PREPARING TO STOP AT NEXT SIGNAL TRAIN EXCEEDING 40MPH MUST AT ONCE REDUCE TO THAT SPEED UNTIL IT CAN BE PLAINLY SEEN THAT INDICATION OF NEXT SIGNAL ALLOWS TRAIN TO PROCEED.

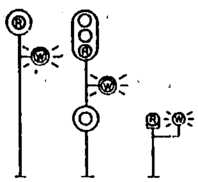
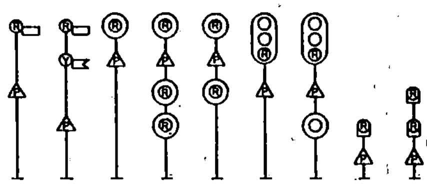
RULE NO.	SEABOARD COAST LINE			
	HIGH SIGNAL	DWARF SIGNAL	NAME	INDICATION
513			MEDIUM APPROACH	MEDIUM SPEED THROUGH TURNOUTS, THEN NOT EXCEEDING 40 MPH PREPARING TO STOP AT NEXT SIGNAL UNTIL IT CAN BE PLAINLY SEEN THAT INDICATION OF NEXT SIGNAL ALLOWS TRAIN TO PROCEED
514			APPROACH CONVERGING	PROCEED AUTHORIZED SPEED THROUGH TURNOUTS, THEN NOT EXCEEDING 40 MPH PREPARING TO STOP AT NEXT SIGNAL, UNTIL IT CAN BE PLAINLY SEEN THAT INDICATION OF NEXT SIGNAL ALLOWS TRAIN TO PROCEED.
515			RESTRICTING	PROCEED AT RESTRICTED SPEED UNTIL ENGINE REACHES NEXT GOVERNING SIGNAL OR END OF BLOCK.
516			RESTRICTED PROCEED	PROCEED AT RESTRICTED SPEED UNTIL ENGINE REACHES NEXT GOVERNING SIGNAL OR END OF BLOCK. NOTE: RESTRICTED PROCEED SIGNAL IS DESIGNATED BY NON-ILLUMINATED NUMBER PLATE OR "P" MARKER.
517			STOP AND CHECK	STOP AND CHECK POSITION OF DRAWBRIDGE, DERAILS OR GATES PROTECTING RAILROAD CROSSING OR SPRING SWITCH. IF WAY IS CLEAR PROCEED AT RESTRICTED SPEED UNTIL ENGINE REACHES NEXT GOVERNING SIGNAL OR END OF BLOCK. NOTE: STOP AND CHECK SIGNAL IS DESIGNATED BY NON-ILLUMINATED "C" MARKER.
			STOP	STOP

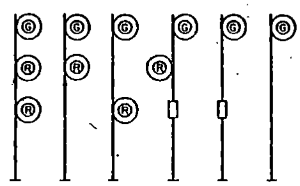
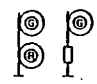
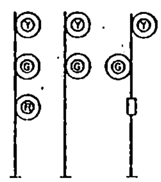
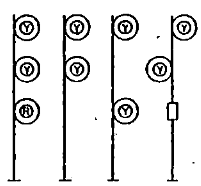
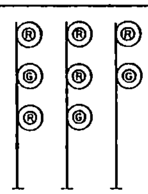
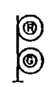
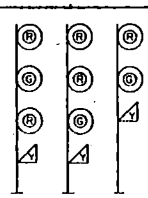
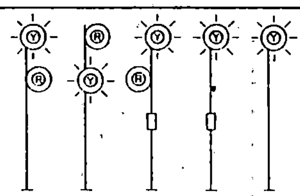
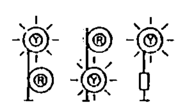
RULE NO.	SOUTHERN PACIFIC		
	SIGNAL	NAME	INDICATION
280			
281		BLOCK SIGNAL GREEN	PROCEED
281-A			
281-B			
281-C			
281-D			

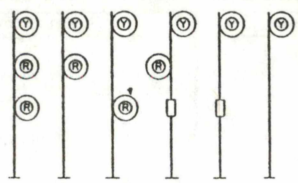
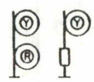
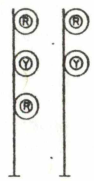
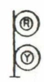
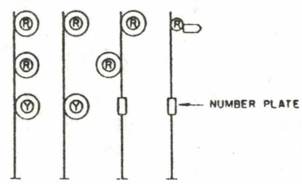
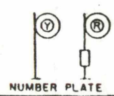
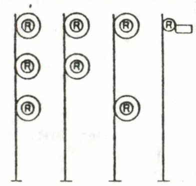
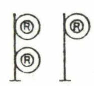
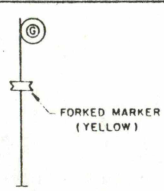
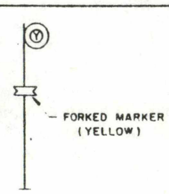
RULE NO.	SOUTHERN PACIFIC		
	SIGNAL	NAME	INDICATION
281-E			
282		BLOCK SIGNAL GREEN	PROCEED EXCEPT ON DIVERGING ROUTE
282-A			
283		BLOCK SIGNAL GREEN FOR DIVERGING ROUTE	PROCEED ON DIVERGING ROUTE
283-A			
283-B			

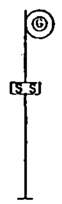
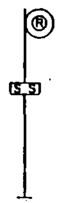
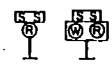
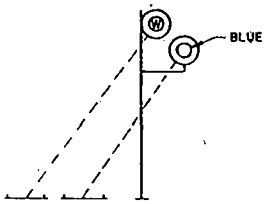
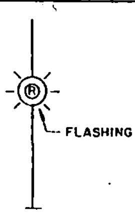
RULE NO.	SOUTHERN PACIFIC		
	SIGNAL	NAME	INDICATION
283-C			
284		BLOCK SIGNAL YELLOW OVER GREEN	REDUCE TO MEDIUM SPEED AND PROCEED. NEXT SIGNAL INDICATES "PROCEED ON DIVERGING ROUTE"
285		APPROACH SIGNAL YELLOW	PROCEED NOT EXCEEDING MEDIUM SPEED, PREPARED TO STOP SHORT OF NEXT HOME SIGNAL.
285-A		APPROACH MEDIUM FLASHING YELLOW	PROCEED PREPARED TO PASS NEXT SIGNAL AT NOT EXCEEDING MEDIUM SPEED.
285-B			
286		DISTANT SIGNAL YELLOW	PROCEED NOT EXCEEDING MEDIUM SPEED, PREPARED TO STOP SHORT OF NEXT HOME SIGNAL.

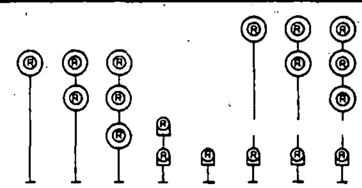
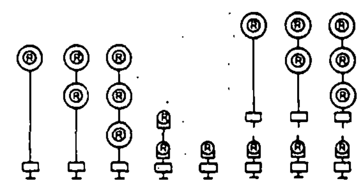
RULE NO.	SOUTHERN PACIFIC SIGNAL	NAME	INDICATION
287		GRADE SIGNAL RED	REDUCE TO RESTRICTED SPEED AND PROCEED.
288		HOME SIGNAL YELLOW FOR DIVERGING ROUTE	PROCEED ON DIVERGING ROUTE AT RESTRICTED SPEED.
289		HOME SIGNAL RED OVER LUNAR	PROCEED WITHOUT STOPPING AT RESTRICTED SPEED ON OTHER THAN MAIN TRACK.
290		HOME SIGNAL RED	STOP
290-A		FLASHING RED	PROCEED WITHOUT STOPPING NOT EXCEEDING RESTRICTED SPEED, PREPARED TO STOP SHORT OF NEXT HOME SIGNAL.
291		FLASHING YELLOW	STOP. THEN PROCEED AT RESTRICTED SPEED WITHOUT CALLING TRAIN DISPATCHER OR OPERATOR

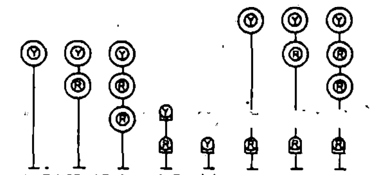
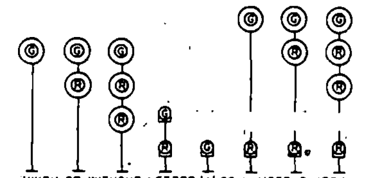
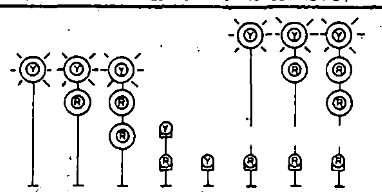
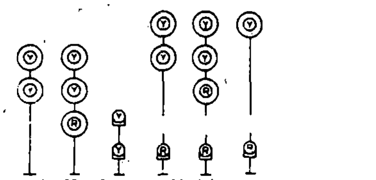
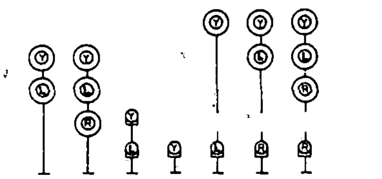
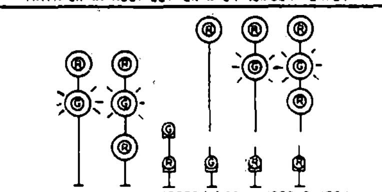
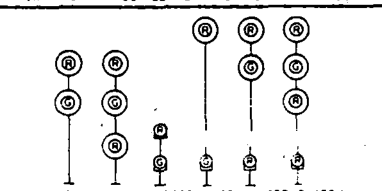
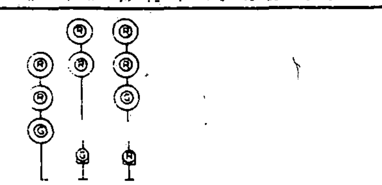
RULE NO.	SOUTHERN PACIFIC		
	SIGNAL	NAME	INDICATION
291-A			
292		FLASHING WHITE	STOP. WHEN FLASHING WHITE DISPLAYED BE GOVERNED BY TIMETABLE
293		HOME SIGNAL RED, WITH TRIANGULAR PLATE	STOP. (INSTRUCTION SAYS TO THEN INSPECT TRAIN AS PROVIDED IN TIMETABLE AND PROCEED IN ACCORDANCE WITH ONE OF SEVERAL ALTERNATIVE RULES.)
293-A			
294			
295			

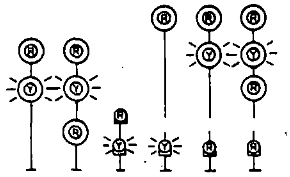
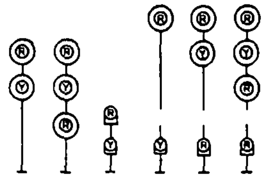
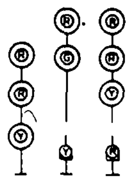
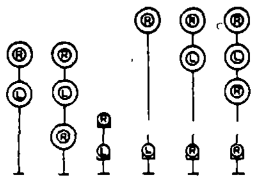
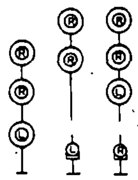
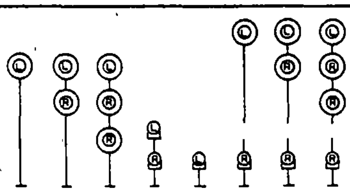
RULE NO.	SOUTHERN RAILWAY			
	HIGH SIGNAL	DWARF SIGNAL	NAME	INDICATION
301			CLEAR	PROCEED
302			APPROACH DIVERGING	PROCEED, APPROACHING NEXT SIGNAL PREPARED TO TAKE DIVERGING ROUTE.
303			ADVANCE APPROACH	PROCEED, PREPARING TO STOP AT SECOND SIGNAL.
304			DIVERGING ROUTE CLEAR	PROCEED THROUGH DIVERGING ROUTE OBSERVING AUTHORIZED SPEED THROUGH TURNOUT OR CROSSOVER.
305			DIVERGING ROUTE CLEAR, APPROACH LIMITED	PROCEED THROUGH DIVERGING ROUTE OBSERVING AUTHORIZED SPEED THROUGH TURNOUT OR CROSSOVER, AND APPROACH NEXT SIGNAL AT AUTHORIZED SPEED, NOT EXCEEDING LIMITED SPEED.
306			APPROACH SLOW	PROCEED, APPROACHING NEXT SIGNAL AT SLOW SPEED. TRAIN EXCEEDING MEDIUM SPEED MUST AT ONCE REDUCE TO THAT SPEED.

<table>
<tr><th rowspan="2">RULE NO.</th><th colspan="4">SOUTHERN RAILWAY</th></tr>
<tr><th>HIGH SIGNAL</th><th>DWARF SIGNAL</th><th>NAME</th><th>INDICATION</th></tr>
<tr><td>307</td><td></td><td></td><td>APPROACH</td><td>PROCEED, PREPARING TO STOP AT NEXT SIGNAL. TRAINS EXCEEDING MEDIUM SPEED MUST AT ONCE REDUCE TO THAT SPEED.</td></tr>
<tr><td>308</td><td></td><td></td><td>DIVERGING ROUTE APPROACH</td><td>PROCEED THROUGH DIVERGING ROUTE OBSERVING AUTHORIZED SPEED THROUGH TURNOUT OR CROSSOVER, THEN NOT EXCEEDING MEDIUM SPEED, PREPARING TO STOP AT NEXT SIGNAL.</td></tr>
<tr><td>309</td><td></td><td></td><td>RESTRICTED PROCEED</td><td>PROCEED AT RESTRICTED SPEED.</td></tr>
<tr><td>310</td><td></td><td></td><td>STOP</td><td>STOP</td></tr>
<tr><td>311</td><td></td><td></td><td>NON-AUTOMATIC BLOCK, CLEAR</td><td>PROCEED
NOTE: A TRAIN OR ENGINE THAT IS DELAYED AFTER PASSING THIS SIGNAL MUST APPROACH NEXT SIGNAL PREPARED TO STOP.</td></tr>
<tr><td>312</td><td></td><td></td><td>NON-AUTOMATIC BLOCK, APPROACH</td><td>APPROACH NEXT SIGNAL PREPARED TO STOP. TRAIN EXCEEDING MEDIUM SPEED MUST AT ONCE REDUCE TO THAT SPEED.</td></tr>
</table>

RULE NO.	SOUTHERN RAILWAY			
	HIGH SIGNAL	DWARF SIGNAL	NAME	INDICATION
313			SPRING SWITCH MARKER LIGHT	SWITCH POINTS IN NORMAL POSITION.
314			SPRING SWITCH MARKER LIGHT	STOP AND EXAMINE SWITCH POINTS.
315			DOLL MAST	A TRACK INTERVENES BETWEEN THE SIGNAL AND THE TRACK GOVERNED BY THE SIGNAL. WHEN MORE THAN ONE TRACK INTERVENES, THE NUMBER OF DOLL MASTS, WITH OR WITHOUT BLUE LIGHT, IS CORRESPONDINGLY INCREASED.
316			DRAGGING EQUIPMENT INDICATOR	STOP AND INSPECT TRAIN FOR DRAGGING EQUIPMENT.
317			TAKE SIDING INDICATOR	WHEN LETTER "S" IS ILLUMINATED TAKE SIDING.
318			HOLDING SIGNAL	WHEN LETTER "H" IS ILLUMINATED, STAY UNTIL AUTHORIZED TO PROCEED.

RULE NO.	UNION PACIFIC		
	SIGNAL	NAME	INDICATION
222-A			
222-B			
222-C			
240-A		STOP	STOP BEFORE ANY PART OF TRAIN OR ENGINE PASSES THE SIGNAL.
240-B		STOP AND PROCEED	STOP BEFORE ANY PART OF TRAIN OR ENGINE PASSES THE SIGNAL THEN PROCEED AT RESTRICTED SPEED THROUGH ENTIRE BLOCK.
240-C		FLASHING STOP & PROCEED	STOP. BLOCK OCCUPIED. PROCEED AT RESTRICTED SPEED.

RULE NO.	UNION PACIFIC		
	SIGNAL	NAME	INDICATION
240-D	 (WITH OR WITHOUT LETTER 'A' OR NUMBER PLATE)	APPROACH	PROCEED PREPARED TO STOP BEFORE ANY PART OF TRAIN OR ENGINE PASSES THE NEXT SIGNAL. TRAINS EXCEEDING 30 MPH MUST IMMEDIATELY REDUCE TO THAT SPEED.
240-E	 (WITH OR WITHOUT LETTER 'A' OR NUMBER PLATE)	CLEAR	PROCEED
240-F	 (WITH OR WITHOUT LETTER 'A' OR NUMBER PLATE)	APPROACH LIMITED	PROCEED. SPEED PASSING NEXT SIGNAL MUST NOT EXCEED 40 MPH.
240-G	 (WITH OR WITHOUT LETTER 'A' OR NUMBER PLATE)	APPROACH DIVERGING	PROCEED. SPEED PASSING NEXT SIGNAL MUST NOT EXCEED 30 MPH.
240-H	 (WITH OR WITHOUT LETTER 'A' OR NUMBER PLATE)	APPROACH SLOW	PROCEED. SPEED PASSING NEXT SIGNAL MUST NOT EXCEED 15 MPH.
240-J	 (WITH OR WITHOUT LETTER 'A' OR NUMBER PLATE)	DIVERGING CLEAR LIMITED	PROCEED ON DIVERGING ROUTE. SPEED THROUGH TURNOUT MUST NOT EXCEED 40 MPH.
240-K	 (WITH OR WITHOUT LETTER 'A' OR NUMBER PLATE)	DIVERGING CLEAR MEDIUM	PROCEED ON DIVERGING ROUTE. SPEED THROUGH TURNOUT MUST NOT EXCEED 30 MPH.
240-L	 (WITH OR WITHOUT LETTER 'A' OR NUMBER PLATE)	DIVERGING CLEAR SLOW	PROCEED ON DIVERGING ROUTE. SPEED THROUGH TURNOUT MUST NOT EXCEED 15 MPH.

RULE NO.	UNION PACIFIC SIGNAL	NAME	INDICATION
240-M		DIVERGING APPROACH LIMITED	PROCEED ON DIVERGING ROUTE. SPEED THROUGH TURNOUT MUST NOT EXCEED 40 MPH. SPEED PASSING NEXT SIGNAL MUST NOT EXCEED 40 MPH.
240-N		DIVERGING APPROACH MEDIUM	PROCEED ON DIVERGING ROUTE PREPARED TO STOP AT NEXT SIGNAL. SPEED THROUGH TURNOUT AND TO NEXT SIGNAL MUST NOT EXCEED 30 MPH.
240-P		DIVERGING APPROACH SLOW	PROCEED ON DIVERGING ROUTE PREPARED TO STOP AT NEXT SIGNAL. SPEED THROUGH TURNOUT MUST NOT EXCEED 15 MPH. SPEED TO NEXT SIGNAL MUST NOT EXCEED 30 MPH.
240-Q		DIVERGING RESTRICTING	PROCEED ON DIVERGING ROUTE AT RESTRICTED SPEED.
240-R		DIVERGING RESTRICTING SLOW	PROCEED ON DIVERGING ROUTE AT RESTRICTED SPEED. SPEED THROUGH TRUNOUT MUST NOT EXCEED 15 MPH.
240-S		RESTRICTING	PROCEED AT RESTRICTED SPEED.
240-T	 LETTER "P"	PERMISSIVE	PROCEED AT RESTRICTED SPEED THROUGH ENTIRE BLOCK.

APPENDIX D

RAILROAD SIGNAL TITLE AND INDICATIONS (BY RULE NUMBER)

The information included in this appendix is a rearrangment of information shown in appendix C. It represents only the rules of the 18 railroads listed there. The listing is in alpha-numeric sequence by rule number, and was developed to highlight rules used by more than one railroad. The signal aspects were not included to conserve space.

RULE NO	RAILROAD	TITLE	INDICATION
240A	MIL, UP	STOP	Stop before any part of train or engine passes the signal.
240A1	NP	STOP	Stop before any part of train or engine passes the signal.
240A2	NP	STOP & PROCEED	Stop before any part of train or engine passes the signal then proceed at restricted speed (20) through entire block.
240A3	NP	FLASHING STOP & PROCEED	Stop. Block occupied. Proceed at restricted speed (20).
240B	MIL, UP	STOP & PROCEED	Stop before any part of train or engine passes the signal then proceed at restricted speed (20) through entire block.
240B	NP	PERMISSIVE	Proceed at restricted speed (20) without stopping.
240C	MIL, UP	FLASHING STOP & PROCEED	Stop. Block occupied. Proceed at restricted speed (20).
240C	NP	APPROACH	Proceed prepared to stop before any part of train or engine passes the next signal.
240D	MIL	APPROACH	Proceed prepared to stop before any part of train or engine passes the next signal. Trains exceeding 40 mph must immediately reduce to that speed.
240D	UP	APPROACH	Proceed prepared to stop before any part of train or engine passes the next signal. Trains exceeding 30 mph must immediately reduce to that speed.
240D	NP	CLEAR	Proceed.
240E	MIL, UP	CLEAR	Proceed.
240E	NP	LIMITED APPROACH	Proceed not exceeding 50 mph prepared to stop at next signal.
240F	MIL	ADVANCE APPROACH	Proceed prepared to pass next signal not exceeding 40 mph.
240F	UP	APPROACH LIMITED	Proceed. Speed passing next signal must not exceed 40 mph.

RULE NO	RAILROAD	TITLE	INDICATION
240F1	NP	LIMITED CLEAR APPROACH SLOW	Proceed not exceeding 50 mph. Approach next signal not exceeding 15 mph.
240F2	NP	LIMITED CLEAR APPROACH MEDIUM	Proceed not exceeding 50 mph. Approach next signal not exceeding 30 mph.
240G	MIL	APPROACH DIVERGING	Approach next signal prepared to proceed on diverging route at prescribed speed.
240G	UP	APPROACH MEDIUM	Proceed. Speed passing next signal must not exceed 30 mph.
240G	NP	APPROACH LIMITED	Proceed. Approach next signal not exceeding 50 mph.
240H	UP	APPROACH SLOW	Proceed. Speed passing next signal must not exceed 15 mph.
240H	NP	LIMITED CLEAR	Proceed; 50 mph within interlocking limits.
240I	NP	MEDIUM APPROACH	Proceed not exceeding 30 mph, prepared to stop at next signal.
240J	UP	DIVERGING CLEAR LIMITED	Proceed on diverging route. Speed through turnout must not exceed 40 mph.
240J1	NP	MEDIUM CLEAR APPROACH SLOW	Proceed. 30 mph within interlocking limits. Approach next signal not exceeding 15 mph.
240J2	NP	MEDIUM CLEAR APPROACH MEDIUM	Proceed; 30 mph within interlocking limits. Approach next signal not exceeding 30 mph.
240K	NP	APPROACH MEDIUM	Proceed. Approach next signal not exceeding 30 mph.
240K	UP	DIVERGING CLEAR MEDIUM	Proceed on diverging route. Speed through turnout must not exceed 30 mph.
240K	MIL	DIVERGING ADVANCE APPROACH	Proceed on diverging route at prescribed speed prepard to pass next signal at not exceeding 40 mph.

RULE NO	RAILROAD	TITLE	INDICATION
240L	UP	DIVERGING CLEAR SLOW	Proceed on diverging route. Speed through turnout must not exceed 15 mph.
240L	MIL	DIVERGING APPROACH	Proceed on diverging route at prescribed speed prepared to stop before any part of train or engine passes the next signal.
240L	NP	MEDIUM CLEAR	Proceed; 30 mph within interlocking limits.
240M	UP	DIVERGING APPROACH LIMITED	Proceed on diverging route. Speed through turnout must not exceed 40 mph. Speed passing next signal must not exceed 40 mph.
240M	MIL	DIVERGING CLEAR	Proceed on diverging route at prescribed speed.
240M	UP	DIVERGING CLEAR	Proceed on diverging route. Prescribed speed through turnout.
240M	NP	SLOW APPROACH	Proceed not exceeding 15 mph prepared to stop at next signal.
240N	MIL	RESTRICTING	Proceed at restricted speed (20).
240N	NP	SLOW CLEAR APPROACH MEDIUM	Proceed 15 mph within interlocking limit. Approach next signal not exceeding 30 mph.
240N	UP	DIVERGING APPROACH MEDIUM	Proceed on diverging route prepared to stop at next signal. Speed through turnout and to next signal must not exceed 30 mph.
240O	NP	APPROACH SLOW	Proceed. Approach next signal not exceeding 15 mph.
240P	UP	DIVERGING APPROACH SLOW	Proceed on diverging route prepared to stop at next signal. Speed through turnout must not exceed 15 mph. Speed to next signal must not exceed 30 mph.
240P	MIL, UP	PERMISSIVE	Proceed at restricted speed (20) without stopping.
240P1	NP	SLOW CLEAR	Proceed; 15 mph within interlocking limits.

RULE NO	RAILROAD	TITLE	INDICATION
240P2	NP	SLOW CLEAR	Proceed not exceeding 15 mph.
240Q	UP	DIVERGING RESTRICTING	Proceed on diverging route at restricted speed.
240R	NP	RESTRICTING	Proceed at restricted speed (20) not exceeding 15 mph.
240R	UP	DIVERGING RESTRICING SLOW	Proceed on diverging route at restricted speed. Speed through turnout must not exceed 15 mph.
240S	UP	RESTRICTING	Proceed at restricted speed.
240T	UP	PERMISSIVE	Proceed at restricted speed through entire block.
280	CR	CLEAR BLOCK	Proceed; for passenger trains, manual block clear, for trains other than passenger trains, manual block clear outside yard limits.
281	AT&SF, MIL, C&O, CR, D&H, D&RGW, ICG, L&N, RF&P, RI, MP, SP	CLEAR	Proceed.
281	CN	CLEAR SIGNAL	Proceed.
281	N&W	CLEAR	Proceed at prescribed speed.
281A	AT&SF	APPROACH LIMITED	Proceed; approach next signal not exceeding medium speed (40) and be prepared to enter diverging route at prescribed speed.
281A	CR	ADVANCE APPROACH MEDIUM	Proceed approaching 2nd signal at medium speed (30).
281B	CR	APPROACH LIMITED	Proceed approaching next signal at limited speed (45).
281B	D&RGW	DIVERGING APPROACH MEDIUM	Proceed authorized speed until entire train is through turnout approaching next signal medium speed (30).

RULE NO	RAILROAD	TITLE	INDICATION
281C	CR	LIMITED CLEAR	Proceed: Limited speed (45) within interlocking limits.
281D	CR	LIMITED APPROACH	Proceed at limited speed (45) preparing to stop at next signal.
281E	CR	APPROACH CLEAR	Proceed.
B281	B&O	CLEAR	Proceed.
282	CN	APPROACH MEDIUM SIGNAL	Proceed approaching next signal at medium speed (30).
282	C&O, CR, D&H, D&RGW, L&N, RF&P	APPROACH MEDIUM	Proceed approaching next signal at medium speed (30).
282	SP	BLOCK SIGNAL GREEN	Proceed except on diverging route.
282	RI, MP	ADVANCE APPROACH	Proceed, reducing to 50 mph before reaching next signal.
282	ICG	ADVANCE APPROACH	Proceed; prepared to stop at second signal. Train exceeding 30 mph must at once reduce to that speed.
282	N&W	APPROACH DIVERGING	Proceed preparing to take diverging route beyond next signal at prescribed speed.
282	AT&SF	APPROACH MEDIUM	Proceed; approach next signal not exceeding medium speed (40) and be prepared to enter diverging route at prescribed speed.
282A	CR	ADVANCE APPROACH	Proceed preparing to stop at second signal. Train exceeding limited speed (45) must at once reduce to that speed.
282A	D&H, N&W	ADVANCE APPROACH	Proceed preparing to stop at second signal.
282A	CN	APPROACH LIMITED SIGNAL	Proceed approaching next signal at limited speed (45).
B282	B&O	APPROACH LIMITED	Proceed approaching next signal at not exceeding limited speed (45).
B282A	B&O	APPROACH MEDIUM	Proceed approaching next signal at not exceeding medium speed (30).

RULE NO	RAILROAD	TITLE	INDICATION
283	CR	MEDIUM CLEAR	Proceed; medium speed (30) within interlocking limits.
283	AT&SF,RI, MP	DIVERGING CLEAR	Proceed on diverging route, not exceeding prescribed speed through turnout.
283	SP	BLOCK SIGNAL GREEN FOR DIVERGING ROUTE	Proceed on diverging route.
283	RF&P	MEDIUM CLEAR	Proceed: Medium speed (25) within interlocking limits.
283	D&H	MEDIUM CLEAR	Proceed: Medium speed (30) within interlocking limits.
283	L&N	MEDIUM CLEAR	Proceed at not exceeding medium speed ( ). If flashing green light, resume normal speed after turnout or crossover is cleared.
283	ICG	APPROACH LIMITED	Proceed: Approaching next signal prepared to enter turnout at prescribed speed, but not exceeding 40 mph.
283	N&W	DIVERGING CLEAR	Proceed through turnout or turnouts at prescribed speed.
283	D&RGW	DIVERGING CLEAR	Proceed authorized speed until entire train is through turnout.
283	C&O	MEDIUM CLEAR	Medium speed (30) through crossovers, turnouts, sidings, interlocking limits and over power switches; then proceed at maximum authorized speed.
283	CN	MEDIUM CLEAR SIGNAL	Proceed, medium speed (30) within interlocking limits or through turnouts.
283A	CN, D&H	MEDIUM ADVANCE APPROACH	Proceed preparing to stop at second signal; medium speed (30) within interlocking limits.
283A	C&O	MEDIUM APPROACH SLOW	Proceed at not exceeding medium speed (30) approaching next signal at not exceeding slow speed (15).
283A	CN	LIMITED CLEAR SIGNAL	Proceed, limited speed (45) within interlocking limits or through turnouts.
283B	CR	MEDIUM APPROACH SLOW	Proceed at medium speed (30) approaching next signal at slow speed (15).

RULE NO	RAILROAD	TITLE	INDICATION
283B	D&H	MEDIUM APPROACH MEDIUM	Proceed at medium speed (30) approaching next signal at medium speed.
B283	B&O	LIMITED CLEAR	Limited speed (45) through corossovers, turnouts, sidings, interlocking limits and over power switches, then proceed at maximum authorized speed.
B283A	B&O	MEDIUM CLEAR	Medium speed (30) through crossovers, turnouts, sidings, interlocking limits and over power switches, then proceed at maximum authorized speed.
B283B	B&O	MEDIUM APPROACH MEDIUM	Proceed at medium speed (30) approaching next signal at not exceeding medium speed.
B283C	B&O	MEDIUM APPROACH SLOW	Proceed at not exceeding medium speed (30) approaching next signal at not exceeding slow speed (15).
284	CN	APPROACH SLOW SIGNAL	Proceed, approaching next signal at slow speed (15). Trains exceeding medium speed (30) must at once reduce to that speed.
284	CR	APPROACH SLOW	Proceed, approaching next signal at slow speed (15). Trains exceeding medium speed (30) must at once reduce to that speed.
284	ICG	MEDIUM APPROACH	Proceed; approaching next signal prepared to enter turnout at prescribed speed, but not exceeding 30 mph.
284	RI, MP	APPROACH MEDIUM	Proceed, reducing to 35 mph before reaching next signal.
284	AT&SF	APPROACH RESTRICTED	Proceed, prepared to pass next signal at restricted speed (20); if exceeding medium speed (40), immediately reduce to medium speed.
B284	B&O	APPROACH SLOW	Proceed approaching next signal at slow speed (15). Train or engine exceeding medium speed (30) when indication is seen must take action at once to reduce to medium speed or slower if necessary.
284	C&O	APPROACH SLOW	Proceed approaching next signal at slow speed (15). Train or engine exceeding medium speed (30) must take action at or before reaching approach slow indication to reduce to that speed.

RULE NO	RAILROAD	TITLE	INDICATION
284	SP	BLOCK SIGNAL YELLOW OVER GREEN	Reduce to medium speed (40) and proceed. Next signal indicates proceed on diverging route.
285	ICG	APPROACH	Proceed; prepared to stop at next signal. Train exceeding 30 mph must at once reduce to that speed.
285	N&W	APPROACH	Proceed preparing to stop at the next signal. If exceeding medium speed (30) immediately take action to reduce speed.
285	CR, D&H, D&RGW, RF&P	APPROACH	Proceed preparing to stop at next signal. Trains exceeding medium speed (30) must at once reduce to that speed.
285	RI, MP	APPROACH	Proceed, immediately reducing to 40 mph or slower if necessary, prepared to stop before reaching next signal.
285	AT&SF	APPROACH	Proceed preparing to stop at next signal: If exceeding medium speed (40) immediately reduce to medium speed.
285	C&O	APPROACH	Proceed prepared to stop at next signal. Train or engine exceeding medium speed (30) must take action at or before reaching approach indication to reduce to that speed.
285	SP	APPROACH SIGNAL YELLOW	Proceed not exceeding medium speed (40), prepared to stop short of the next home signal.
285	L&N	APPROACH	Prepare to stop at next signal. Train exceeding medium speed ( ) must at once reduce to that speed.
285	CN	APPROACH SIGNAL	Proceed, preparing to stop at next signal. Trains exceeding medium speed (30) must at once reduce to that speed. Reduction to medium speed must commence before passing signal.
285A	CR	CAUTION	Train exceeding medium speed (30) must at once reduce to that speed. Where a facing switch is connected with the signal, approach that switch prepared to stop. Approach next signal prepared to stop.
285A	C&O	DISTANT SIGNAL	Approach next signal prepared to stop.

RULE NO	RAILROAD	TITLE	INDICATION
285A	SP	APPROACH MEDIUM FLASHING YELLOW	Proceed prepared to pass next signal at not exceeding medium speed (40).
285B	CR	APPROACH RESTRICTING	Proceed prepared to stop at next signal. Trains exceeding medium speed (30) must at once reduce to that speed. (Does not convey condition of track between approach signal and interlocking signal.)
B285	B&O	APPROACH	Proceed prepared to stop at next signal. Train or engine exceeding medium speed (30) when indication is seen must take action at once to reduce to medium speed or slower if necessary.
B285A	B&O	DISTANT SIGNAL	Approach next signal prepared to stop.
286	ICG	DIVERGING CLEAR	Proceed on diverging route; not exceeding prescribed speed through turnout.
286	N&W	DIVERGING APPROACH	Proceed through turnout of turnouts at prescribed speed preparing to stop at next signal. If exceeding medium speed (30) immediately take action to reduce to that speed.
286	CN	MEDIUM APPROACH SIGNAL	Proceed at medium speed (30) preparing to stop at next signal.
286	C&O, CR, D&H, L&N, RF&P	MEDIUM APPROACH	Proceed at medium speed (30) preparing to stop at next signal.
286	D&RGW	DIVERGING APPROACH	Proceed medium speed (30) through turnout, prepared to stop at next signal, except when leaving main track, be governed by rule 105.
286	RI, MP	DIVERGING APPROACH MEDIUM	Proceed on diverging route, not exceeding prescribed speed through turnout, reducing to 35 mph before reaching next signal.
286	AT&SF	DIVERGING APPROACH	Proceed through diverging route; prescribed speed through turnout; approach next signal preparing to stop, if exceeding medium speed (40) immediately reduce to that speed.
286	SP	DISTANT SIGNAL YELLOW	Proceed not exceeding medium speed (40) prepared to stop short of next home signal.

RULE NO	RAILROAD	TITLE	INDICATION
286A	CN	LIMITED APPROACH SIGNAL	Proceed at limited speed (45) preparing to stop at next signal.
B286	B&O	MEDIUM APPROACH	Proceed at medium speed (30) preparing to stop at next signal.
287	N&W	SLOW CLEAR	Proceed, slow speed (15) within interlocking limits or through turnouts.
287	SP	GRADE SIGNAL RED	Reduce to restricted speed (20) and proceed.
287	C&O	SLOW CLEAR	Slow speed (15) through crossovers, turnouts, sidings, interlocking limits, and over power switches; then proceed at maximum authorized speed.
287	RF&P	SLOW CLEAR	Proceed slow speed (*) through crossovers and turnouts and then proceed at authorized speed. (* not defined in rule book)
287	ICG	DIVERGING APPROACH	Proceed on diverging route; through turnout at prescribed speed; prepared to stop at next signal, but not exceeding 30 mph.
287	RI, MP	APPROACH DIVERGING	Proceed, prepared to advance on diverging route at next signal, at prescribed speed through turnout.
287	CR	SLOW CLEAR	Proceed slow speed (15) within interlocking limits.
287	CN	SLOW CLEAR SIGNAL	Proceed slow speed (15) within interlocking limits or through turnouts.
B287	B&O	SLOW APPROACH SLOW	Slow speed (15) through crossovers, turnouts, sidings, interlocking limits, and over power switches. Train or engine may then proceed at maximum authorized speed, if conditions permit, but must approach the next signal at not exceeding slow speed.
288	CN	SLOW APPROACH SIGNAL	Proceed, prepared to stop at next signal. Slow speed (15) within interlocking limits or through turnouts, medium speed must then not be exceeded until a more favorable indication has been accepted.
288	SP	HOME SIGNAL YELLOW FOR DIVERGING ROUTE	Proceed on diverging route at restricted speed (20).

RULE NO	RAILROAD	TITLE	INDICATION
288	B&O, C&O	SLOW APPROACH	Slow speed (15) through crossovers, turnouts, sidings, interlocking limits, and over power switches; then proceed at not exceeding medium speed (30) prepared to stop at next signal.
B288	B&O		
288	ICG	SLOW CLEAR	Proceed at prescribed speed within interlocking limits, or through turnout.
288	CR, N&W	SLOW APPROACH	Proceed preparing to stop at next signal; slow speed (15) within interlocking limits.
288	RI, MP	DIVERGING APPROACH	Proceed on diverging route at prescribed speed through turnout, prepared to stop before reaching next signal.
289	SP	HOME SIGNAL RED OVER LUNAR	Proceed without stopping at restricted speed (20) on other than main track.
289	ICG	SLOW APPROACH	Proceed; at prescribed speed through turnout of within interlocking limits prepared to stop at next signal, but not exceeding 30 mph.
289	CR	PERMISSIVE BLOCK	Block occupied; for passenger trains, stop: For trains other than passenger trains proceed prepared to stop short of a train or obstruction, but not exceeding 15 mph.
290	C&O, CR, D&H, N&W, RF&P	RESTRICTING	Proceed at restricted speed (15).
290	AT&SF	RESTRICTING	Proceed at restricted speed (20).
290	CN	RESTRICTING SIGNAL	Proceed at restricted speed (*). (*) speed which will allow stopping in 1/2 visual range of track ahead.)
290	ICG	RESTRICTING	Proceed at restricted speed ( ).
290	SP	HOME SIGNAL RED	Stop.
290	L&N	RESTRICTING	Proceed at restricted speed ( ).

RULE NO	RAILROAD	TITLE	INDICATION
290	D&RGW	RESTRICTING	Proceed at restricted speed (15); (1) within ABS to next signal governing in same direction (2) At interlocking outside ABS through interlocking limits (3) Onto non signaled track until entire train is through turnout, if there is no turnout, until head end of train has passed the signal.
290	RI, MP	LOW	Proceed at low speed (20) (1) Within ABS to next signal ogverning in the same direction (2) At interlocking outside ABS - through interlocking limits (3) Where this signal governs movement onto non-signaled track - until entire train is through turnout.
290A	SP	FLASHING RED	Proceed without stopping not exceeding restricted speed (20), prepared to stop short of next signal.
290A	AT&SF	PERMISSIVE	Proceed at restricted speed (20).
290A	ICG	RESTRICTING MAIN ROUTE	Proceed at restricted speed ( ).
291	D&RGW	STOP & PROCEED	Stop then proceed, see rule 509.
B290	B&O	RESTRICTING	Proceed at restricted speed (15).
291	SP	FLASHING YELLOW	Stop then proceed at restricted speed (20 without calling train dispatcher or operator.
291	AT&SF	STOP & PROCEED	Stop then proceed as described by rule 320.
291	CR, D&H, N&W	STOP & PROCEED	Stop then proceed at restricted speed (15).
291	CN	STOP & PROCEED SIGNAL	Stop; then proceed at restricted speed (*). (* Speed which will allow stopping in 1/2 visual range of track ahead).
291	C&O	STOP & PROCEED	Stop; then proceed at restricted speed (*). (* Speed which will allow stopping in 1/2 visual range of track ahead).
291	ICG, L&N	RESTRICTED PROCEED	Proceed at restricted speed ( ).

RULE NO	RAILROAD	TITLE	INDICATION
291	RI , MP	STOP & PROCEED	Stop, then proceed at low speed (20) through the entire block.
291A	D&H	RESTRICTING	Proceed at restricted speed (15) prepared to enter siding.
B291A	B&O	GRADE SIGNAL	Proceed at restricted speed (15) without stopping.
291B	CN	STATION PROTECTION SIGNAL	Stop, then proceed at restricted speed (*) and proceed by a flagman when necessary to ensure full protection. (* Speed which will allow stopping in 1/2 visual range of track ahead.)
B291	B&O	STOP & PROCEED	Stop; then proceed at restricted speed (15).
292	AT&SF, C&O, CR, D&H, D&RGW, ICG, L&N, RF&P, RI , MP	STOP	Stop.
292	CN	STOP SIGNAL	Stop.
292	N&W	STOP & STAY	Stop and stay.
292	SP	FLASHING WHITE	Stop. When flashing white displayed be governed by timetable.
B292	B&O	STOP	Stop.
301	SR	CLEAR	Proceed.
302	SR	APPROACH DIVERGING	Proceed, approaching next signal prepared to take diverging route.
303	SR	ADVANCE APPROACH	Proceed, preparing to stop at second signal.
304	SR	DIVERGING ROUTE CLEAR	Proceed through diverging route observing authorized speed through turnout or crossover.

RULE NO	RAILROAD	TITLE	INDICATION
305	SR	DIVERGING ROUTE CLEAR, APPROACH LIMITED	Proceed through diverging route observing authorized speed through turnout or crossover, and approach next signal at authorized speed not exceeding limited speed (45).
306	SR	APPROACH SLOW	Proceed, approaching next signal at slow speed (15). Train exceeding medium speed (30) must at once reduce to that speed.
307	SR	APPROACH	Proceed, preparing to stop at next signal. Train exceeding medium speed (30) must at once reduce to that speed.
308	SR	DIVERGING ROUTE APPROACH	Proceed through diverging route, observing authorized speed through turnout or crossover, then not exceeding medium speed (30), preparing to stop at next signal.
309	SR	RESTRICTED PROCEED	Proceed at restricted speed (15).
310	SR	STOP	Stop.
311	SR	NON-AUTOMATIC BLOCK, CLEAR	Proceed.
312	SR	NON-AUTOMATIC BLOCK, APPROACH	Approach next signal prepared to stop. Train exceeding medium speed (30) must at once reduce to that speed.
501	BN, SCL	CLEAR	Proceed.
501A	BN	APPROACH MEDIUM	Proceed approaching next signal not exceeding 30 mph.
501B	BN	APPROACH	Proceed prepared to stop before any part of train or engine passes the next signal.
501C	BN	DIVERGING CLEAR	Proceed on diverging route at prescribed speed.
501D	BN	DIVERGING APPROACH MEDIUM	Proceed on diverging route at prescribed speed and approach next signal not exceeding 30 mph.

RULE NO	RAILROAD	TITLE	INDICATION
501E	BN	DIVERGING APPROACH	Proceed on diverging route at prescribed speed prepared to stop before any part of train or engine passes the next signal.
501F	BN	APPROACH RESTRICTING	Proceed approaching next signal not exceeding restricted speed (20).
501G	BN	RESTRICTING	Proceed at restricted speed (20).
501I	BN	PERMISSIVE	Proceed at restricted speed (20) through entire block.
501J	BN	STOP & PROCEED	Stop before any part of train or engine passes the signal, then proceed at restricted speed (20) through entire block.
501K	BN	STOP	Stop before any part of train or engine passes the next signal.
502	SCL	ADVANCE APPROACH	Proceed preparing to stop at next signal.
503	SCL	LIMITED CLEAR	Proceed, limited speed ( ) through turnouts.
504	SCL	APPROACH LIMITED	Proceed approach next signal at limited speed ( ); limited speed through turnouts.
505	SCL	MEDIUM CLEAR	Proceed medium speed ( ) through turnouts.
506	SCL	MEDIUM ADVANCE APPROACH	Proceed preparing to stop at second signal; medium speed ( ) through turnouts.
507	SCL	CLEAR CONVERGING	Proceed, authorized speed through turnouts.
508	SCL	APPROACH	Proceed approaching next signal at medium speed ( ).
509	SCL	SPEED APPROACH	Proceed approaching next signal at speed designated by illuminated numeral.
510	SCL	APPROACH SLOW	Proceed approaching next signat a slow speed ( ). Train exceeding 40 mph must at once reduce to that speed.

RULE NO	RAILROAD	TITLE	INDICATION
511	SCL	MEDIUM APPROACH SLOW	Proceed at medium speed ( ) approaching next signal at slow speed ( ).
512	SCL	APPROACH	Proceed preparing to stop at next signal. Train exceeding 40 mph must at once reduce to tht speed until it can be plainly seen that indication of next signal allows train to proceed.
513	SCL	MEDIUM APPROACH	Medium speed ( ) through turnouts, then not exceeding 40 mph preparing to stop at next signal until it can be plainly seen that indication of next signal allows train to proceed.
514	SCL	APPROACH CONVERGING	Proceed, authorized speed through turnouts, then not exceeding 40 mph preparing to stop at next signal, until it can be plainly seen that indication of next signal allows train to proceed.
515	SCL	RESTRICTING	Proceed at restricted speed ( ) until engine reaches next governing signal or end of block.
516	SCL	RESTRICTED PROCEED	Proceed at restricted speed ( ) until engine reaches next governing signal or end of block.

APPENDIX E

SIGNAL ASPECT/RULE COMPARISON

The information included in this appendix is a rearrangment of the signal aspects shown for the various railroads represented in appendix C. In this presentation similar signal arrangements are grouped for comparison. For example, single arm semaphore signals are grouped together, three arm semaphores together and etc. The signal titles and indications were not included to conserve space.

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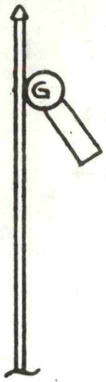
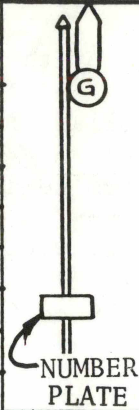
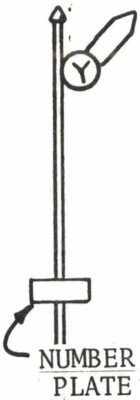
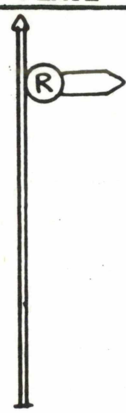
	SP	281		CN	281		B&O	B281
	BN	501						
	B&O	B285		C&O	285A			
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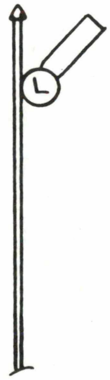
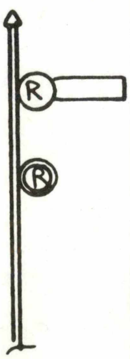
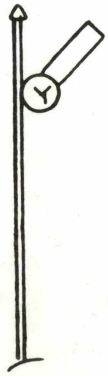
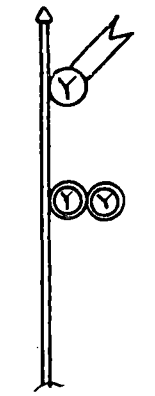
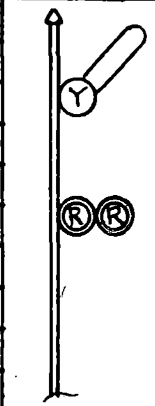
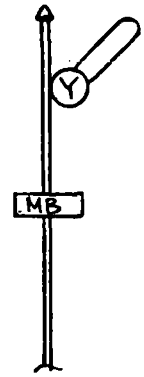
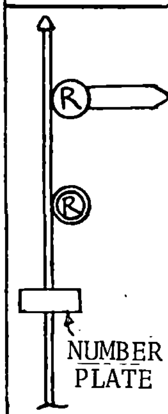
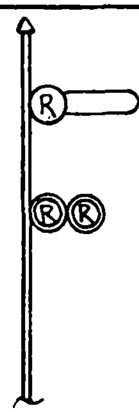
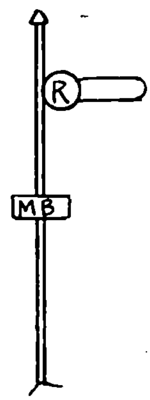
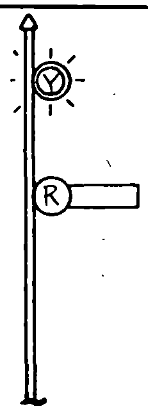
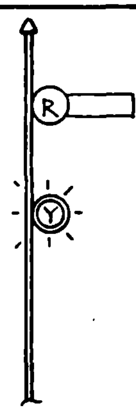
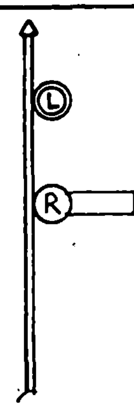
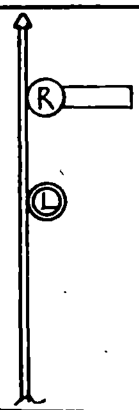
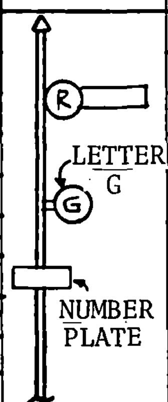
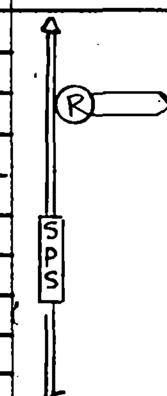
	B&O	B281		B&O	B285		B&O	B285A
	B&O	B292		MIL	240E		MIL	240D
				AT&SF	281		AT&SF	285
				RI,MP	281		RI,MP	285
				BN	501		ICG	285
							BN	501B
							L&N	285

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	CR	285A		CR	289		CR	289
	CR	291		CR	292		CR	292
	RI,MP	284		RI,MP	286		RI,MP	290
	RI,MP	290		RI,MP	290		CN	291B
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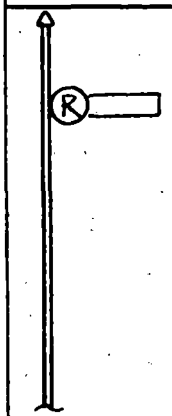
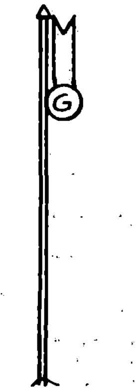
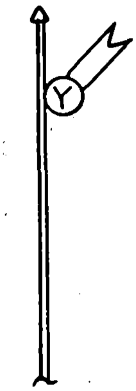
SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	BN	501K						
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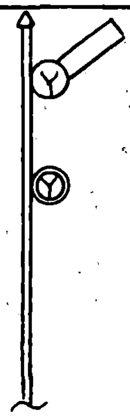
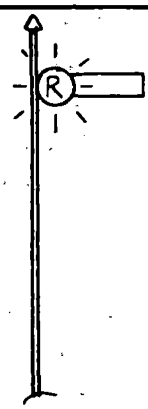
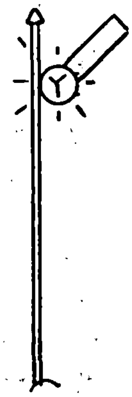
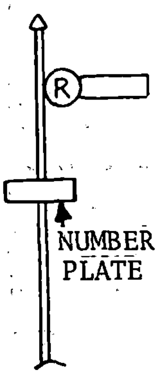
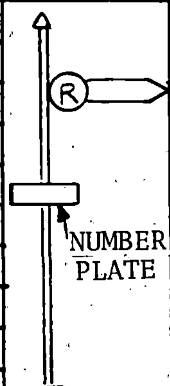
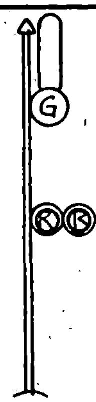
	AT&SF	282		AT&SF	290		AT&SF	282
	AT&SF	291		SR	309		CR	280
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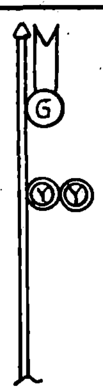
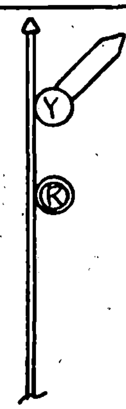
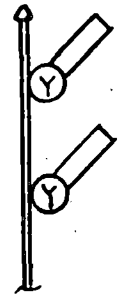
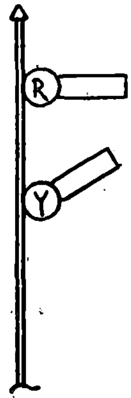
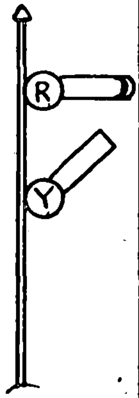
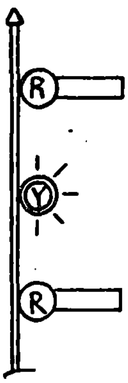
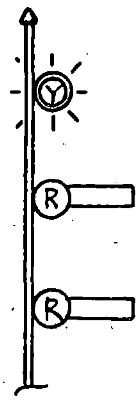
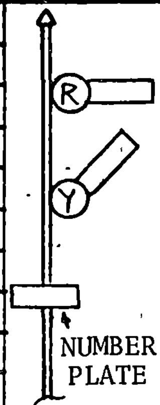
	CR	281		CR	281		CR	285

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	MIL	240G		MIL	240L		CR	290
	RI,MP	282		CN	290			
	N&W	282A		RI,MP	288			
	SOU	303		SOU	308			
	BN	501		BN	501E			
				3	501E			
	RI,MP	286		RI,MP	284		RI,MP	287
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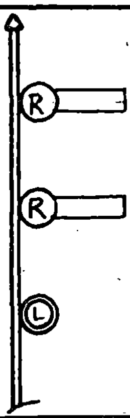
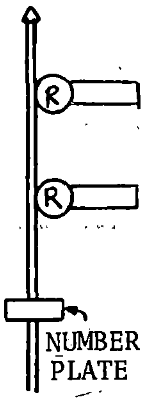
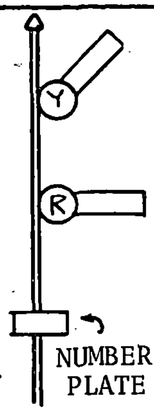
	RI,MP	290		RI,MP	291		SOU	307
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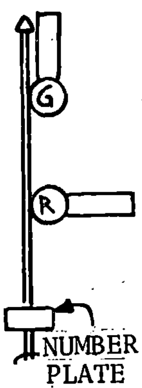
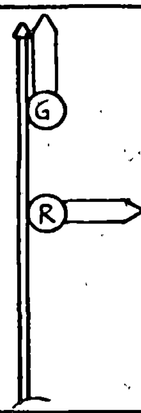
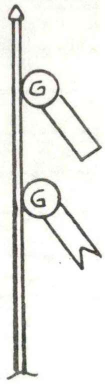
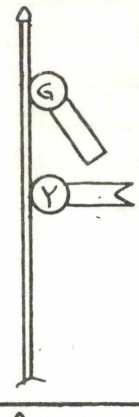
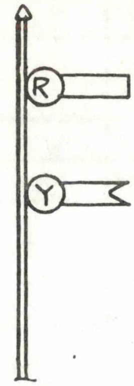
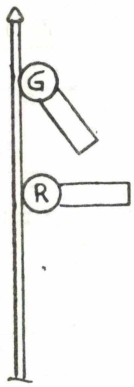
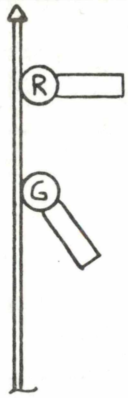
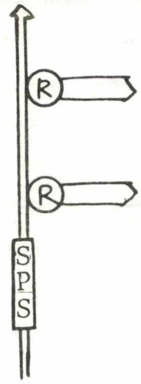
	SOU	301					CN	281

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	SP	281		SP	285		SP	290
	SP	282		SP	283		CN	291B
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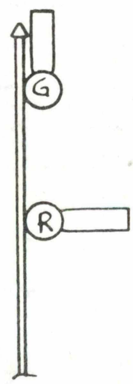
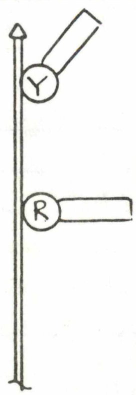
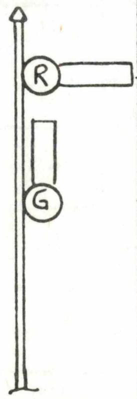
	B&O	B281		B&O	B285			
	MIL	240E		MIL	240D		MIL	240M
	CR	281		CN	285		RI,MP	283
	CN	281		RI,MP	285		CN	287
	RI,MP	281		L&N	285		B&O	B287
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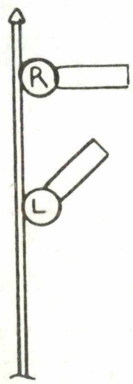
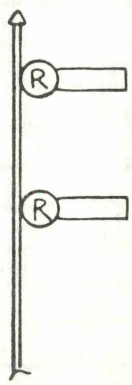
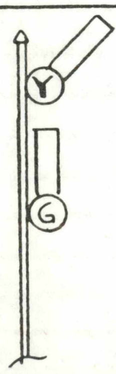
	B&O	B290		SP	290		MIL	240F
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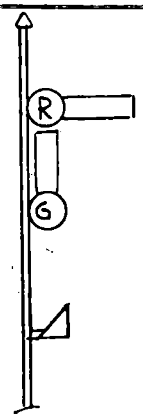
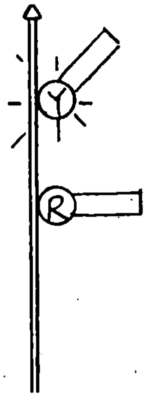
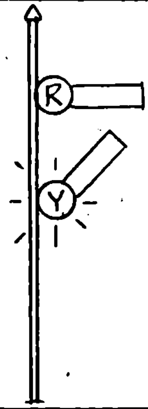
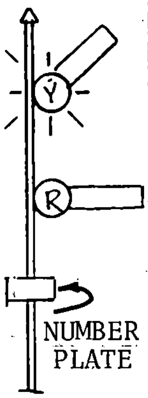
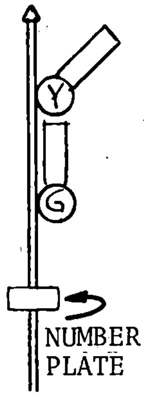
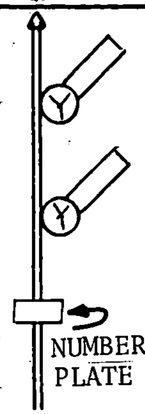
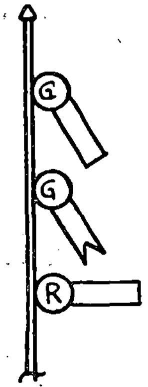
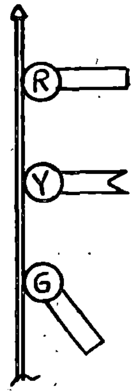
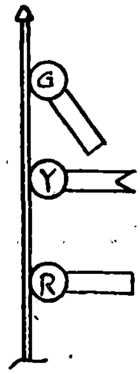
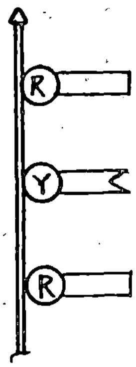
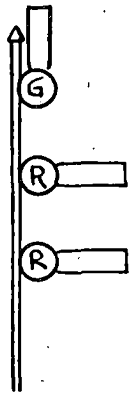
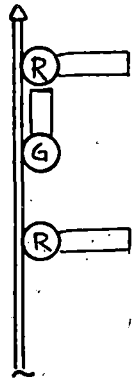
	BN	501G		B&O	B292		SOU	302
				RI,MP	292			
				CN	292			
				SOU	310			
				BN	501K			

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	SOU	305		SOU	306		SOU	306
	SOU	306		SOU	302		SOU	303

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	SP	282		SP	283		SP	285
	SP	290		B&O	B281		B&O	B283A
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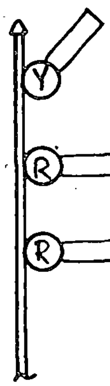
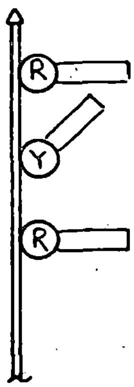
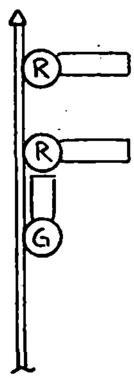
	B&O	B285		B&O	B286		B&O	B287
	MIL	240D		MIL	240L		MIL	240M
	N&W	285		CN	286		CN	287
	ICG	285		RI,MP	288		SOU	304
	CN	285		ICG	287			
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	SOU	307		BN	501E			
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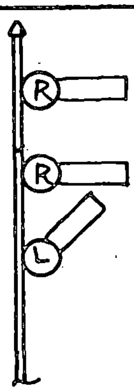
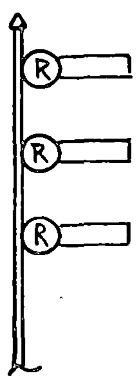
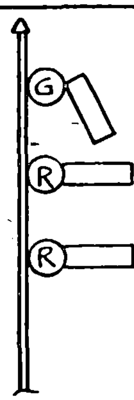
	B&O	B290		B&O	B292		MIL	240E
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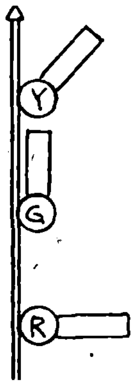
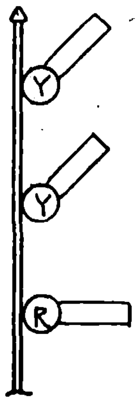
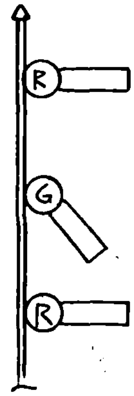
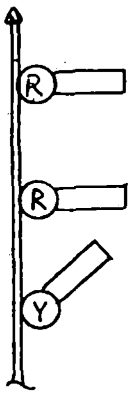
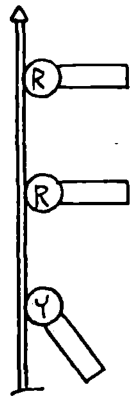
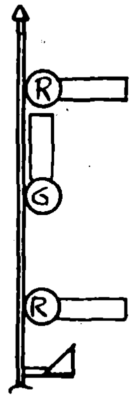
SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	MIL	240F		MIL	240G		MIL	240M
	N&W	282		RI,MP	282			
	SOU	302		N&W	282A			
				SOU	303			
				BN	501F			
	MIL	240N		MIL	240N		SOU	305
	CN	290						
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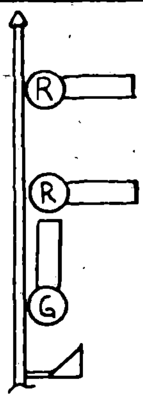
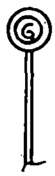
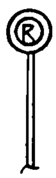
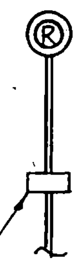
	SOU	305						

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	UP	240E		UP	240D		MIL	240F
	AT&SF	281		AT&SF	285		UP	240F
	BN,CN	281		CR,D&H	285		AT&SF	282
	CR	281		D&RGW	285		D&RGW	282
	D&H	281		N&W,SP	285		ICG	282
	D&RGW	281		RI,MP	285		RI,MP	284
	N&W	281		L&N	285		SP	285A
	SP	281		RF&P	290		SOU	306
	RF&P	287		SOU	307		BN	501A
	SOU	301		SCL	512			
	UP	240A		MIL	240C		SP	292
	SP	290		UP	240C			
	AT&SF	292		AT&SF	290			
	CR	292		SP	290A			
	D&RGW	292		BN	501J			
	RF&P	292						
	RI,MP	292						
	MIL	240N		AT&SF	281A		UP	240B
	UP	240S					AT&SF	291
	D&RGW	290					CR	291
	RI,MP	290					D&RGW	291
	BN	501G					RI,MP	291
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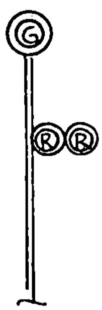
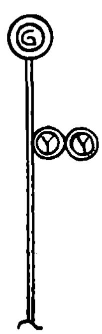
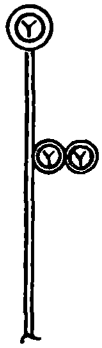
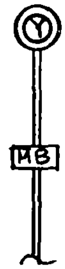
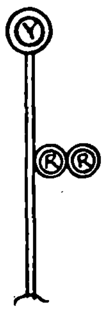
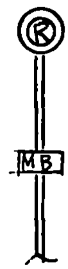
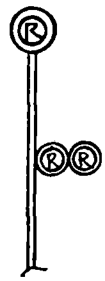
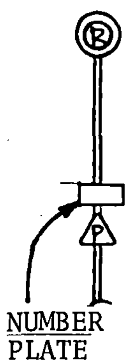
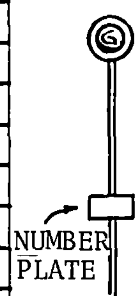
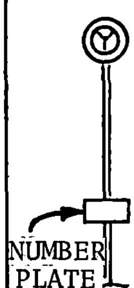
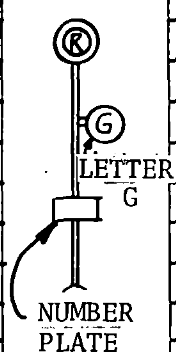
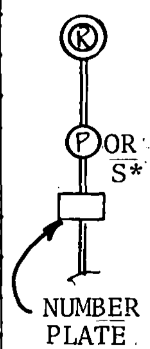
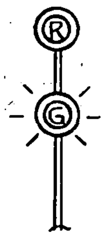
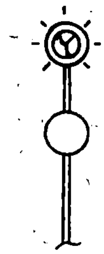
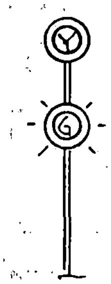
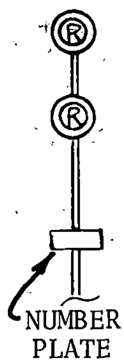
	CR	280		CR	281		CR	281E

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	CR	285A		CR	285B		CR	289
	CR	289		CR	292		CR	292
	AT&SF	290A					SOU	301
	SOU	307		RI,MP	290		UP	240T
	L&N	285		N&W	290		SCL	516
	SP	286		SP	287		D&H*	291A

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	RI,MP	281		SP	282		CR	281C
							UP	240J
	CR	281		RI,MP	285		SP	285A
							RI,MP	284
	CR	281A		CR	281B		UP	240B
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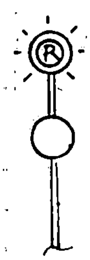
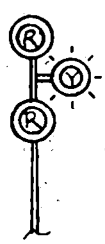
							RI,MP	291
	SP	290A		SP	291		UP	240E
							CR	281
							D&H	281
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							N&W	281
							RF&P	281
							RI,MP	281
							SOU	301

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	AT&SF	281A		UP	240K		UP	240D
	CN	282		AT&SF	283		CR	285
	CR	282		D&H	283		D&H	285
	N&W	282		D&RGW	283		D&RGW	285
	L&N	283		N&W,RF&P	283		N&W	285
	SP	284		RI,MP	283		RF&P	285
	SOU	302		SP	283		RI,MP	285
				CR	287		L&N	285
				SOU	304		SOU	307
				SCL	505		SCL	512
	UP	240N		UP	240A		MIL	240C
	D&RGW	286		SP	290		BN	501J
	RI,MP	288		CR	292			
	SP	288		D&H	292			
	AT&SF	290		D&RGW	292			
	CR,D&H	290		N&W	292			
	RF&P,N&W	290		RF&P	292			
	L&N	290		RI,MP	292			
	SOU	308		SOU	310			
	SCL	515						
	MIL	240F		MIL	240K		MIL	240N
	UP	240F		UP	240M		UP	240Q
	D&RGW	282		D&RGW	281B		SP	289
	ICG	282		CR	281D		D&RGW	290
	RI,MP	284		AT&SF	286		L&N	290
	SOU	306		RI,MP	286		RI,MP	290
	BN	501A		CN	288		BN	501G
				SOU	306			
				BN	501D			
				SCL	515			
	MIL	240N		UP	240G		UP	240H
	UP	240S		AT&SF	282		AT&SF	284
	RI,MP	290		RI,MP	282			
	BN	501G		CR	282A			
				N&W	282A			
				CN	284			
				SOU	303			
				SCL	502			

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	N&W	283		N&W	286		SOU	305
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							SCL	503
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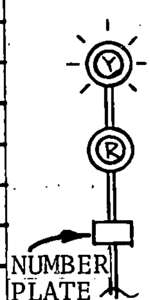
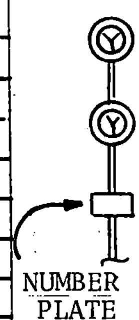
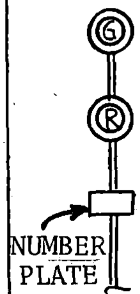
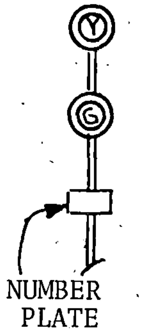
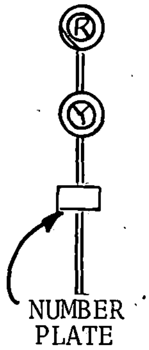
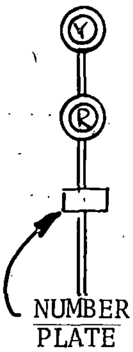
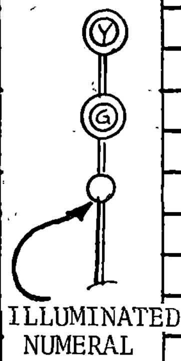
	CN	282A		CN	283A		CN	286A
	SCL	504						
				SOU	307		SOU	303

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	SOU	301		SOU	302		RI,MP	287
	L&N	285		SCL	509			

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
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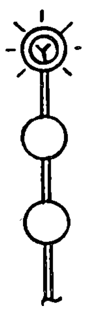
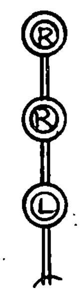
				UP	240L			
				SOU	304			
				SCL	507			
	SP	285A		SP	288		SP	289
				RF&P	290		D&RGW	290
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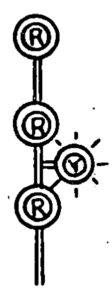
				CR	290		L&N	290
				D&H	290		UP	240R
				SOU	309			
				N&W	290			
				UP	240P			
				L&N	290			
	SP	290		SP	291		D&H	281
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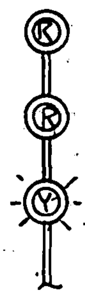
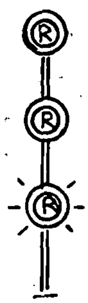
	UP	240A					VP	240E
	CR	292					SOU	301
	SOU	310					CR	281
	N&W	292					RI,MP	281
	RI,MP	292					D&RGW	281
	D&H	292					N&W	281
	D&RGW	292					RF&P	281
	CN	282		D&RGW	283		RF&P	285
	CR	282		SCL	505		L&N	285
	D&H	282		RF&P	283		UP	240D
	SOU	302		CR	283		CR	285
	N&W	282		SOU	304		SOU	307
	SCL	508		RI,MP	283		RI,MP	285
	ICG	283		D&H	283		D&H	285
				N&W	283		N&W	285
				UP	240K		SCL	512
							D&RGW	285

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	UP	240N		UP	240L		CN	288
	CR	286		N&W	287		SCL	515
	D&H	286		RF&P	287			
	D&RGW	286		ICG	288			
	N&W	286						
	RF&P	286						
	RI,MP	288						
	SOU	308						
	SCL	513						
				MIL	240C		UP	240G
				BN	501J		CR	282
							D&H	282
							RI,MP	282
							N&W	282A
							CN	284
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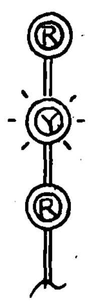
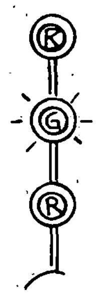
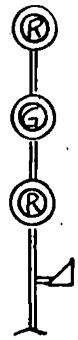
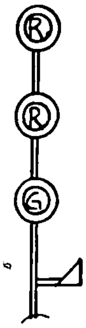
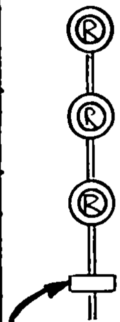
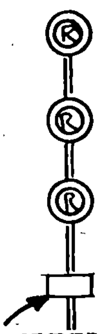
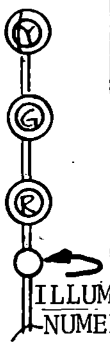
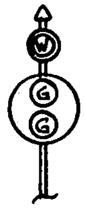
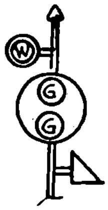
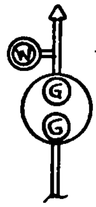
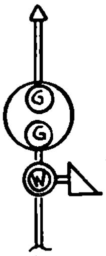
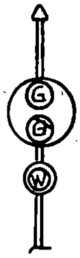
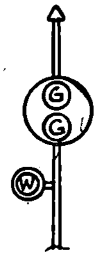
							SCL	502
	MIL	240F		MIL	240K			
	UP	240F		UP	240M			
	D&RGW	282		D&RGW	281B			
	SOU	282		CR	281D			
	RI,MP	284		D&H	286			
	BN	501A		RI,MP	286			
				BN	501D			
				CR	281B		UP	240J
							CR	281C
							D&H	283

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	CR	283A					SOU	305
	D&H	283A					L&N	283
	SCL	506						
	SOU	305	 NUMBER PLATE	VP	240B		CR	281
	CR	281A		CR	283B		CR	284
				SCL	511		SCL	510
				D&H	283B			
 NUMBER PLATE	CR	291		CN	282A		CN	283A

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	CN	286A		UP	240H		UP	240Q
	UP	240S		SCL	503			
	SCL	509		SCL	504			

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	B&O	B281		B&O	B282		B&O	B282A
	B&O	B283		B&O	B283A		B&O	B283B
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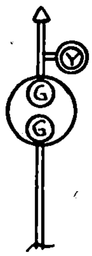
	B&O	B283C		B&O	B284		B&O	B285
							ICG	285
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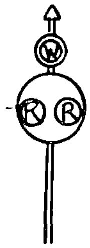
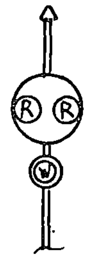
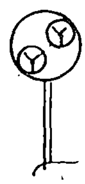
	GMO	287						

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	B&O	B290		B&O	B291		B&O	B291
	B&O	B292		N&W	281		N&W	285
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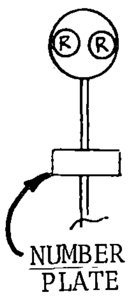
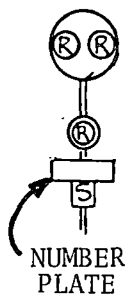
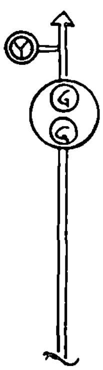
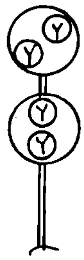
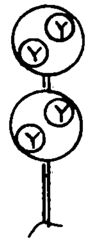
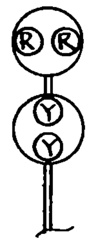
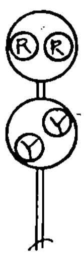
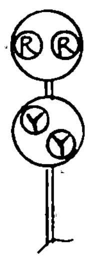
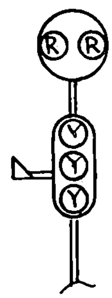
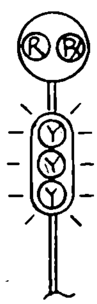
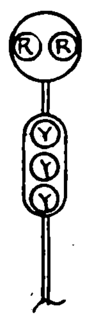
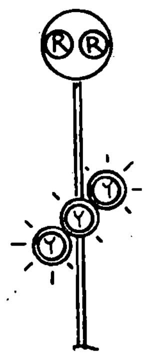
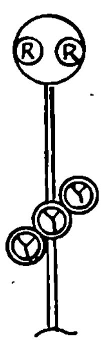
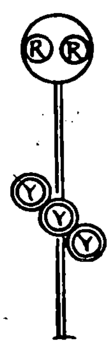
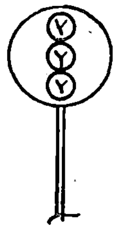
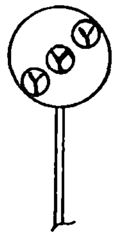
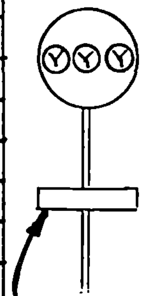
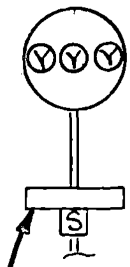
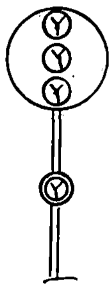
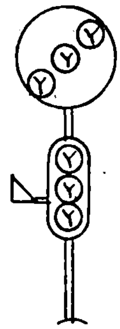
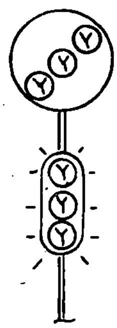
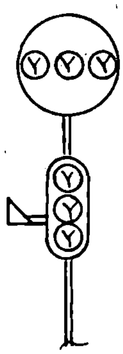
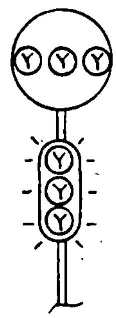
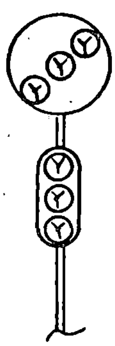
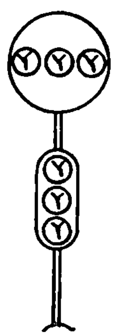
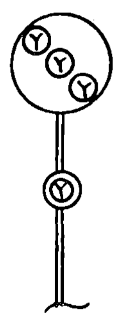
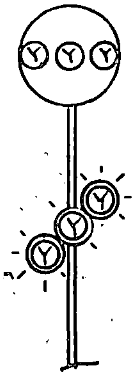
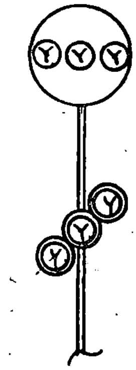
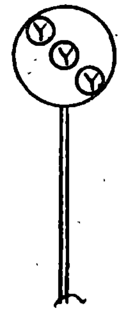
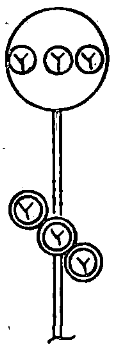
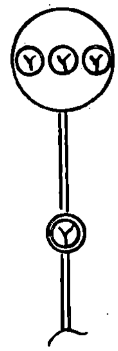
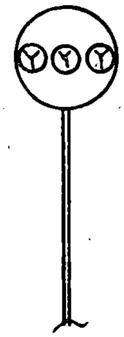
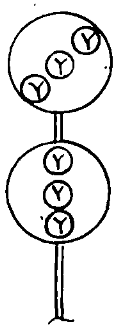
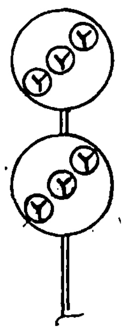
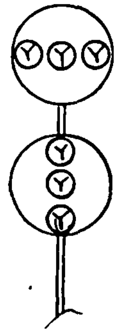
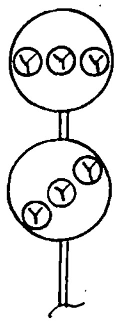
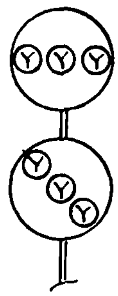
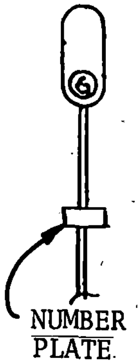
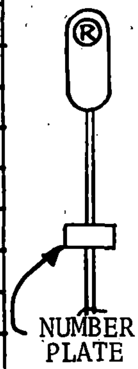
	N&W	291		N&W	292		CR	291
	ICG	283						

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	N&W	282		N&W	282A		N&W	283
	N&W	286		N&W	290		CR	281C
	CR	281C		CR	283		CR	286
	CR	288		CR	290			

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	N&W	281		N&W	285	 NUMBER PLATE	N&W	291
 NUMBER PLATE	N&W	292		CR	280		CR	281B
	CR	281B		CR	281C		CR	281C
	CR	282		CR	283		CR	285A

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	CR	286		CR	288		CR	289
	CR	290		CR	291		CR	292

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	N&W	282		N&W	282A		N&W	283
	N&W	286		N&W	290			

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	C&O	281					C&O	291
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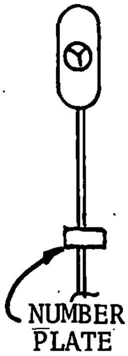
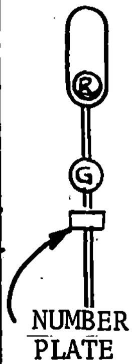
	SP	281		L&N	285		SP	285A
				C&O	285			
	SP	290		SP	287			

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
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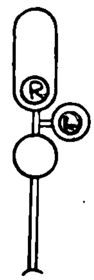
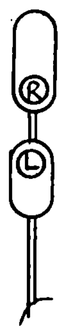
	SP	285A		SP	290		SP	292
	L&N	285		L&N	290			

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
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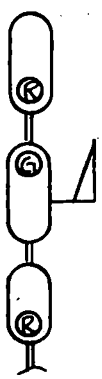
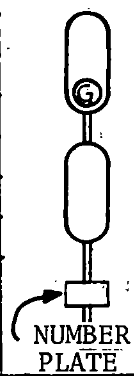
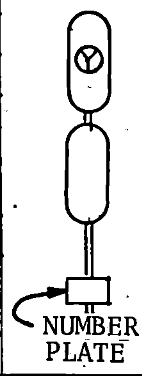
	C&O	284		C&O	285		C&O	290
	C&O	291		C&O	292		L&N	285
	L&N	283		C&O	281		C&O	285

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
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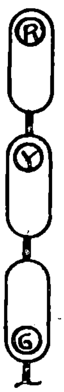
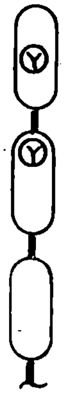
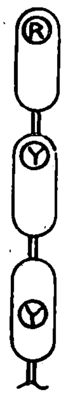
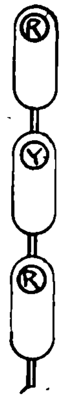
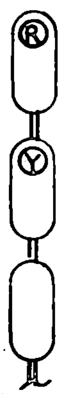
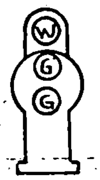
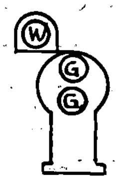
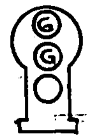
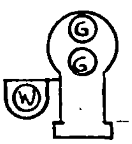
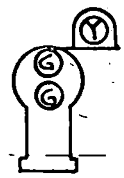
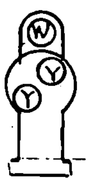
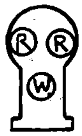
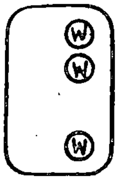
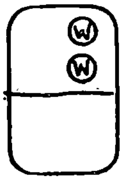
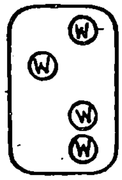
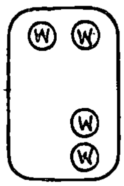
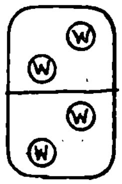
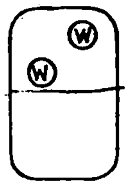
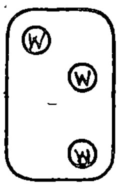
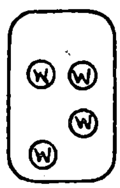
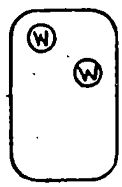
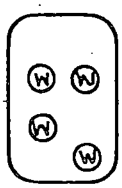
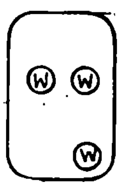
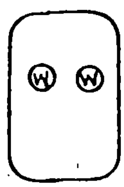
	C&O	283A		C&O	284		C&O	285
	C&O	286		C&O	287		C&O	288
	C&O	290		C&O	292			

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	B&O	B281		B&O	B282A		B&O	B283A
							ICG	286
	B&O	B283B		B&O	B283C		B&O	B284
	B&O	B285		B&O	B286		B&O	B287
	ICG	285		ICG	287			288
	B&O	B288		B&O	B290		B&O	B291
	ICG	289						

SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	B&O	B291		B&O	B292			

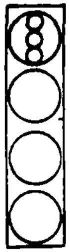
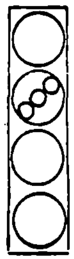
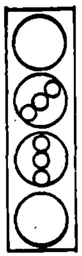
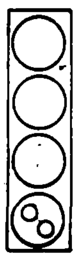
SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.	SIGNAL ASPECT	R.R. CODE	RULE NO.
	CR	280		CR	281		CR	282
	CR	283		CR	284		CR	285
	CR	285A		CR	288		CR	289
	CR	290		CR	291		CR	292

APPENDIX F

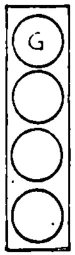
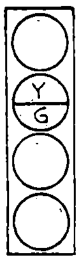
CAB SIGNAL ASPECTS, TITLES AND INDICATIONS

The cab signal aspects and indications shown in this presentation come from the official rule book of the four railroads shown. The rule books for the other railroads surveyed did not cover cab signaling. The table shows the cab signal aspect, the title, indication, rule number and railroad assigning the rule. One aspect in some cases has more than one rule number, title and indication for a specific railroad.

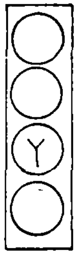
CAB SIGNAL ASPECTS & INDICATIONS

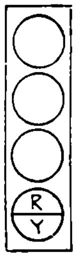
SIGNAL ASPECT	TITLE	INDICATION	RULE NO.	RAILROAD
	CLEAR	PROCEED.	281	CR
	APPROACH SLOW	PROCEED, APPROACHING NEXT SIGNAL AT SLOW SPEED (15). TRAINS EXCEEDING MEDIUM SPEED (30) MUST AT ONCE REDUCE TO THAT SPEED.	284	CR
	APPROACH	PROCEED PREPARING TO STOP AT NEXT SIGNAL. TRAINS EXCEEDING MEDIUM SPEED (30) MUST AT ONCE REDUCE TO THAT SPEED.	285	CR
	MEDIUM APPROACH	PROCEED AT MEDIUM SPEED (30) PREPARING TO STOP AT NEXT SIGNAL.	286	CR
	APPROACH LIMITED	PROCEED APPROACHING NEXT SIGNAL AT LIMITED SPEED (45).	281B	CR
	LIMITED CLEAR	PROCEED: LIMITED SPEED (45) WITHIN INTERLOCKING LIMITS.	281C	CR
	APPROACH MEDIUM	PROCEED APPROACHING NEXT SIGNAL AT MEDIUM SPEED (30).	282	CR
	MEDIUM CLEAR	PROCEED; MEDIUM SPEED (30) WITHIN INTERLOCKING LIMITS.	283	CR
	SLOW CLEAR	PROCEED SLOW SPEED (15) WITHIN INTERLOCKING LIMITS.	287	CR
	SLOW APPROACH	PROCEED PREPARING TO STOP AT NEXT SIGNAL; SLOW SPEED (15) WITHIN INTERLOCKING LIMITS.	288	CR
	RESTRICTING	PROCEED AT RESTRICTED SPEED (15).	290	CR
	STOP & PROCEED	STOP THEN PROCEED AT RESTRICTED SPEED (15).	291	CR
	STOP SIGNAL	STOP.	292	CR

CAB SIGNAL ASPECTS & INDICATIONS

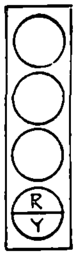
SIGNAL ASPECT	TITLE	INDICATION	RULE NO.	RAILROAD
	CLEAR	PROCEED.	240E	UP
			281	RI, MP
			501	BN
	APPROACH LIMITED	PROCEED. SPEED PASSING NEXT SIGNAL MUST NOT EXCEED 40 MPH.	240F	UP
	DIVERGING CLEAR LIMITED	PROCEED ON DIVERGING ROUTE. SPEED THROUGH TURNOUT MUST NOT EXCEED 40 MPH.	240J	UP
	DIVERGING APPROACH LIMITED	PROCEED ON DIVERGING ROUTE. SPEED THROUGH TURNOUT MUST NOT EXCEED 40 MPH. SPEED PASSING NEXT SIGNAL MUST NOT EXCEED 40 MPH.	240M	UP
	ADVANCE APPROACH	PROCEED, REDUCING TO 50 MPH BEFORE REACHING NEXT SIGNAL.	282	RI, MP
	DIVERGING CLEAR	PROCEED ON DIVERGING ROUTE, NOT EXCEEDING PRESCRIBED SPEED THROUGH TURNOUT.	283	RI, MP
	APPROACH MEDIUM	PROCEED APPROACHING NEXT SIGNAL NOT EXCEEDING 30 MPH.	501A	BN
	DIVERGING CLEAR	PROCEED ON DIVERGING ROUTE AT PRESCRIBED SPEED.	501C	BN
	DIVERGING APPROACH MEDIUM	PROCEED ON DIVERGING ROUTE AT PRESCRIBED SPEED AND APPROACH NEXT SIGNAL NOT EXCEEDING 30 MPH.	501D	BN

CAB SIGNAL ASPECTS & INDICATIONS

SIGNAL ASPECT	TITLE	INDICATION	RULE NO.	RAILROAD
	APPROACH	PROCEED PREPARED TO STOP BEFORE ANY PART OF TRAIN OR ENGINE PASSES THE NEXT SIGNAL. TRAINS EXCEEDING 30 MPH MUST IMMEDIATELY REDUCE TO THAT SPEED.	240D	UP
	APPROACH MEDIUM	PROCEED. SPEED PASSING NEXT SIGNAL MUST NOT EXCEED 30 MPH.	240G	UP
	DIVERGING CLEAR MEDIUM	PROCEED ON DIVERGING ROUTE. SPEED THROUGH TURNOUT MUST NOT EXCEED 30 MPH.	240K	UP
	DIVERGING APPROACH MEDIUM	PROCEED ON DIVERGING ROUTE PREPARED TO STOP AT NEXT SIGNAL. SPEED THROUGH TURNOUT AND TO NEXT SIGNAL MUST NOT EXCEED 30 MPH.	240N	UP
	APPROACH MEDIUM	PROCEED, REDUCING TO 35 MPH BEFORE REACHING NEXT SIGNAL.	284	RI, MP
	APPROACH	PROCEED, IMMEDIATELY REDUCING TO 40 MPH OR SLOWER IF NECESSARY, PREPARED TO STOP BEFORE REACHING NEXT SIGNAL.	285	RI, MP
	DIVERGING APPROACH MEDIUM	PROCEED ON DIVERGING ROUTE, NOT EXCEEDING PRESCRIBED SPEED THROUGH TURNOUT, REDUCING TO 35 MPH BEFORE REACHING NEXT SIGNAL.	286	RI, MP
	APPROACH DIVERGING	PROCEED, PREPARED TO ADVANCE ON DIVERGING ROUTE AT NEXT SIGNAL, AT PRESCRIBED SPEED THROUGH TURNOUT.	287	RI, MP
	DIVERGING APPROACH	PROCEED ON DIVERGING ROUTE AT PRESCRIBED SPEED THROUGH TURNOUT, PREPARED TO STOP BEFORE REACHING NEXT SIGNAL.	288	RI, MP
	APPROACH	PROCEED PREPARED TO STOP BEFORE ANY PART OF TRAIN OR ENGINE PASSES THE NEXT SIGNAL.	501B	BN
	DIVERGING APPROACH	PROCEED ON DIVERGING ROUTE AT PRESCRIBED SPEED PREPARED TO STOP BEFORE ANY PART OF TRAIN OR ENGINE PASSES THE NEXT SIGNAL.	501E	BN
	APPROACH RESTRICTING	PROCEED APPROACHING NEXT SIGNAL NOT EXCEEDING RESTRICTED SPEED (20).	501F	BN

SIGNAL ASPECT	TITLE	INDICATION	RULE NO.	RAILROAD
	STOP	STOP BEFORE ANY PART OF TRAIN OR ENGINE PASSES THE SIGNAL.	240A	UP
	STOP AND PROCEED	STOP BEFORE ANY PART OF TRAIN OR ENGINE PASSES THE SIGNAL THEN PROCEED AT RESTRICTED SPEED (20) THROUGH ENTIRE BLOCK.	240B	UP
	FLASHING STOP AND PROCEED	STOP. BLOCK OCCUPIED. PROCEED AT RESTRICTED SPEED (20).	240C	UP
	APPROACH SLOW	PROCEED. SPEED PASSING NEXT SIGNAL MUST NOT EXCEED 15 MPH.	240H	UP
	DIVERGING CLEAR SLOW	PROCEED ON DIVERGING ROUTE. SPEED THROUGH TURNOUT MUST NOT EXCEED 15 MPH.	240L	UP
	DIVERGING APPROACH SLOW	PROCEED ON DIVERGING ROUTE PREPARED TO STOP AT NEXT SIGNAL. SPEED THROUGH TURNOUT MUST NOT EXCEED 15 MPH. SPEED TO NEXT SIGNAL MUST NOT EXCEED 30 MPH.	240P	UP
	DIVERGING RESTRICTING	PROCEED ON DIVERGING ROUTE AT RESTRICTED SPEED.	240Q	UP
	DIVERGING RESTRICTING SLOW	PROCEED AT RESTRICTED SPEED (20) NOT EXCEEDING 15 MPH.	240R	UP
	RESTRICTING	PROCEED AT RESTRICTED SPEED.	240S	UP
	PERMISSIVE	PROCEED AT RESTRICTED SPEED THROUGH ENTIRE BLOCK.	240T	UP
	LOW	PROCEED AT LOW SPEED (20) (1) WITHIN ABS TO NEXT SIGNAL GOVERNING IN THE SAME DIRECTION (2) AT INTERLOCKING OUTSIDE ABS - THROUGH INTERLOCKING LIMITS. (3) WHERE THIS SIGNAL GOVERNS MOVEMENT ONTO NON-SIGNALED TRACK - UNTIL ENTIRE TRAIN IS THROUGH TURNOUT.	290	RI, MP
	STOP & PROCEED	STOP, THEN PROCEED AT LOW SPEED (20) THROUGH THE ENTIRE BLOCK.	291	RI, MP
	STOP	STOP.	292	RI, MP

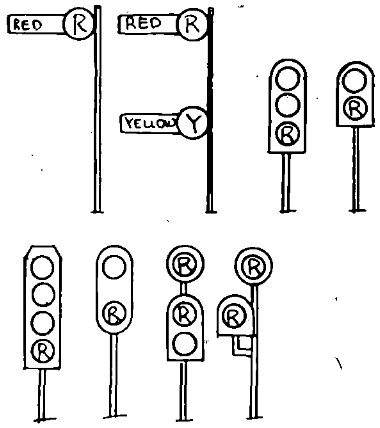
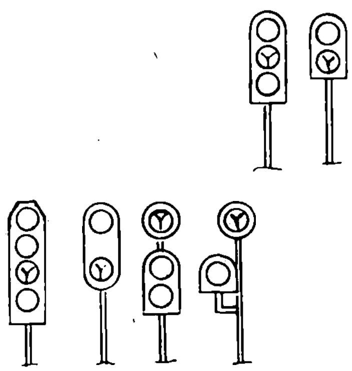
CAB SIGNAL ASPECTS & INDICATIONS

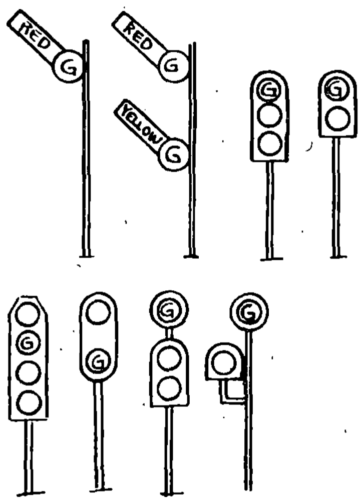
SIGNAL ASPECT	TITLE	INDICATION	RULE NO.	RAILROAD
		PROCEED AT RESTRICTED SPEED (20).	501G	BN
		TAKE SIDING INDICATOR FOR HAND OPERATION OF SWITCH.	501H	BN
		PROCEED AT RESTRICTED SPEED (20) THROUGH ENTIRE BLOCK.	501I	BN
		STOP BEFORE ANY PART OF TRAIN OR ENGINE PASSES THE SIGNAL, THEN PROCEED AT RESTRICTED SPEED (20) THROUGH ENTIRE BLOCK.	501J	BN
		STOP BEFORE ANY PART OF TRAIN OR ENGINE PASSES THE NEXT SIGNAL.	501K	BN

APPENDIX G

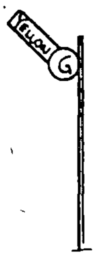
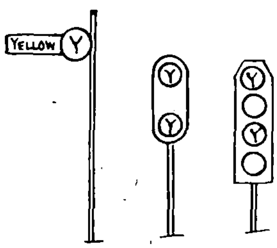
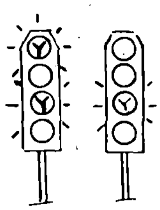
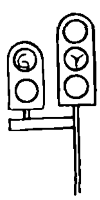
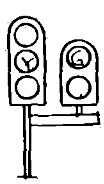
BRITISH RAILROAD SIGNAL ASPECTS, NAMES AND INDICATIONS

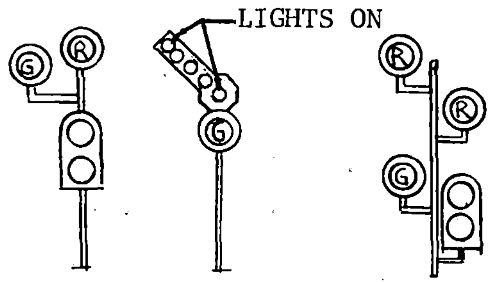
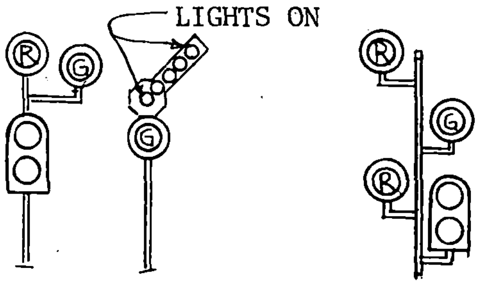
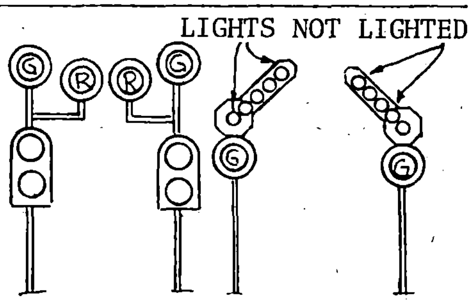
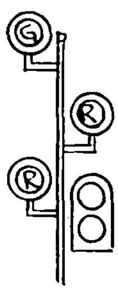
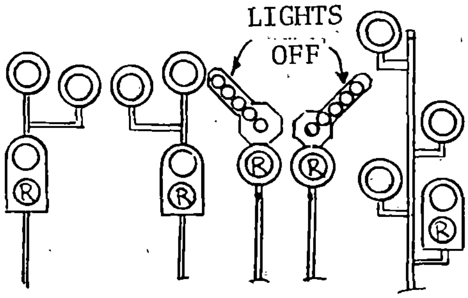
The information contained in this appendix is a digest of information from reference document number 80 "British Railway Signaling". The information has been rearranged to be consisted with other formats included in the report.

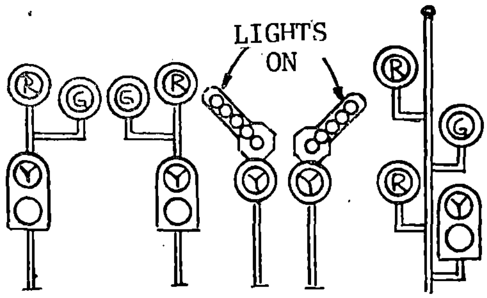
BRITISH RAILROADS		(MAIN SIGNALS)
SIGNAL	NAME	INDICATION
	DANGER	STOP
	CALLING ON	STOP AND PROCEED PREPARED TO STOP SHORT OF OBSTRUCTION
	CAUTION	

BRITISH RAILROADS;		(MAIN SIGNALS)
SIGNAL	NAME	INDICATION
	CLEAR	PROCEED

BRITISH RAILROADS (DISTANCE SIGNALS)

SIGNAL	NAME	INDICATION
		NEXT SIGNAL CLEAR
		NEXT SIGNAL CAUTION
		NEXT SIGNAL DIVERGING ROUTE
		NEXT SIGNAL DIVERGE LEFT
		NEXT SIGNAL DEVERGE RIGHT

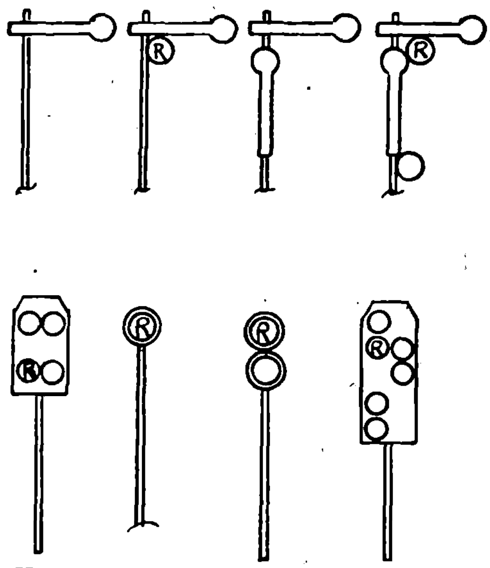
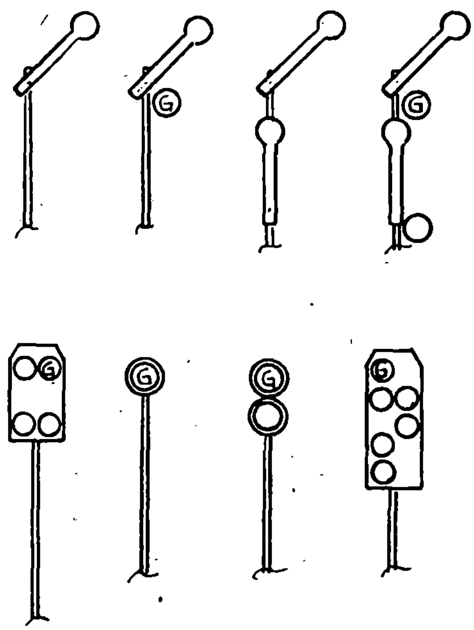
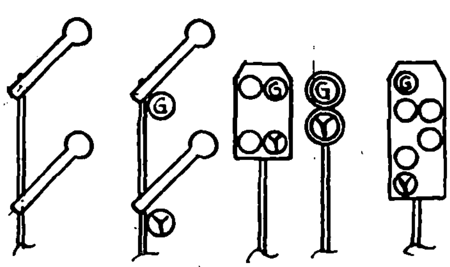
BRITISH RAILROADS (JUNCTION SIGNALS)		
SIGNAL	NAME	INDICATION
		CLEAR-DIVERGE LEFT
		CLEAR-DIVERGE RIGHT
		CLEAR ON MAIN TRACK
		CLEAR DIVERGE SECOND LEFT
		STOP

BRITISH RAILROADS (JUNCTION SIGNALS)		
SIGNAL	NAME	INDICATION
		PROCEED ON ROUTE INDICATED WITH CAUTION

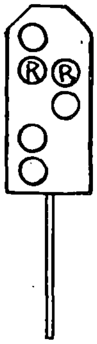
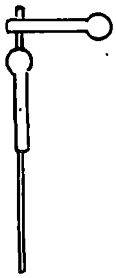
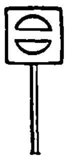
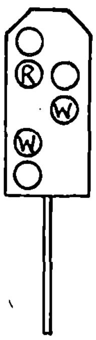
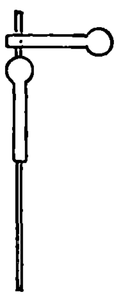
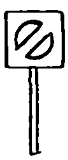
APPENDIX H

WEST GERMAN RAILROAD SIGNAL ASPECTS NAMES AND INDICATIONS

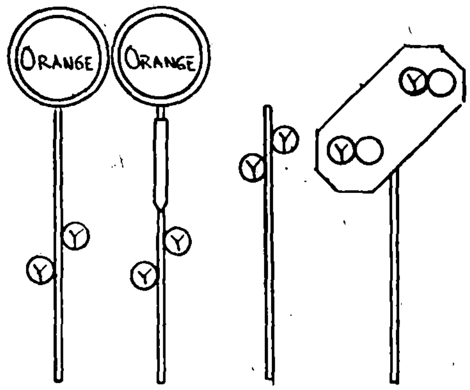
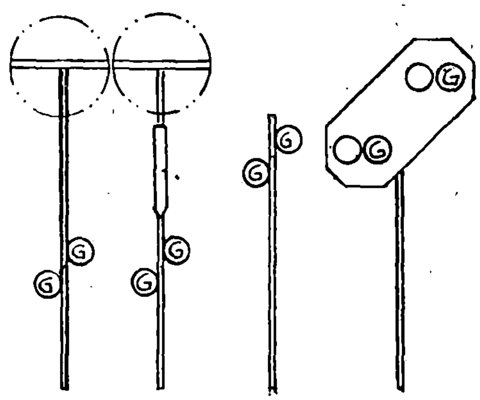
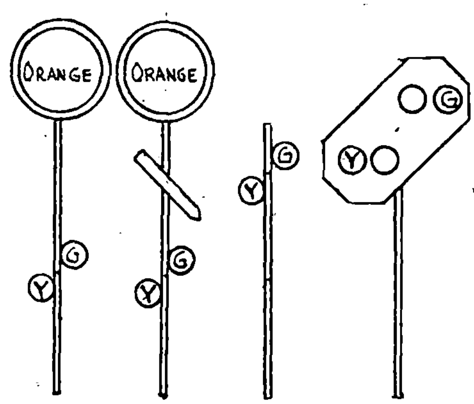
The information contained in this appendix was derived from two reference documents. Number 315 "The Signals of the German Railroads" was the source for the contemporary signal aspects and indications. Document number 371 "New Signal Aspects for the German Railroads" is the source for the Proposed Signal Display included as page H-5.

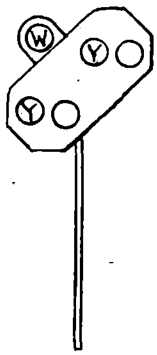
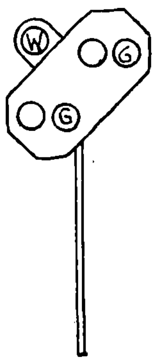
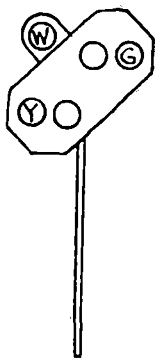
GERMAN RAILROADS (PRIMARY SIGNAL)		
SIGNAL	NAME	INDICATION
	Hp0	STOP
	Hp1	PROCEED (PROCEED AT AUTHORIZED SPEED.)
	Hp2	SLOW (PROCEED AT SLOW SPEED.)

GERMAN RAILROADS (SWITCHING SIGNALS)

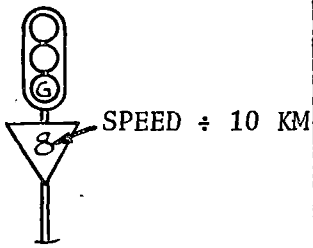
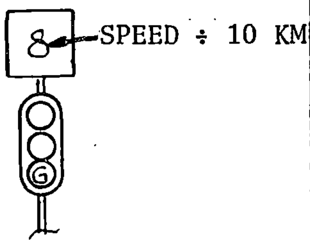
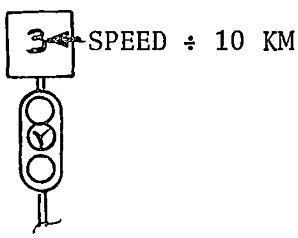
SIGNAL	NAME	INDICATION
	Hp00	STOPPING & SWITCHING PROHIBITED
 HPO  SHO	Hp0 & Sh0	
	Hp0/Sh1	STOPPING & SWITCHING PERMITTED
 HPO  SH1	Hp0 & Sh1	

GERMAN RAILROADS (DISTANT SIGNALS)

SIGNAL	NAME	INDICATION
	Vr0	EXPECT STOP SIGNAL (APPROACH MAIN SIGNAL PREPARED TO STOP.)
	Vr1	EXPECT PROCEED SIGNAL AHEAD (MAIN SIGNAL PERMITS PROCEEDING AT AUTHORIZED SPEED.)
	Vr2	EXPECT SLOW SIGNAL AHEAD (MAIN SIGNAL LIMITS SPEED TO SLOW TRAVEL.)

GERMAN RAILROADS (DISTANT SIGNAL REPEATER)		
SIGNAL	NAME	INDICATION
	Wv0	DISTANT SIGNAL CAUTIONS TO APPROACH MAIN SIGNAL PREPARED TO STOP.
	Wv1	DISTANT SIGNAL INDICATES MAIN SIGNAL IS SET FOR MAXIMUM AUTHORIZED SPEED.
	Wv2	DISTANT SIGNAL CAUTIONS TO APPROACH MAIN SIGNAL AT SLOW SPEED.

GERMAN RAILROADS (PROPOSED SIGNAL DISPLAY)

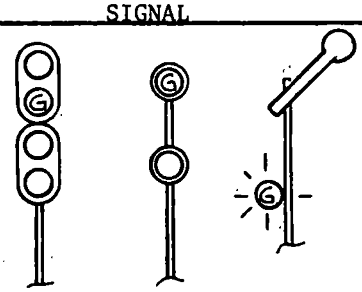
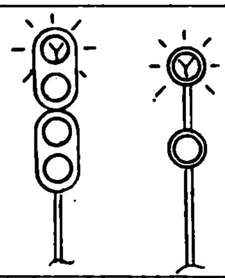
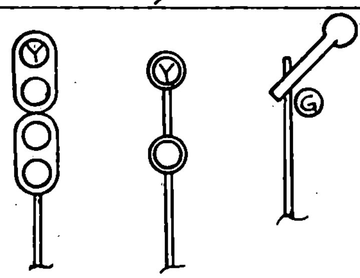
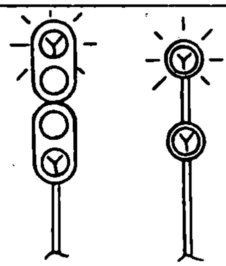
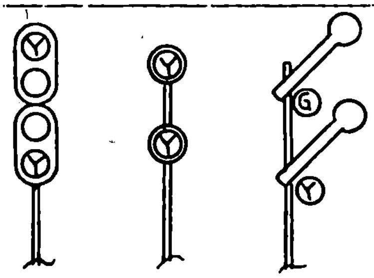
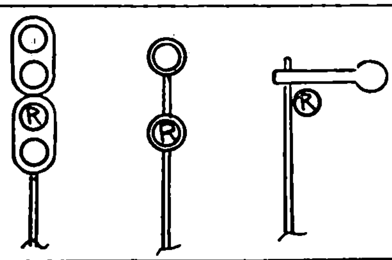
SIGNAL	NAME	INDICATION
	NONE DECIDED ON	CLEAR - PROCEED AT CURRENT SPEED.
	NONE DECIDED ON	CLEAR - REDUCE SPEED TO THAT INDICATED.
	NONE DECIDED ON	CLEAR - PROCEED AT SPEED INDICATED.
	NONE DECIDED ON	PREPARE TO STOP.
	NONE DECIDED ON	PREPARE TO STOP; LINE CLEAR AT REDUCED SPEED.
	NONE DECIDED ON	STOP

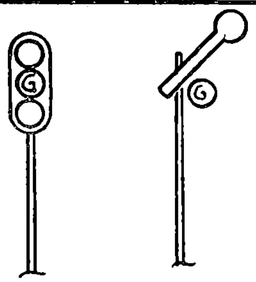
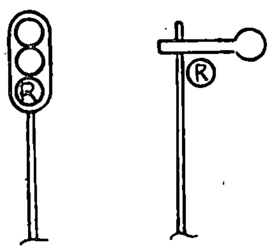
APPENDIX I

RUSSIAN RAILROAD SIGNAL ASPECTS, NAMES AND INDICATIONS

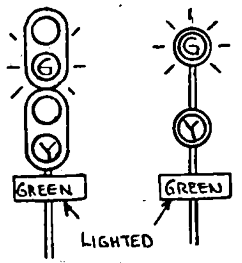
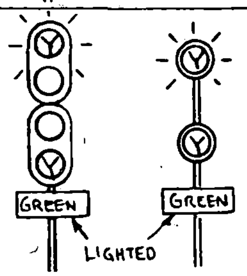
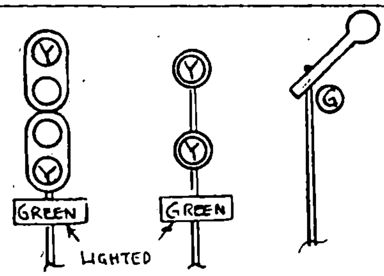
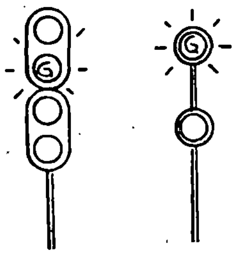
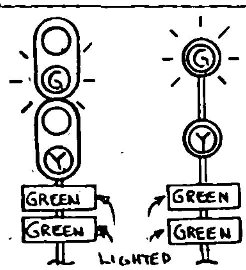
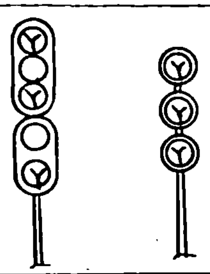
The signal aspects and indications shown in this appendix come from source document 264 "Handbook of Signaling on Soviet Railroads", and was rearragned to conform to a more uniform format for comparison to U.S. and other systems.

RUSSIAN RAILROADS (HOME SIGNALS)

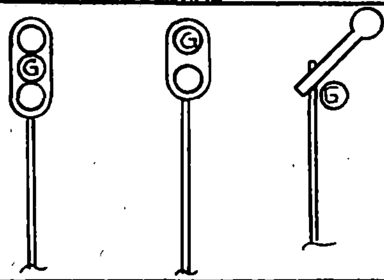
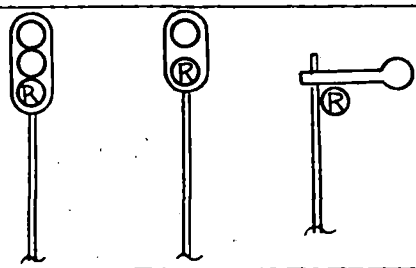
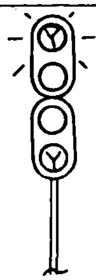
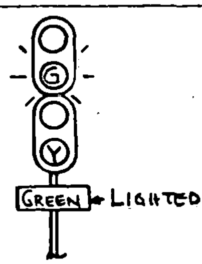
SIGNAL	RULE BOOK PARAGRAPH	INDICATION
	9a 33	PROCEED INTO STATION ON MAIN TRACK AT AUTHORIZED SPEED. NEXT TWO SIGNALS ARE CLEAR.
	9b	PROCEED INTO STATION ON MAIN TRACK AT AUTHORIZED SPEED PREPARED TO PASS NEXT SIGNAL AT REDUCED SPEED(50 kph)
	9c 30a	PROCEED INTO STATION ON MAIN TRACK PREPARED TO STOP AT NEXT SIGNAL.
	9d	PROCEED INTO STATION AT REDUCED SPEED(50 kph max.) PREPARED TO TAKE DIVERGING ROUTE. PROCEED PAST NEXT SIGNAL AT REDUCED SPEED.
	9e 31	PROCEED INTO STATION AT REDUCED SPEED(50 kph max.) PREPARED TO TAKE DIVERGING ROUTE AND STOP AT NEXT SIGNAL.
	9f 30b	STOP. DO NOT PASS SIGNAL.

RUSSIAN RAILROADS (INTERMEDIATE BLOCK SIGNALS)		
SIGNAL	RULE BOOK PARAGRAPH	INDICATION
	18a 19a 21a 30a	PROCEED AT AUTHORIZED SPEED. TWO OR MORE BLOCKS ARE CLEAR. (FOR FOUR INDICATOR SIGNALING 3 OR MORE BLOCKS ARE CLEAR.)
	18b	PROCEED PREPARED TO STOP AT NEXT SIGNAL.
	19b	PROCEED AT AUTHORIZED SPEED PREPARING TO STOP AT SECOND SIGNAL. (FOR FOUR INDICATOR SIGNALING ONLY.)
	18c 19c 21b 30b	STOP. DO NOT PASS SIGNAL.

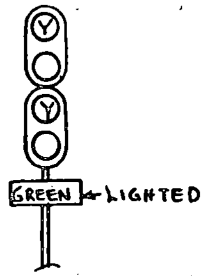
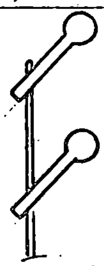
RUSSIAN RAILROADS (ROUTE SIGNALS)

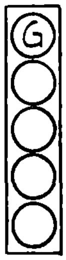
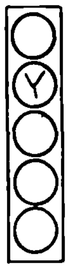
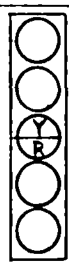
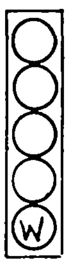
SIGNAL	RULE BOOK PARAGRAPH	INDICATION
	10a	PROCEED INTO STATION AT SPEED NOT OVER 80 kph PREPARING TO TAKE DIVERGING ROUTE. SPEED PASSING NEXT SIGNAL SHALL NOT EXCEED 80 kph.
	10b	PROCEED INTO STATION AT SPEED NOT OVER 80 kph PREPARING TO TAKE DIVERGING ROUTE. SPEED PASSING NEXT SIGNAL SHALL NOT EXCEED REDUCED SPEED(50 kph),
	10c	PROCEED INTO STATION AT SPEED NOT OVER 80 kph PREPARING TO TAKE DIVERGING ROUTE AND STOP AT NEXT SIGNAL.
	10-	PROCEED INTO STATION ON MAIN TRACK AT AUTHORIZED SPEED PREPARING TO PASS NEXT SIGNAL AT NOT OVER 80 kph.
	10-	PROCEED INTO STATION AT SPEED NOT OVER 120 kph PREPARED TO TAKE DIVERGING ROUTE. SPEED PASSING NEXT SIGNAL SHALL NOT EXCEED 120 kph
	10-	PROCEED INTO STATION AT SPEED NOT OVER 25 kph AND PREPARE TO STOP SHORT OF TRAIN AHEAD.

RUSSIAN RAILROADS (STARTING SIGNALS)

SIGNAL	RULE BOOK PARAGRAPH	INDICATION
	12a 14a 30a	PROCEED OUT OF STATION AT AUTHORIZED SPEED. TRACK IS CLEAR TWO BLOCKS MINIMUM.
	12b	PROCEED OUT OF STATION PREPARED TO STOP AT NEXT SIGNAL.
	12c 14b 30b	STOP. DO NOT LEAVE STATION.
	12d	PROCEED OUT OF STATION AT REDUCED SPEED (50 kph max.) THROUGH SWITCH PREPARED TO PASS NEXT SIGNAL AT AUTHORIZED SPEED.
	12e	PROCEED OUT OF STATION AT REDUCED SPEED (50 kph max.) THROUGH SWITCH PREPARED TO STOP AT NEXT SIGNAL.
	13a	PROCEED OUT OF STATION AT NOT OVER 80 kph THROUGH SWITCH PREPARED TO PASS NEXT SIGNAL AT AUTHORIZED SPEED.

RUSSIAN RAILROADS (STARTING SIGNALS)

SIGNAL	RULE BOOK PARAGRAPH	INDICATION
	13b	PROCEED OUT OF STATION AT NOT OVER 80 kph THROUGH SWITCH PREPARED TO STOP AT NEXT SIGNAL.
	15-	PROCEED ONTO SIDING OR AGAINST TRAFFIC. ROUTE IS CLEAR TWO BLOCKS MINIMUM.
	31-	PROCEED PREPARING TO TAKE DIVERGING ROUTE.

RUSSIAN RAILROADS (CAB SIGNALING)		
SIGNAL	RULE BOOK PARAGRAPH	INDICATION
	28a & -	PROCEED AT AUTHORIZED SPEED. (WAYSIDE SIGNAL DISPLAYS (a)ONE YELLOW FLASHING LIGHT (b)ONE GREEN FLASHING LIGHT (c)ONE YELLOW AND ONE GREEN, OR (d)ONE GREEN LIGHT.)
	28b & -	PROCEED AT REDUCED SPEED(50 kph). (WAYSIDE SIGNAL DISPLAYS (a)ONE YELLOW LIGHT (b)TWO YELLOW LIGHTS OR (c)TWO YELLOW LIGHTS THE UPPER FLASHING.)
	28c & -	PROCEED PREPARED TO STOP AT NEXT SIGNAL. (WAYSIDE SIGNAL DISPLAYS STOP INDICATION.)
	28 -	BE GOVERNED BY WAYSIDE SIGNALS.

APPENDIX J

REPORT ON FEDERAL RAILROAD ADMINISTRATION GENERAL SAFETY INQUIRY

This appendix is a condensation of two days of testimony before the General Safety Inquiry, conducted by the FRA in February 1979. This study effort was represented at that hearing. During the hearing the study representatives recorded the testimony which has been transcribed for inclusion in the study library. This testimony is fragmented in some cases, particularly in the question and answer sessions because the questioner and the respondee were not always near the microphone; however, these transcriptions are available for reference.

REPORT ON
FEDERAL RAILROAD ADMINISTRATION
GENERAL SAFETY INQUIRY

A. INTRODUCTION

FRA General Safety Inquiry Public Hearing on Signal and Train Control (S/TC) Regulations and orders Docket No. RSSI-78-5, Notice No. 6.

Two days of public hearing regarding safety of Signal and Train Control Systems were conducted by FRA on February 22, 23, 1979.

Oral presentations were often briefs of written responses to the public questions published prior to the hearings. Material was obtained on presentations by the Southern-Pacific Railway Company, Railway Labor Executives Association, and AAR's Prepared Revision to the Rules, Standards and Instructions, (RS&I). Additional tape recordings were made of the meetings and will be made available as soon as the transcription is completed.

B. SUMMARY AND CONCLUSIONS

It was unanimous with all participants that safety was the ultimate goal for signal and train control systems. It was interesting to note that a definition for "fail safe" was given as not being safe from failure, but in the event of failure, the system would be in a safe operational mode, admitting that failures will and do occur.

The operating railroads, in general, would like to operate without federal regulations but are realistic enough to realize and understand the requirement for some regulation. The most repeated items where change or deletion of federal regulations was requested, are summarized as follows:

a) Permit railroads to remove signal systems when they are no longer beneficial to operations and/or economics. Request for modification or upgrading should not be required.

b) Let the railroads establish their own signal placement and spacing based on type of traffic, traffic density and operational requirements.

c) Length of time for FRA response to requests for signal change averages six months and in many cases is detrimental to railroad operations.

d) Human error and vandalism are two of the largest problems facing railroads.

e) Personnel training provided by the railroads is adequate. No regulations are needed nor is qualification of personnel deemed necessary.

f) Section 236.410 requiring electric locks on switches for TCS was probably the most often-voiced target of complaints and requests for deletion as unnecessary and totally beyond economic justification.

g) Testing of specific components, especially relays and cable resistance, was widely mentioned as too stringent.

h) The Brotherhood of Signalmen (B of RS) supported the performance specification approach to tests and regulations, although some felt a combination of performance and design specifications would provide the best regulations.

i) The B of RS felt a firm interpretation and application of "undue delay" should be used in enformcement of signal repairs.

The National Transportation Safety Board (NTSB) and the Railway Labor Executive Association (RLEA) voiced concern to FRA for failure to do a good job of inspection and enforcement of current regulations.

The RPI stressed a slow evolution into solid state signal systems citing the current "fail safe" system as reliable and proven safe. The National Transportation Safety Board recommended more use of signal systems, especially cab signaling for improved safety and reduced collisions and other accidents noting that the purpose of a signal system is to provide safety of operations, while control of operations is secondary. The board did stress the need for simplified performance standards with design specifications but improved enforcement. The board recommended the elimination of the "stop and proceed" indication.

C. PUBLIC HEARING AGENDA

22 February 1979

1. Missouri Pacific Railroad Company
2. Association of American Railroad (AAR)
3. The Chessie System
4. National Railroad Passenger Corp. (AMTRAK)
5. Railway Progress Institute (RPI)
6. Southern Pacific Transportation Company
7. St. Louis-San Francisco Railway Company
8. Southern Railway System
9. Burlington Northern

23 February 1979

1. National Transportation Safety Board (NTSB)
2. Railway Labor Executive Association (B of RS)

Board of Inquiry

Raymond K. James	Chief Counsel
Steven R. Ditmeyer	Assoc. Admin., Policy and Program Development
Robert E. Parsons	Assoc. Admin., Research & Development
Edward F. Conway	Counsel

Technical Panel

Rolf Mowatt-Larssen	Director, Office of Standards
Leavitt A. Peterson	Director, Office of Rail Safety Research
W. R. Paxton	Chief, Maintenance of Way Division
S. H. Stotts	Signal and Train Control Specialist

D. NOTES OF THE MEETING

1. Missouri Pacific RR Co.

Mr. J.A. German, Vice President, Engineering

Mr. J.F. Derochie, Signal Engineer

Mr. German summarized his company's signal equipment investment, maintenance and improvement budgets. He did state that they had 21 "false clear" failures of which no cause was found for ten, five were from vandalism and six were caused by equipment failures.

Mr. German stated that the decision to retire signal systems that are outdated or not required because of reduced traffic density should be the railroads' responsibility and prerogative. Other more specific references were:

a) The requirement for signal systems should be on an economic cost benefit analysis and not required by regulation alone.

b) Much of the signal maintenance and repair is too stringent and not safety related.

c) Electric locks (236.410) do affect and hinder the upgrading or installation of new signal systems. At a maximum cost of $10,500 per lock, it represents a major cost of a signal system and adds nothing to safety.

d) Eliminate rule 236.410 and allow speeds in excess of 20 MPH through the switches if they are designed for speeds in excess of 20 MPH.

e) MOPAC has an effective and improving training program and sees no need for regulations affecting training or qualification of personnel.

f) Vandalism is a major problem, but a social problem not solved by redundancy or regulation.

g) The term "undue delay" and the attention it is receiving is out of proportion. A railroad cannot allow a signal to be more restrictive than required, since by nature the system will be safe even in failure. "Undue delay" should mean, "before the next train operation."

h) Many test requirements and/or frequencies are unjustified or unnecessary, i.e., cable resistance and relay testing.

Questions and answers generally followed or expanded previous statements; however, when asked if current regulations hindered the use of solid state components, Mr. German felt they did, but also felt solid state systems should be developed on a natural evolutionary, not revelutionary basis. Economics will not allow rapid change.

2. <u>Association of American Railroads (Signal Liaison Committee)</u>

R. D. Liggett	Chief Engr. Comm. & Signal	Seaboard Coast Lines
P. Foley	Signal Engr.	AAR
M. M. Shultz	Dir., Signal Engineering	Burlington Northern
H. Alexander	Chf. Engineer-Comm. & Singals	Conrail
B. J. Hutton	Asst. Chf. Engineer-Signals	Santa Fe

The AAR has completed and will submit a proposed revision to the RS&I. A copy of this proposal was obtained. Specific comments to FRA questions will be submitted later. The AAR specifically noted inconsistent administration by the FRA, mostly in interpretation of rules and the delays incurred in processing requests.

Mr. Liggett stated that of all the reported signal failures the past year 20.2% were man-related and 14.9% were due to vandalism. These were the leading causes of signal failures, followed by 14.4% line faults, 12.2% relay or signal devices, 9% undetermined. The remaining were miscellaneous in nature.

Section 236.21 regarding signal location to the right of the track which it governs should be deleted. AAR noted that of 900 applications for relief, 896 were approved and only four were denied. The paper work and delay is costing more than the rule is worth.

Mr. Liggett cited Part 235, requiring application for signal systems installations, modifications, upgrading, or removal as unnecessary. He stated that only the removal of a signal system should require approval of regulations.

Sections 236.314 and 236.410 were also used to illustrate regulations which unnecessarily hinder operating railroads. Switch locks are costly to install/maintain and do not add to safety since they are not required in ABS or older installations. Radio communications have added considerably to the safety of operations. The AAR, and likewise all member railroads, feel that the railroads need the flexibility from regulation to adapt to the operational and expecially economic needs of the properties. In answer to questions by the panel the AAR stated the following:

a) The cost for delayed applications for signal removal includes the continued maintenance and operating costs as well as the clerical help required for processing at $64.00 per day. It was also noted that a signal maintainer costs between $75/$80 per eight hour unit.

b) In non-signaled territory, a train sheet is used for recording out-of-station time. Mr. Ditmeyer questions the practicality of the Graphic Train Sheet used in Europe and Africa. Would it add to safety?

c) In questioning on man-caused failures, FRA statistics indicate in 1971 8% of false proceed failures were man-caused while the percentage was 25% in 1978. Can the rise be stopped or even decreased? AAR responded that training will help, further stating that many experienced rail people are reaching retirement age and new and less experienced signalmen are having to replace them.

d) In answer to defining <u>downgrading</u>; downgrade was expressed as the removal or lowering of a signal system to the next lower performance level.

e) Many of the questions posed dealt with trying to define levels of safety and effects on safety.

f) The AAR Panel was asked to rate the technology in Signal/Control Systems to other railroad systems. The response indicated signal system technology is advancing, and more solid state components and systems are being utilized. The harsh environment is still the paramount design consideration. A signal control system using relay logic is not economically practical at today's system cost.

3. THE CHESSIE SYSTEM

M. Giftus - Attorney

G. A. Costello - Attorney

J. M. Beavers - Program Coordinator Signals & Communications

B. C. Morris - Signal & Comm. Engineer

Mr. Giftus presented a summary statement of a written report in response to the hearing questions. He stated that since resources are not unlimited, safety improvements should be carried out on a priority basis in response to needs. He specifically cited the testing of relays (every two years) and wire insulation (every year) as archaic and wasteful since both have established proven failure rates many times less then the testing requirements.

Mr. Giftus also stressed the adoption of performance standards rather than the current design-maintenance standards now comprising the RS&I/ICC Orders.

He pointed out that Paragraph 236.24 dealing with the spacing of wayside signals included spacing in accordance with braking distances - which is a goal not a specification. He further indicated that railroads must have the right to arrange signal spacing in accordance with their operational needs without approval. He also stated that vandalism is a social problem and cannot be eliminated or reduced by regulations.

Mr. Costello provided statistics on the cost of signal systems. It was noted that the Chessis System budgets are approximately $15 million per year for signal maintenance including material and labor. Mr. Costello also noted that signal system repair is completed as rapidly as possible since train delays cost between $750 and $800 per train hour.

The panel asked Chessie if they could define levels of performance standards. They also asked what standards Chessie followed to operate their Canadian Lines. The response was to the RS&I which was in accordance with Canadian regulations.

4. National Railroad Passenger Corporation - AMTRAK

J. C. McNabb	Asst. Chf. Engineer - Comm. & Signals
James A. Early	Asst. Chf. Engineer C&S ET
Fredrick C. Olie	Asst. Gen. Counsel

Amtrak is primarily concerned with the Northeast Corridor (NEC) since most of their properties lie in this area, but are concerned with other rail properties since they operate over them too.

Mr. McNabb cited Section 236.204 concerning track signaled for bidirectional running as an example of regulations that could better serve the rail industry as a performance specification. Mr. McNabb felt that performance specifications coupled with sensible maintenance requirements would allow development of signal systems that would provide:

a) Lower Capital Costs

b) More Reliability

c) Smaller Size

d) Lower Maintenance Costs

e) Improved Train Operation

f) Optimum Compatibility with Computers

Amtrak felt the existing regulations are sufficient for safe operations and should be revised to provide performance and maintenance standards, but not increased in scope - just more flexibility to the railroads at the same level of regulation.

In the question-and-answer sessions following the presentation, Mr. McNabb stated that to eliminate the "stop and proceed" indication from the

NEC would cost the railroad $4 billion. Amtrak reiterated the need for system level performance specifications that provided each railroad more operational flexibility. For example, since route locking regulations are based on relay logic, why not computer logic?

When queried on which regulations needed clarification, Mr. McNabb stated, "Those that do not let each railroad select the systems they will use and where they use them"; citing both additions and deletions. As an example, he quoted a low density line (one train per day each way) from Rensselear to Post, N.Y., that application for deletion of the current signal system has been denied.

Cost savings can be accomplished by reduction of relay and cable testing. It was felt that the requirement for cab signals above 80 MPH was an operational limitation imposed by the RS&I. Many cab signals are being removed, which is a detriment to passenger train operations.

5. Railway Progress Institute (RPI)

Paul Wheeler	VP, Safetran
Hugh Kendall	General Railway Signal Co.

Mr. Wheeler addressed issues #18 through #21 dealing with solid state devices or systems, stating that the RS&I does not currently provide performance specifications, and they are not needed. Performance specifications would inhibit the orderly development of solid state equipment. RPI feels that solid state equipment must be innovative and evolutionary not revolutionary. The Institute feels the current system best demonstrates the "fail safe" principle of failing in a safe mode. He stated that no system is fail proof, but how it fails is important.

When queried about European systems that are not based on relay logic he replied that all systems for export are developed to AAR specifications and utilize relays.

When asked about the RS&I and which parts need change, it was noted that the members of RPI sell signal systems and they do not care if signals are on the right or left.

6. Southern Pacific (SP)

R. C. Nagel	Engineer, Signals
W. F. Adams	Attorney

Mr. Nagel stated that the railroads have done an excellent job in achieving safety and felt that less, rather than more, regulations should be imparted by the FRA. Mr. Nagel cited the improvements in signaling that SP has initiated since 1950. He was critical of the requirements of approval for system modifications, deletions or upgrading.

SP has a two year training program including 40 days of classroom instruction. Older employees are also given periodic refresher courses.

Mr. Nagel stated that SP had 15 "false proceed" indications in 1978 and classified the causes as follows:

5 - Environmental elements

3 - False reports

1 - Vandalism

4 - Improper Hookup

2 - Improper Maintenance

Mr. Nagel went into detail citing several instances where he felt the FRA inspector was too strict in interpretation of the RS&I or had lost sight of the prupose or language of the RS&I.

A copy of SP's presentation and comments are available.

7. St. Louis - San Francisco Railway Co. (Frisco)

Jack Downs	Signal Superintendent
Thomas H. Smothers	Attorney

Mr. Downs made eight specific points in his presentation:

a. Those involved in the interpretation of rules and regulations should consider the operating rules of each railroad in evaluating safety compliance with RS&I.

b. Applications and approvals for signal upgrading should not be required.

c. The FRA reaction time is much too long: 4½ to 7 months for the processing of any request.

d. Sections 236.314 and .410 require electric locks which are not necessary for safety and are unduly expensive. In three recent signal projects electric locks represented 20%, 13%, and 24% respectively of total installation costs.

e. Modification of signal systems should not require FRA approval. The requirement is justified by the railroad or it would not be considered.

f. FRA cannot always justify reasons cited for deletion or addition of signal systems.

g. Training of signal employees is provided and should remain under the control of the railroad. Frisco has a $100,000 training facility and has spent $200,000 on training. They have 73 signal maintainers in training. They basically use Canadian National's training programs.

h. The term "undue delay" is prohibitive as interpreted by FRA. The "hours of service" laws often prohibit immediate repair.

During the question period, Mr. Downs proposed that requests for discontinuance of a signal system be required only if they exceed 100 miles in length or when they exceed a specified number of signals.

8. Southern

Walter W. Simpson	VP, Engineering
J. T. Hudson	Asst. V.P. - Comm. & Signals
F. H. McIntyer	Gen. Supt. - Oper. Comm. & Signals
W. P. Stallsmith, Jr.	Senior Gen. Attorney

Southern supported AAR's position and proposed changes to the RS&I. In speaking for Southern, Mr. Simpson felt that regulations should be based on risk analysis, involving economics as well as regulatory controls.

He felt that the term "undue delay" as interpreted by FRA is too stringent and often requires extra employees to conform. In regards to regulations for solid state equipment (issue #19), Southern felt that industry and equipment manufacturers did an adequate job of assuring safety of operation. They did not want to see regulations established for automatic train control at all. Southern has been operated successfully and safely without regulation.

During response to questions posed by the panel, Mr. Simpson stated there are too few advances in signal technology, but that the current RS&I did not necessarily deter these advances. Speaking on a major cause of signal failure, he also felt that insulated rail joints are a major item but added regulations would not help, since Southern could not find a suitable insulator in the industry. They are successfully making their own.

Train speeds do not bother Southern since they operate all their freight trains below 60 MPH.

Mr. Simpson noted that he felt the current RS&I is adequate for safety regulations, but added that when developed (ICC-29543), they did not take into consideration operating factors such as rail type, rail condition, and geographical limitations.

When asked about their quality control organization, Mr. Simpson stated that it has not been included in the signal section in the past, but is being integrated into the section now. The organization has proven effective in other areas.

9. Burlington Northern

Walter J. Johnson	VP, Operations
George W. Thompson	Chief Engineer, Signal & Comm.
M. Shultz	Director, Signal Engineering

Mr. Johnson stressed the increase of signal failures caused by vandalism, especially signal lights. He would like to see all lenses replaced with high impact lenses. He stated that searchlight signals are expecailly susceptible to vandals because broken lenses jam the mechanism. Other needed improvements include good vegetation control and replacing pole lines with underground cabling. BN has had formal training since 1972, and feels qualifications of signal repairmen is sufficient without regulations. Specific points directed at the RS&I include:

a) Interlocking, testing (236.378), indication locking (236.380), and traffic locking (286.381) testing requirements are unnecessary and do not add anything to safety of operation since signaling will indicate the proper signal if a switch is open.

b) The requirements for electric locks in Section 236.314 and .410 should not be required. The requirements of 236.301 are sufficient for safe operation.

c) Requests for discontinuance or material retirement (under Part 235) are not being approved in a timely manner. An application has been in for 186 days and not approved - yet trains still must operate.

In response to the panel's question on a solution to vandalims, Mr. Johnson replied that what little the railroad could do was frustrated by local statutes. Of the vandals caught, very few convictions were made. He would like to see federal statutes established with strict prosecution of offenders.

10. National Transportation Safety Board (NTSB)

Harold Garner — Railroad Specialist, Accident Investigations

William Gossard — Plans and Programs

The NTSB have issued 34 recommendations for improved safety to the FRA and would like all items considered and accepted.

The Board in their statement addressed the first six issues, making the following significant points:

a. S/TC regulations should be useable, understandable, and be the result of safety analyses. They would like to see equipment for all main lines equipped with cab signaling plus ABS.

b. NTSB feel that the increasing accident rate reflects the ineffectiveness of the RS&I.

c. The FRA sould concern themselves with human factors as well as equipment failures.

d. Mr. Garner stated that many railroads deferred maintenance on signal systems to cut costs. He feels that this has a direct relationship to safety.

e. The request by many properties for downgrading of signal systems is strictly economic. NTSB would like to see a level established for downgrading without loss of safety.

f. The NTSB feel that present regulations are not optimum. There is a need to reduce head and rear end collisions. They would like to see new regulations extablished for better performance and design specifications and would include both current systems and new technology. The regulations should be simple, flexible, and be enforceable.

g. A positive training program with definite standards is necessary to stem the amount of man-caused failures.

8. Mr. Garner stated that some protection should be provided when switch points fail to close.

Mr. Garner was asked to rate the FRA's performance in enforcing safety. He provided the following statistical data on accidents due to signal failures:

Year	No. of Accidents	Fatalities	Injuries	Damage
1975	11	0	1	$300,000
1976	11	0	0	400,000
1977	12	0	2	100,000

The following statistics were provided on man-caused accidents.

1975	67	4	566	$8.5 Million
1976	83	4	88	5.9 Million

The NTSB want positive regulations with strong enforcement. They admit that 100% safety is not possible but should be a target goal. They feel that economics should not enter into consideration in formulating regulations.

11. Railway Labor Executive Association (Represented by the Brotherhood of Railroad Signalmen) (B of RS)

R. T. Bates	President, B of RS
John E. Hanson	Vice President B of RS
W. W. Lauer	Grand Lodge Representative
Lawrence Mann	Attorney

Mr. Bates presented a lengthy discussion citing the railroads with lack of proper maintenance, using defective equipment and lack of testing to RS&I requirements. He likewise cited the FRA with failure to properly enforce the regulations stating only 30 fines were imposed out of 7,000 viloations filed.

Mr. Bates stated that even though signal systems have increased each year, the number of signal maintainers has decreased 6% over the past 15 years.

In regard to Section 326.11 incorporating "undue delay" Mr. Bates felt that false restrictive as well as false proceed signals require immediate repair.

Recommendations were made that any revision to the RS&I be made by a unified panel with knowledgeable representative from RLEA, AAR, FRA and RPI, if they wish to participate. The B of RS also recommended standardizing signal aspects and their indications.

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