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Cab Signal Automatic Train Control Train Performance Recorder General Specification

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FYI
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NORTHEAST CORRIDOR IMPROVEMENT PROJECT
WASHINGTON, DC 20590

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FRA/RNC-80/4

Cab Signal □ Automatic Train Control □ Train Performance Recorder □ General Specification □

NORTHEAST CORRIDOR IMPROVEMENT PROJECT

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16. Abstract

This document defines the standards and general specifications for the cab signal/automatic train control/train performance recorder system to be installed on vehicles to be operated on the improved Northeast Corridor. The specification indicates the features, performance, and other basic requirements of the apparatus, so that a supplier can make use of his experience to prepare a detailed design which he considers most suitable in response to a request for proposal.

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PREFACE

This Cab Signal/Automatic Train Control/Train Performance Recorder General Specification is submitted as a continuing part of the DeLeuw, Cather/Parsons development of the Northeast Corridor Project of the Federal Railroad Administration. The specification has been developed to provide an overall guide for the procurement of new apparatus for use on vehicles using the Northeast Corridor.

Separate detailed modification specifications will be provided for each class of vehicle to be upgraded for use on the Northeast Corridor.

METRIC CONVERSION FACTORS

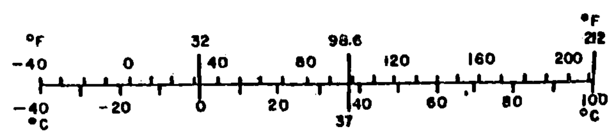
Approximate Conversions to Metric Measures

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

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

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



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1.0 GENERAL REQUIREMENTS

1.1 Scope

All locomotives and multiple-unit cars operating on the Northeast Corridor (NEC) shall be equipped with continuous coded speed-aspect cab signals, automatic train control (ATC) providing enforcement of speed-limits imposed by the signal system, and a multichannel train performance recorder (TPR) system. The speeds authorized by the railroad signal system, displayed by the cab signals, and enforced by the ATC apparatus, shall be as follows:

- Restricted speed (R) - proceed prepared to stop short of train, obstruction, or switch not properly lined; looking out for broken rail; and not exceeding 15 mph.
- 30 mph
- 45 mph
- 60 mph
- 80 mph
- Normal speed - the maximum authorized speed (not to exceed 120 mph).

Additional intermediate speeds may be added in the future to provide for civil restrictions and an additional speed may be added to permit selected trains to operate at speeds exceeding 120 mph.

It is intended that the apparatus furnished for application to individual vehicles shall be provided by one supplier who shall be responsible for the design, manufacture, performance and warranty of the complete integrated cab signal/ATC/TPR system.

It is not the purpose of this specification to absolutely predetermine all details of a specific system design, but only to indicate the general features, performance, and other basic requirements concerning the apparatus, so that a supplier can make use of his experience to prepare a detailed design which he considers most suitable.

1.2 Spares

To provide for proper operation of the entire NEC signal and train control system, it is imperative that proper amounts and kinds of spare parts and modules be made available, especially during system test and introduction to revenue operation. It is envisioned that, during system test and introduction to revenue operation, spares of all types shall be available to ensure continuity of service. The cab signal/ATC/TPR system supplier shall recommend the spare parts and modules and the stocking levels required for the introductory operation and for the normal maintenance services to be expected after the introductory period.

1.3 Warranty

Warranty requirements will be specified in the basic supply contract for each agency procuring equipment.

2.0 GENERAL TECHNICAL REQUIREMENTS

2.1 Design Criteria

2.1.1 Systems Engineering

The cab signal/ATC/TPR apparatus shall be considered as an integral subsystem within the overall railroad signal system as described in the Northeast Corridor Improvement Project (NECIP) Signaling and Traffic Control System Standards, volumes I and II, latest revisions.

Elements to be considered in the system approach shall include but not be limited to the following as applied to the cab signal/ATC/TPR system in itself and to the interface requirements with the overall vehicle-signaling system:

- Maintenance effort and periodicity
- Vehicle-operator interface
- Wayside signal equipment function
- Functional safety.

This system engineering effort shall require a continuing active engineering relationship on the part of the contractor with suppliers of other system elements and with the railroad operating agency.

2.1.2 Compatibility

The cab signal/ATC/TPR apparatus supplied under this specification shall be fully compatible with existing and planned wayside power and signal equipment and with the control systems of vehicles now using the NEC.

Where cab signal apparatus being supplied under this contract is similar in function and manufacture to existing apparatus, it shall be directly interchangeable. In addition, this existing apparatus shall be used to the maximum extent possible in the construction of the system being supplied under this contract, and shall be subjected to normal overhaul, if necessary, as part of this contract.

Joint contractor-customer determination of existing apparatus items and quantities to be reused and the equipment's condition and the extent of overhaul required shall be made before the award of the contract.

Specific wayside conditions and parameters with which apparatus to be supplied under this contract shall be compatible include, but are not limited to:

- Traction power return current in the rails of 25 kV, 60 Hz; 12.5 kV, 60 Hz; and 11 kV, 25 Hz, at a maximum normal (non-short-circuit) current of 2400 amperes measured at 11 kV, 25 Hz and a maximum normal (non-failure-condition) unbalance of 10 percent.

- The system shall function with both 91.66 Hz and 100 Hz F1 carrier frequencies as detailed in section 2.2.

- Avoidance of inadvertent operation from mixing of 60 Hz traction power and 200 Hz coded carrier used in certain interlockings.

- The code rates at the two carrier frequencies shall correspond to speed limits as follows:

Code Rates (ppm)		Speed Limit (mph)
F1 Carrier	F2 Carrier	
No current (-)	No current(-)	15 (Restricted)
0	-	15 (Restricted)
75	-	30
120	-	45
75	75	60
120	120	80
180	-	Maximum authorized speed up to 120 - Normal

The design shall not preclude the future addition of F1 50 ppm code operation. Provisions shall be made for future addition of F2 180 ppm code (super-speed) operation.

2.1.3 Train Safety

Train safety shall be the prime consideration in the design of the cab signal/ATC/TPR system and in the selection of its components, including insulated wire, wire terminals, binding posts, housings, conduits, resistors, capacitors, transformers, inductors, and other similar items, as well as devices with moving parts.

The entire system shall meet the requirements of section 2.1.3.1 or the system shall consist of subsystems, each of which shall meet the requirements of either section 2.1.3.1 or 2.1.3.2, assembled in a manner meeting the requirements of section 2.1.3.1.

In this section, the terms "restrictive" and "permissive" are used in connection with the binary outputs of two-position components or subsystems and denote such alternatives as: stop and proceed, a lower speed and a higher speed, deceleration and acceleration, brakes applied and brakes released, actuation of alarm and no actuation of alarm, and similar situations.

2.1.3.1 Important considerations in the design of those portions of the system or a subsystem affecting train safety are listed below:

- Only components that have high reliability and predictable failure modes and that have been proven in conditions similar to the projected service are to be utilized.

- Components must be combined in a manner that ensures that a restrictive rather than a permissive condition will result from a component failing.

- All circuits not wholly within the cab signal/ATC apparatus enclosure shall be double wire, double break.

- Circuits shall be based on closed-loop principles; i.e., broken wires, dirty contacts, a relay failing to respond when energized, or a loss of power supply energy shall not result in unsafe conditions.

- Component or system failures shall cause the train to stop or run at a more restrictive speed than that permitted with no failure.

- System safety equipment design must be such that any single independent component or subsystem failure results in a safe condition. Failures that are not independent (those failures which in turn always cause others) must be considered in combination as a single failure and must not cause an unsafe condition.

- Any component or wire becoming grounded shall not cause an unsafe condition. Safety circuits shall be kept free of any combination of grounds that will permit a flow of current equal to or in excess of 75 percent of the release value of any safety device in the circuit.

- Electronic circuit design shall have as an objective that the following types of component failures shall have a restrictive rather than a permissive effect.

  1. Two-terminal devices: open, short, partial open, or partial short.

  2. Multiterminal devices: combination of opens, shorts, partial opens, and/or partial shorts.

- All requirements, specifications, standards, principles and practices of the AAR Communications and Signals section, as of the date of contract award, shall be met.

- Wherever possible, built-in checks shall be included that impose a restriction and/or actuate an alarm whenever a device fails to assume its restrictive position when conditions require that it should.

2.1.3.2 As an alternate, certain portions of the system affecting train safety shall:

- Include not less than two entirely independent, parallel channels to perform each function and require a permissive decision from both channels (if only two are provided) or a permissive decision from a majority (if more than two are provided) before a permissive decision can be obtained from the combination. The arrangement for comparing channel decisions shall meet the requirements of section 2.1.3.1. The design of the channels shall ensure that an event modifying one channel such that it is no longer capable of withholding the permissive decision under all system states in which permission is not safe will not cause any other channel to be modified in a way that would permit the other channel to reach an unsafe permissive decision. When such an event occurs, it must be detected and alarmed immediately. If, subsequent to such an event, there remains only one properly functioning channel, the combination must be prevented from providing a permissive output under any condition.

  Should an alternative for a relay specified for vital circuits, as defined by the AAR manual part 55, be proposed for use that is an independent direct item replacement for the relay specified, the alternative will be subject to customer approval evaluated on the basis of its physical materials and construction, electrical characteristics, circuit analysis, and reliability.

Should an alternative be proposed for a specified system, or components thereof, whose function affects the safety of train operation and because of its magnitude and integration parameters precludes absolute fail-safe engineering analysis, the customer will require definitive factory and field tests and documentation of research and development tests, prior to granting approval of the alternative. Fail-safe equipment proposed must be proven by in-service experience or made available for type acceptance testing.

2.1.3.3 Verification of Failed Cab Signals

A means shall be provided for an engineman to ascertain whether or not cab signal energy is being received on board the vehicle so that he can determine whether a restricted cab signal aspect is the result of cab signal failure or is a speed command resulting from uncoded track circuit energy or from no track circuit energy being received.

2.1.3.4 Safety Analysis

The contractor shall analyze the entire cab signal/ ATC system, its subsystems, and components in a systematic manner to determine the possible failure modes and their effect on safety.

This analysis shall cover at least the following levels of concern:

- Theoretical circuit behavior
- Hardware design
- Random component failures
- Electrical interference
- Systematic component failures
- Software errors
- User-dependent hazards.

The analysis shall be recorded in a single document that shall describe in detail the procedures used and the results. This document shall be controlled and updated throughout the period of performance of this contract and shall be available for reference if required by the customer or his agents. The analysis shall conform to the requirements of section 8.2.2 of this specification.

2.1.4 Modular Design

Modular design shall be incorporated to the maximum practical extent. Components or subassemblies with discrete function shall be plug-in modules and shall be labeled for ready identification. Plug connectors shall be of rugged design suitable for the safety-related circuits involved. Positive retention of plug-in modules shall be provided.

Functionally interchangeable modules shall be physically interchangeable and those that are not functionally interchangeable shall be provided with positive means to prevent physical interchangeability.

The design shall be such that failure to install a module shall cause more-restrictive-than-normal system operation.

2.1.5 Interface Requirements

The contractor shall be responsible for defining the interface parameters for the installation of the specified apparatus in existing cars and locomotives. He shall work directly with the car or locomotive builder to develop these parameters in the case of new vehicles. In either case, the interface parameters shall be submitted to the customer for approval. This approval must be obtained before commitment to manufacture.

The areas of concern relative to interface design include, but are not limited to:

- Vehicle structure
- Engineman control areas
- Propulsion control
- Braking equipment and compressed-air supply
- Low-voltage power supply
- Electromagnetic Interference (EMI)

Wiring interface presents a specific area of concern. All indication and control functions that require wire or cable runs to locations remote from the cab signal/ATC apparatus enclosure shall be of the double-break type, and this wiring shall be provided with adequate physical protection such as rigid conduit or armored flexible conduit where applicable. The design of the TPR shall be such that remote wire or cable runs shall not directly affect train safety circuits.

2.1.6 Environmental Factors

All elements of the combined cab signal/ATC/TPR system shall be designed for normal, safe operation at the most severe specified ambient conditions assuming maximum power supply tolerances.

The design ambient conditions shall be as follows:

- Ambient temperature — -40°C to +70°C
- Relative humidity — 20 to 100 percent noncondensing
- Shock and vibration
  (typical values, not necessarily worst case)

  Body-mounted equipment
  0.2 g up to 100 Hz, vibration.
  2.5 g random shock loads.

  Truck-frame-mounted equipment
  8 g up to 100 Hz, vibration.
  16 g vertical and 12 g horizontal shock loads.

  Axle-mounted equipment
  20 g up to 100 Hz, vibration.
  50 g random shock loads.

  Shock and vibration requirements depend on the type of truck and spring system and railway conditions. It is required that the cab signal/ATC/TPR system supplier work closely with the truck and carbody supplier to jointly determine the most severe shock and vibration values so that apparatus suitable for the service intended will be provided.

- Contaminants - The equipment shall operate as specified in the atmosphere commonly found in locomotive and car control-mounting areas. The most common contaminants are silica, iron, carbon, oil vapor, water vapor, ozone, copper, nitrous oxide, hydrogen sulfide, and cleaning solutions.

Underfloor-mounted equipment enclosures shall be watertight when subjected to hose cleaning and driving rain. The enclosure shall contain drain holes fitted with cotter keys or other simple drain mechanisms for condensation and leakage due to damaged seals.

2.1.7 Reliability

The reliability of the specified equipment shall be given a priority during design exceeded only by safety considerations.

This equipment shall be designed to have the following minimum mean system operating time between failure:

- Cab signal/ATC subsystem 15,000 hours per vehicle (12 operating hours per day)
- Train performance recorder subsystem 15,000 hours per vehicle (12 operating hours per day)

A system failure is defined as any independent malfunction, occurrence or failure that prevents or causes disruption of system operation. The failure of a function that may be bypassed thereby reducing the system performance level is a chargeable system failure. However, the failure of a function that has a redundant path with the capability of maintaining proper system operation is not a chargeable system failure provided the switchover can be performed automatically or manually from an accessible panel.

2.1.7.1 Reliability Design

Reliability design shall be a continuing activity throughout the design, manufacture, and test phases of equipment production. It shall be an integrated effort with other design engineering disciplines.

2.1.7.2 Reliability Verification

If it can be shown in a manner approved by the customer that equipment identical to that being supplied under this specification has been operated successfully in a similar environment, no further reliability verification program need be undertaken. Successful operation is defined as the accumulation of 25×10^6 vehicle miles on a fleet of at least 50 vehicles while having a mean time between failures equal to or greater than that specified in this section. The supplier shall provide verifiable data to substantiate mean time between failures, including definitions of failure.

If the equipment experience requirements cannot be met, a reliability verification program shall be performed by the contractor at no additional cost to the customer. This program shall be performed during a period of two years of actual revenue service and shall demonstrate compliance with the minimum mean-system-operating-time-between-failure requirements stated above. This demonstration shall commence at a date to be determined by agreement between the customer and the contractor but not later than one year after the delivery, installation, and acceptance by the customer of the first production vehicle set of equipment.

If necessary, the demonstration fleet may be made up of different vehicle types fitted with essentially identical equipment as approved by the customer. Program data shall then be weighted according to the minor vehicle equipment differences and different annual service mileage.

The contractor shall, within 90 days after award of contract, submit for approval a preliminary program plan and tentative schedule for this verification program if it is required. The plan shall include as a minimum, provisions for the following:

- A 200-hour-per-system burn-in period prior to initiation of the formal demonstration testing.
- Parametric accept-reject and risk criteria in general conformance with MIL STD 781C.
- Conducting the test such that all accept or reject decisions are based on actual operational experience, or performance under conditions like those under which the system will be required to operate throughout its lifetime.
- The operating environment such that it is representative of anticipated operational conditions including traffic, humidity, temperature, operating modes, maintenance, and EMI.
- A method for weighting of data for variations in the individual vehicles in the demonstration test.
- Test records of all performance. which shall be maintained for the test period, and contain, as a minimum, the following information for each failure or malfunction:

1. Identification of the equipment, including nomenclature, serial number, manufacturer's part number, and location

2. Operating time of each failure or malfunction including each shutdown and its cause

3. Date and time of each failure or malfunction

4. Failure indication, mode, cause and effect

5. Identification of the failed hardware

6. Classification of the failure or malfunction (relevant system failure or acceptable malfunction or failure)

7. Corrective maintenance or operational procedures required to restore the system to operation

8. Time to restore the system to operation and active repair time including man-hours

- Delineation of all contractor-furnished equipment required to monitor system performance throughout the test.

- Identification, as required, of all customer furnished special facilities, procedures, and personnel required to support the verification test.

- Inclusion of specific test and/or monitoring of all reliability and maintainability (R&M) significant items and critical failure modes as identified in the failure mode and effects analysis (FMEA).

- A failure review board consisting of one representative of the contractor and one of the customer. This board shall review all test data to verify the classification of failures, assign responsibility, and monitor corrective action.

- Delineation of the consequences of both accept and reject decisions. This delineation shall include documentation of all test data and, in the event of a rejection decision, a plan for analysis of the cause of the deficiency, preparation of recommendations for remedial action for customer approval, implementation of approved recommendations, and retesting.

- Demonstration test reports on a monthly basis and a final report when all testing is terminated.

Submit the final verification program plan, including detailed procedures, no later than 90 days prior to scheduled start of testing.

During the verification program, the vehicles and equipment involved will be maintained in the normal fashion by the operating agency in accordance with the approved maintenance concepts and manuals.

2.1.7.3 Reliability Program Requirements

The contractor shall provide the following, which are described in detail in section 8.2.1:

- List of tasks and submissions
- Significant-items list
- Reliability block diagrams
- Failure mode and effects analysis
- Reliability predictions.

2.1.8 Maintainability

Maintainability of the equipment supplied under this specification shall be given maximum design and manufacturing attention to the extent that safety and reliability are not adversely affected.

Exclusive of any required daily tests, neither the cab signal/ATC/TPR system nor any component or subsystem of it shall require scheduled periodic maintenance, test or inspection more frequently than once every 30 days. By design, the level of effort during these periodic procedures shall be minimized in accordance with FRA requirements.

Maintainability design criteria to be used in the design and construction of the specified apparatus shall include, but not be limited to:

- Simplification of maintenance functions.
- Reduction of the complexity and frequency of required tasks such as calibration, adjustment, and inspection.
- Reduction of skills and training required of maintenance personnel.

- Reduction of the number and complexity of tools and test apparatus required.
- Provision for maximum accessibility to those areas and components requiring the greatest maintenance, test, inspection, and replacement.
- Use of fasteners of standard industrial design chosen for maximum service life in the railroad environment. Captive fasteners shall be used for removable access panels, covers and doors. Locking arrangements shall conform to standard railroad practice.
- Designing for safety and protection of both maintenance personnel and equipment.
- Assurance of rapid positive identification of a defective replaceable part, component, or assembly through the use of comprehensive simple trouble-shooting and fault-isolating procedures. Built-in fault and function indicators and test points shall be provided where safety and reliability requirements permit.
- Identification of all test points, fault indicators, modules, wires, pipes, tubing, terminal points and connectors by nameplates, color coding, number coding or other means as approved by the customer.

2.1.8.1 Maintainability Program Requirements

The Contractor shall provide the following which are described in detail in section 8.2.1:

- List of tasks and submissions
- Significant-items list
- Maintainability predictions.

2.1.9 Materials and Workmanship

2.1.9.1 Printed-Circuit-Board Standards

The printed circuit boards shall be of the glass-epoxy type with the components mounted on one side only. The conducting copper laminate shall generally be on the opposite side. The copper laminate shall be firmly attached to the board and shall not blister or peel when heated with a soldering iron.

Soldering of components to the board shall be by the wave solder method, and the entire surface of the copper laminate shall be tinned.

The component side of the board shall be printed with the component references and such other information as may be required. The conductor side of the board shall be marked to indicate capacitor polarity, at least two leads of all transistors, and diode anodes and cathodes.

Equipment shall be fastened to the board in a manner that will withstand repeated exposure to shock and vibration in accordance with the Vibration Stability and Shock Stability requirements of the appropriate Electronic Industries Association standard, or other approved recognized national standard.

Both sides of the assembled printed circuit board shall be coated with an insulating and protecting coating that can be removed easily with a brush-applied solvent where required.

Sufficient clearance shall be provided between components to allow testing, removal, and replacement without difficulty caused by lack of space.

Provisions shall be made on all plug-connected printed circuit boards for keying, which shall ensure that an unsafe condition does not result from improper insertion. These boards shall be provided with a means of positive retention in their connectors.

Printed circuit boards shall be numbered serially for positive identification of specific boards.

2.1.9.2 <u>Electrolytic Capacitors</u>

Hermetically sealed solid tantalum electrolytic capacitors shall be used in place of aluminum electrolytic capacitors. If the required capacitance and voltage rating are beyond the values available in standard tantalum capacitors, computer or higher grade aluminum electrolytic capacitors may be used if approved. In either case, the capacitors must be derated in current, voltage, and temperature to provide a projected life of at least 15 years for at least 95 percent of the population for each operating location. The derating factors must be calculated and presented for approval during the initial design phase.

Four-terminal capacitors shall be used where necessary to conform to the requirements of section 2.1.3.

2.1.9.3 Semiconductor Standards

All electrical and electronic circuitry shall meet the following minimum criteria with regard to the use of semiconductors:

- Discrete semiconductors shall have the following minimum voltage breakdown rating, depending on the use:

  1. Transistors and thyristors operated from the nominal battery supply, and those connected to trainlines, shall have minimum breakdown ratings of four times the maximum circuit voltage for the period of time necessary for suppression devices provided to operate.

  2. Diodes operated from the nominal battery supply, used as suppression devices, and those connected to trainlines, shall have a minimum breakdown rating (PIV) of 1000 volts.

  3. All discrete semiconductors operated from inverters or other isolating devices shall have minimum breakdown ratings of 2 times the maximum circuit voltage for the period of time necessary for suppression devices provided to operate.

- All semiconductors shall be operated at less than 70 percent of the maximum continuous current rating or 70 percent of the maximum continuous power rating, with the more restrictive rating being the controlling value.

- Integrated circuits shall be operated from the nominal battery supply through inverters or other isolating devices and shall be operated within the voltage and current ratings specified by the manufacturer except that the output current shall be derated to less than 80 percent of the maximum stress level at the maximum operating temperature of the device.

- All magnet valves and relay-contactor coils shall have free-wheeling diode or metal oxide varistor transient suppression, except where this will result in deterioration of performance. The methods used for transient suppression in the latter category shall have special approval prior to use.

- All semiconductors shall be hermetically sealed and rated for operation over the temperature range of -40° C to +70° C.

- All thyristors, transistors, and diodes must be Joint Electronic Device Engineering Council (JEDEC) registered and numbered, and must be available from at least two different U.S. suppliers.

- All integrated circuits must be standard devices available from at least two different U.S. suppliers.

- Temperature cycling and burn-in shall be used to environmentally screen all semiconductors for defects. As a minimum, all semiconductors shall be subjected to 10 temperature cycles from -40° C to +70° C and 96 hours of burn-in at +70° C. Integrated circuit burn-in shall be 168 hours at +125° C. The environmental screening methods shall be submitted for approval.

2.1.9.4 Wire and Wiring Devices

- A minimum number of wire types and sizes shall be used in wiring the equipment. All wiring, unless specifically excepted, shall be insulated for 600 volts minimum. Insulation material shall be cross-linked polyolefin or other thermosetting materials as approved by the customer with properties and characteristics as specified in Insulated Power Cable Engineers Association (IPCEA) publication S-66-524, table 3-1, latest revision, as regards stranding, sizes, voltage rating, and insulation thickness. Wire amperage capacities shall conform to table 310-16 of the National Electric Code with a temperature rating of 90° C for one to three conductors. Where more than three conductors are routed in a raceway or cable, the amperage capacities shall be derated as detailed by Article 310, Note 8 of the National Electric Code. All wire shall be stranded, tinned copper and shall conform to American Society for Testing Materials (ASTM) B33-74. All wire shall be U.S. No. 12, except that smaller wire, where adequate and subject to approval, may be permitted for wiring within control cabinets and electronic units as noted below. In all cases, wire must have adequate current-carrying capacity.

- Inside the control cabinets, wire sizes down to U.S. No. 20 may be used, but shall not be included in bundles with larger wires.

- Wiring, or its equivalent, within replaceable modular units of electronic apparatus shall comply with the applicable requirements of the Association of American Railroads (AAR) Signal Section Manual, latest revision, or other approved railway standard. Inside electronic chassis, wire sizes down to U.S. No. 22 may be used if mounted on panels or used in bundles and adequately supported. If solderless wire wrap is used, the terminals must be physically separated by an insulating separator to prevent shorting from conductor to pin and pin to pin. The terminals must be gold plated and assembled using the modified wrap method consisting of two turns of the insulated conductor plus the manufacturer's recommended number of turns of skinned conductor. Wire-wrap techniques shall be allowed only with specific approval of customer.

- Multiconductor cables, where approved, shall be type S.O. for U.S. No. 16 through No. 10 AWG and shall comply with AAR specification No. 560, except that braided jackets may be used for increased flexibility. When braid is used, it must be stripped back at least 2 inches at any termination to prevent electrical leakage due to hygroscopic properties of braided construction.

- All cable connectors for cable runs leaving the equipment enclosures shall be of the environmental watertight variety with removable crimp-terminated contacts of the appropriate size for the wire being used. Cable connectors shall be equipped with sealing gaskets on the front so that the connector interface is sealed and on the back where the cable enters. Extension bodies shall be used if necessary to ensure that there is sufficient room to terminate the cable wires within the connector body and have the cable jacket extend within the body, be held by the clamp, and have the gasket seal the entrance. Unused connector pin positions shall be sealed with either connector contacts or plastic sealing plugs designed for that purpose. Adjacent connectors shall use either different inserts or different insert orientations to prevent erroneous connections. Connectors inside equipment enclosures shall conform to these requirements except that those requirements relating to weather sealing need not be followed.

- Pin-to-pin and pin-to-shell breakdown voltage shall not be less than 3000 volts.

- Cable connectors shall conform to MIL-5015 or an equivalent standard. Equipment box connectors shall be environment-resistant MS series F or R types with rubber inserts. Cable connectors shall be the series F or R types with a cable clamp and sealing gaskets.

- Test connectors for diagnostic test equipment or for other test-monitoring equipment shall be of watertight, bayonet-lock, quick-disconnect type.

- Terminals and connections used in wiring between major components shall be of the mechanical solderless type for which a comprehensive line of tools is available. Terminals shall be attached to the wiring with the proper crimping tools and dies. Where possible, the terminal used shall be of the type that securely grips and holds the insulation of No. 10 wire or smaller. Conductors that will be subject to motion relative to the terminal shall be protected by suitable means to prevent breakage of the conductor at or near the terminal.

- Generally, all electrical terminal points and terminal boards shall have plated brass studs, and connections shall be locked using plated double nuts, single nut with brass flat washer, and plated spring-type lockwasher, barrel nuts, or approved elastic stop nuts in accordance with the AAR <u>Signal Manual</u>.

- Fast-on terminations shall not be permitted.

2.1.9.5 Wiring

All wiring shall be performed by or under the direction of experienced wiring technicians using appropriate tools for skinning insulation, cutting, soldering, and attaching mechanical crimp terminals with the correct dies.

Care must be taken in removing insulation from the conductor to avoid nicking of wire strands. Wire with nicked strands shall not be used in the specified equipment. Proper stripping tools shall be used to avoid such damage.

Nicked or broken wire strands at crimp terminations or wire strands not fully inserted in or crimped in these terminations are not acceptable.

Wire dress shall allow sufficient slack for additional reterminations, without excess tension, for wire sizes as follows:

- No. 16 and smaller - 5
- No. 14 and No. 12 - 4
- No. 10 to No. 2, inclusive - 3
- No. 2 and larger - 2.

Wire splices shall not be permitted, except with written approval.

Wire and cable ties shall be snug but shall not be so tight as to cause indentation and cold flow damage to the insulation.

2.1.9.6 Wiring Arrangement

The layout of wiring shall be designed to minimize mechanical interference and to facilitate maintenance.

As much as practicable, all wiring shall be fabricated on the bench into convenient units and installed in prefabricated groupings and standardized locations.

All circuits and branches must be separable by means of terminal boards to isolate portions when troubleshooting. All circuits subject to high-potential test shall be so arranged that they can be conveniently set up for the tests.

All wire bundles and cables within enclosure shall be supported by use of insulated tape rails and shall be free from equipment-box structure, metal edges, bolt heads, and other interference points, and shall have sufficient clearance from covers regardless of insulation properties of the covers.

Wire bundles should be located above or alongside the apparatus rather than at the bottom of the box. In all cases, wire shall be a minimum of 1 inch above the bottom of the box. Wire entry into control or junction boxes shall not be permitted through the bottom of control boxes.

Wiring needed for calibration and testing functions shall become a part of the permanent wiring to enable the user to maintain the equipment. This wiring shall terminate in connectors in appropriate cabinets.

2.1.9.7 Marking

All wires and terminals studs shall be plainly and suitably identified with permanent markers so that circuit may be easily identified. The wire designations used to identify wires shall be part of a uniform and coordinated wire identification system. The wire designation system should be one that in a practical and logical sense relates the wire designation to the subsystem served and that logically alters the designation as the wire passes through the components it serves or by which it is served. Every individual wire run shall be distinctly identified. Wires attached to terminal studs shall also have markers indicating the terminal studs to which they are attached. For No. 16 and smaller wires included in multiconductor cables where individual wire marking is impractical, color coding of each wire is satisfactory; the cable itself shall be separately identified and marked. The coordinated wire and terminal designation system shall be submitted for approval.

There shall be no common designation for return circuits incorporated in the control circuits.

2.1.9.8 Specialties

Solder shall be at least equal in quality to that designated as grade 60B in ASTM B-32. A noncorrosive flux shall be used, applied immediately before soldering.

Electrical tape shall be polyvinyl chloride as specified in section 10, Chapter 2, part 1 of the AAR Electrical Manual of Standards and Recommended Practices, or equivalent railway practices.

2.1.10 Packaging and Mounting

2.1.10.1 Underfloor Apparatus Enclosures

Underfloor-mounted apparatus enclosures shall be made of steel or other approved construction best suited to meet functional requirements, and shall be protected inside and outside from corrosion by an appropriate paint system or other approved coating. These enclosures shall be sufficiently rugged to protect the enclosed apparatus from normally encountered undercar hazards in the railroad environment.

These enclosures shall be sealed against dirt and water intrusion and shall have cotter keys or other simple drain devices mounted in drilled holes to allow condensation drainage. The covers shall be hinged at the top, removable, and provided with a means for locking by use of shackle locks.

Means shall be provided for the dissipation of heat generated by the apparatus or components enclosed.

Supports for underfloor apparatus enclosures shall be of Low Alloy High Tensile (LAHT) steel or approved equivalent. Where possible, supports for heavy apparatus shall rest on horizontal flanges of side, center, or body sills.

The use of vertically oriented bolts in tension for the support of underfloor apparatus shall be prohibited. Connections between dissimilar metals shall not be used without specific prior approval. If used, appropriate protection of the metals shall be provided. Apparatus supported on or by resilient mounts shall also be provided with safety hangers and suitable grounding connections.

No underfloor apparatus shall be supported by bolts in holes tapped in the floor structure or vehicle structure.

2.1.10.2 Vehicle Interior Apparatus Enclosures

Apparatus enclosures to be mounted in vehicle interiors shall be of sufficient strength to carry and protect the enclosed apparatus in this environment.

These enclosures shall not present to operating or maintenance personnel or, in appropriate vehicles, passengers, any mechanical, electrical or thermal hazard. Means for safely dissipating any heat generated by enclosed apparatus or components shall be provided.

Enclosure mounting shall provide protection against the loads to be encountered from shock and vibration as well as from personnel or passengers. They shall be capable of being removed from the vehicle without disassembly through existing doorways or hatches in the vehicle body. Where susceptible to spills of various liquids, the enclosures shall provide protection for the apparatus.

2.2 Performance

2.2.1 General Operating Requirements

The general operating and functional requirements for the cab signal/ATC/TPR system are as follows. Detailed subsystem descriptions are provided in sections 3, 4, and 5 of this specification:

2.2.1.1 The combined cab signal/ATC system shall provide for train operation under engineman control but with automatic enforcement of train protection speed limits imposed by the railroad signal system and continuously displayed by the cab signal.

2.2.1.2 There shall be a continuously controlled, constantly visible, speed-limit aspect cab signal display in the car or locomotive cab or cabs. This display shall show the speed-limit information transmitted through the rails in coded carrier form by the railroad signal system.

2.2.1.3 The engineman shall be required to acknowledge in a positive manner a reduction in speed-limit aspect. An audible warning shall sound until acknowledgement when this reduction occurs. Alarm shall sound within 1 second of any downward indication change.

2.2.1.4 An irretrievable full-stop penalty brake application shall be made if the engineman fails to acknowledge a reduction in speed limit aspect when a fixed time interval has elapsed.

2.2.1.5 Brakes shall be applied automatically and the power removed on passenger but not on freight trains if the engineman acknowledges a downward change in speed limit but fails to apply braking and the train speed exceeds the new speed limit, after a fixed time interval has elapsed (figure 2-1).

CAB SIGNAL WITH ATC AND PENALTY BRAKE

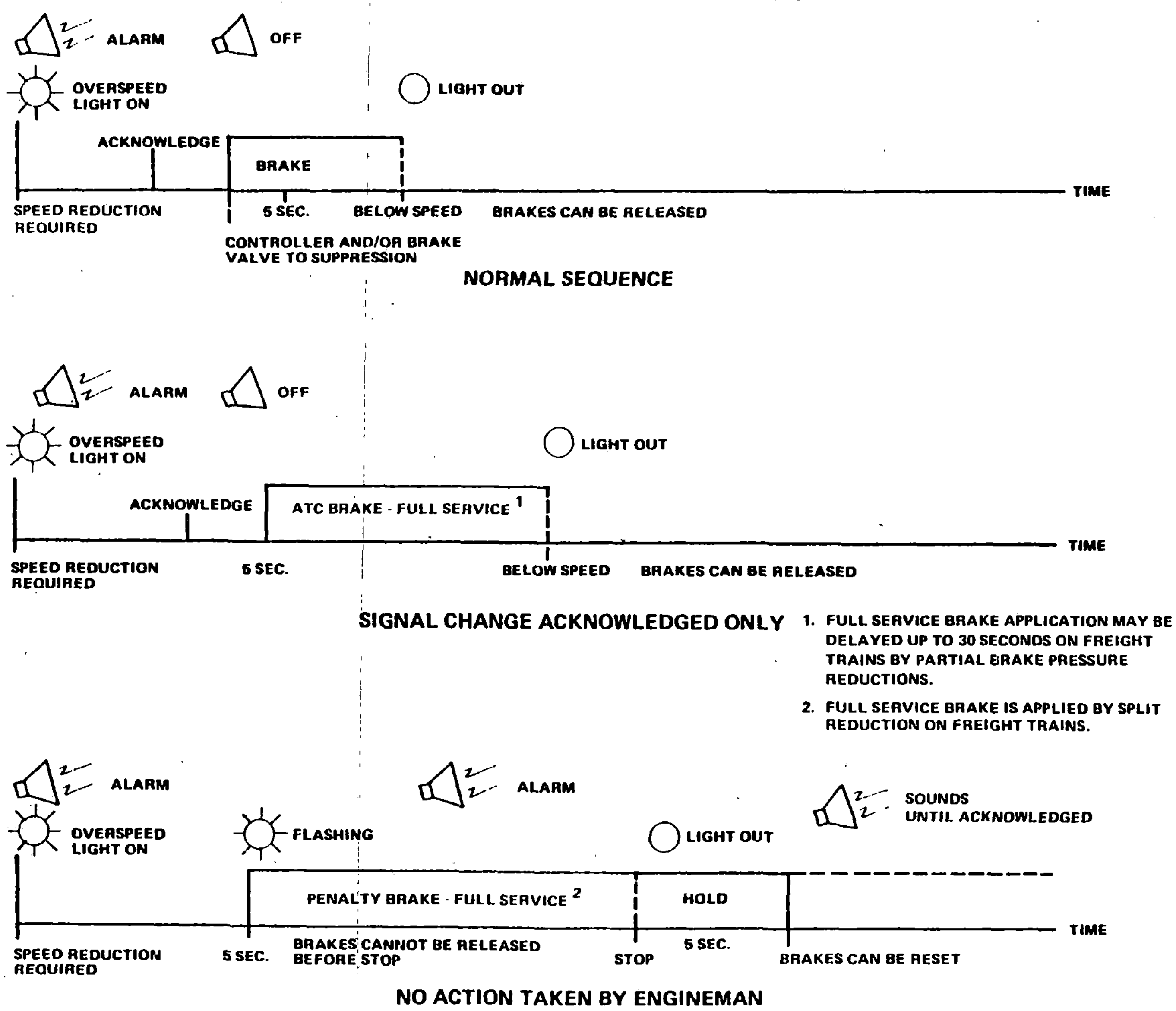

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FIGURE 2 - 1

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2.2.1.6 Release of automatically applied brakes (as in 2.2.1.5 above) shall be possible when train speed is reduced to or below the speed limit in force, provided the correct action has been taken by the engineman.

2.2.1.7 An indicator shall be lighted when the train exceeds the speed limit displayed by the cab signal. In addition, this light shall flash when a penalty brake application has been made by the ATC, extinguishing when the train has stopped.

2.2.1.8 A multichannel TPR shall be provided, that shall record important parameters of vehicle operation. It shall record whenever the cab signal circuits are activated.

2.2.1.9 In the event of malfunction of the ATC system, two levels of reduced system performance shall be available. First, it shall be possible to bypass the ATC function, permitting vehicle operation with cab signals and enforced acknowledgement but with no automatically enforced speed limit. Second, it shall be possible to bypass both the ATC function and the enforced acknowledgement, permitting operation with cab signals only (section 3.6.2).

2.2.2 Specific Operating Requirements for Various Vehicles

The operation of the system will vary for several categories of equipment. In general, the method of operation for passenger equipment will depend on the type of engineman's master controller and/or brake valve. Freight train operation will require special techniques as described in section 2.2.2.3. Figure 2-1 typifies the operation under various conditions.

2.2.2.1 Passenger Equipment with Single-Handle Master Controller

An audible warning shall be caused by a reduction in the speed limit displayed by the cab signal. The alarm shall sound within 1 second of the downward indication change. This warning must be acknowledged, at any train speed, by operating the acknowledging device within 5 seconds of its beginning to sound in order to forestall an automatic removal of power and application of full service braking. Once initiated, it shall be possible to release this brake application only after the train has stopped and the master controller handle has been moved to the full service brake position. The audible alarm shall continue to sound until the acknowledging device is operated.

If the train speed exceeds the speed limit displayed by the cab signal by more than 3 mph and the master controller handle has not been moved to the full-service brake (suppression) position within 5 seconds of the start of the overspeed condition, the ATC subsystem shall apply full-service braking. It shall be possible to release brakes and reapply power after the train speed has been reduced to 3 mph above the speed limit being displayed by the cab signal, provided the master controller handle has been moved to the full-service brake (suppression) position.

The overspeed indicator shall function as in 2.2.1.7 above.

As optional additional equipment, an internally generated speed envelope/braking profile approach to speed limit compliance may be required. See section 4.3 of this specification for system details and requirements.

2.2.2.2 Passenger Equipment with Separate Propulsion Control and Brake Valve

An audible warning shall be caused by a reduction in the speed limit displayed by the cab signal. The alarm shall sound within 1 second of the downward indication change. This warning must be acknowledged, at any train speed, by operating the acknowledging device within 5 seconds of its beginning to sound, in order to forestall an automatic removal of power and application of full-service braking. Once an unacknowledged application is initiated, it shall be possible to release this application only after the train has stopped, the brake valve has been placed in the suppression position, and the throttle has been moved to the OFF position.

The audible warning shall continue to sound until the acknowledging device is operated.

If the train speed exceeds the speed limit displayed by the cab signal by more than 3 mph and the brake valve has not been placed in the suppression position and the throttle has not been placed in the OFF position within 5 seconds of the start of the overspeed condition, the ATC subsystem shall apply full service braking. It shall be possible to release brakes and reapply power after the train speed has been reduced to 3 mph above the speed limit being displayed by the cab signal provided the brake valve has been placed in the suppression position and the throttle has been placed in the OFF position.

The overspeed indicator shall function as in 2.2.1.7.

As optional additional equipment, an internally generated speed envelope/ braking profile approach to speed limit compliance may be required. See section 4.3 of this specification for system details and requirements.

2.2.2.3 Freight Locomotives

Freight locomotives shall respond only to F1 carrier codes.

An audible warning shall be caused by a reduction in the speed limit displayed by the cab signal. The alarm shall sound within 1 second of the downward indication change. This warning must be acknowledged by operating the acknowledging device within 5 seconds of its beginning to sound in order to forestall an automatic sequence of brake application and power removal. Once this sequence is begun, it shall be possible to release brakes only after the train has stopped, the brake valve has been placed in the suppression position, and the throttle has been placed in the OFF position. The audible alarm shall sound until the acknowledging device is operated.

The automatic brake-application sequence shall consist of two stages (split reduction). The first stage shall consist of a 6 psi brake pipe reduction with propulsion power remaining under control of the engineman. The second stage, which shall begin 20 seconds after the beginning of the first stage, shall produce full-service braking. Power shall be removed when full-service brake reduction has been achieved at the locomotive equalizing reservoir.

If the train speed exceeds the speed limit displayed by the cab signal by more than 3 mph, an automatic brake-application sequence as described above shall occur unless the engineman begins and completes a suppression brake application sequence as described below.

The suppression brake-application sequence accomplished by the engineman includes a required initial minimum brake pipe reduction of at least 6 psi to be made within 5 seconds of the start of the overspeed condition followed by further incremental reductions until a reduction level (to be bench set by the customer) between 17 psi and 26 psi is achieved. The time permitted to achieve the reduction at the locomotive equalizing reservoir shall be 30 seconds from the beginning of recognition of the overspeed condition.

It shall be possible to release brakes and reapply power after train speed has been reduced to 3 mph above the speed limit being displayed by the cab signal, provided the suppression brake sequence has been completed within the required time period.

Alternate operation (freight locomotives): If the train speed exceeds the speed limit displayed by the cab signal indicator by more than 3 mph, the engineman shall be required to reduce the train speed with those means that best fulfill train-handling requirements, keeping within the limits of an internally generated speed envelope. The details of the speed envelope generation and its related control indications are described in section 4.3 of this specification. Failure to keep within the speed requirements of the speed envelope shall result in an automatic brake application and power removal sequence as described above.

2.2.2.4 Multipurpose Locomotives

Locomotives that may be used in either freight or passenger service shall be so configured as to be able to function as described in both 2.2.2.2 and 2.2.2.3 above.

2.2.3 Interference Rejection

2.2.3.1 Interference Sources and Effects

Electromagnetic Interference. Interference signals can be either electrically or electromagnetically coupled into the cab signal/ATC system through the low-voltage power supply, equipment elements, track receivers, and wiring among other mechanisms. This coupling can originate from wholly on-vehicle sources including propulsion control devices and traction motors; from in-rail noise due to propulsion return currents, pantograph bounce and other traction power sources or track component failures; or from adjacent tracks due to any combination of normal or abnormal sources discussed above.

Radio Frequency Interference. The cab signal and speed-control equipment shall also be designed for maximum rejection of radiofrequency interference. It also shall not cause interference either on board or to the wayside, in excess of the limits indicated in figure 2-2.

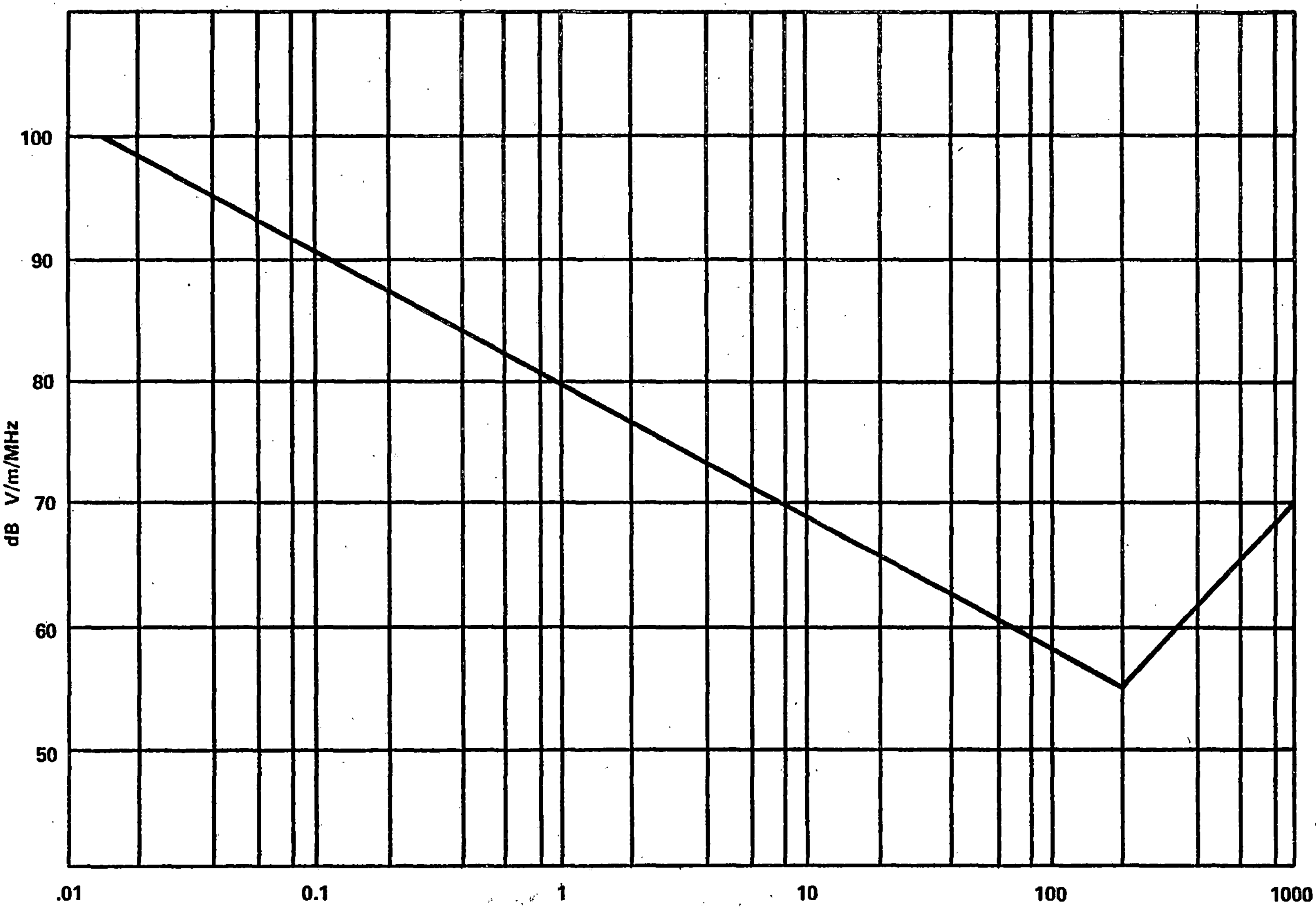

FIGURE 2-2

LIMIT FOR BROADBAND EMISSIONS
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Functional effects of interference can include simulation of a coded signal carrier either by spurious noise or beating among various normal and interference signals that might be present, saturation effects causing loss of a proper coded signal carrier, spurious operation or failure of power supplies or amplifiers, and false generation of vehicle speed information among others.

2.2.3.2 Methods for Interference Reduction

The cab signal/ATC system shall be designed and constructed to maximize rejection of interference. Methods to be used to accomplish this, in addition to appropriate functional circuit design shall include, but are not limited to the following:

- Using two-wire double-break circuits for wiring outside of cab signal/ATC enclosures
- Using separate dedicated conduit for cab signal/ATC wiring
- Twisting and shielding of wiring
- Analyzing and designing the system grounding network to minimize noise coupling and propagation
- Using balanced wiring and circuit layout
- Suppressing transients in internal components and within system power supplies.

2.3.3.3 Requirements

There shall be no false, less restrictive aspects displayed by the cab signal or conveyed to the ATC system, no loss of aspect, and no unsafe function of the ATC system as the result of interference.

2.2.4 Carrier Frequencies and Code Rates

The cab signal system shall respond to two carrier frequencies, F1 (100 Hz nominal with 91.66 Hz used in certain areas) and F2 (250 Hz nominal). These carriers shall be present and coded as noted in section 2.1.2, and shall be interpreted and displayed by the cab signal as the speed limits noted. This speed limit information shall be conveyed to the ATC system. The nominal code rates as listed below for both carriers shall be detected by the cab signal system through the use of tuned decoding.

- 75 ppm
- 120 ppm
- 180 ppm

The equipment design shall not preclude the future addition of tuned detection of a 50 ppm code rate for F1.

2.2.5 Response Times and Values

The response times, values, and limits for the cab signal and ATC systems shall be as follows.

2.2.5.1 Maximum time from the receipt of any speed code (one or both carriers) to the output of the corresponding speed information to the cab signal and the ATC shall be 3.5 seconds.

2.2.5.2 Minimum time in advance of pickup of the F1 code relay of any code, for the F2 code relay of the same code to pick up, shall be one-half the code period.

2.2.5.3 Minimum time after dropout of any F1 code relay, for the F2 code relay of the same code to dropout shall be one-half the code period of the code present at that time.

2.2.5.4 The elapsed time between receipt of the speed information by the ATC system and a penalty brake application due to failure to acknowledge shall be 5 ± 1 seconds.

2.2.5.5 The elapsed time between the occurrence of an overspeed condition and its recognition by the ATC system shall be 0.5 second, maximum.

2.2.5.6 The elapsed time between recognition of an overspeed condition and the commencement of the ATC brake application (due to lack of proper suppression) shall be 5 ± 1 seconds.

2.2.5.7 The time limit for the freight locomotive total suppression sequence shall be 30 ± 5 seconds from recognition of an overspeed condition by the ATC system.

2.2.5.8 The elapsed time from initiation of a split reduction ATC brake application for freight locomotives to the automatic command for full service brake application shall be 15 seconds minimum and 20 seconds maximum.

2.2.5.9 The initial freight locomotive brake pipe reduction to forestall an ATC split reduction brake application shall be 6 + 2, - 0 psi.

2.2.6 Speed Sensing and Control

Speed information shall be derived from a signal that is frequency related to the rotational speed of the vehicle axles. This signal shall be then presented to the overspeed detector and comparator circuits that shall accept logic inputs from the cab signal relay matrix corresponding to allowable vehicle speeds. The comparator circuit shall then compare these two outputs (allowable versus measured speed), and, if the measured speed exceeds the allowable speed, remove the overspeed relay coil energy, indicating that an overspeed condition exists. If the operator fails to respond properly, an ATC brake application shall take place.

Vehicle speed information shall be presented to the engineman through an integrated speedometer system as described in section 3.7.

The ATC overspeed trip point shall be provided with a lockable maintenance adjustment such that the trip point can be set to occur at 1.5 ± 1.0 mph above the actual speed corresponding to the speed limit in force at any time. The system shall have sufficient stability such that when adjusted to within this range this setting shall not exceed 1.5 ± 1.5 mph above this actual speed between normal 30-day periodic inspections.

The speedometer drive circuitry shall be provided with a lockable maintenance adjustment such that the speedometer indicated speed can be set to read 1.5 ± 0.5 mph below the ATC overspeed trip point and with sufficient stability such that the setting shall not drift more than ± 0.5 mph between normal 30-day periodic inspections.

2.3 Design Verification and Testing

2.3.1 Design Qualification

The cab signal and ATC equipment to be supplied under this specification shall have been qualified for this purpose prior to submission of any bid or proposal offering it to the customer.

This qualification shall have been obtained using designs and hardware identical in concept, function, and major components to that being proposed. Any deviation from this requirement shall be permitted only with the specific approval of the customer, who shall have the right to require written justification of any equipment differences and their effect on overall system performance.

This qualification of equipment shall consist of actual revenue service operation of sufficient duration (as approved by the customer) to demonstrate system performance on vehicles run on the Northeast Corridor, or approved equivalent, under the full range of normal operating conditions. The basic areas for demonstration of the performance required by this specification shall include:

- Dual-carrier frequency operation under all code rates
- Response times
- Rejection of interference
- Compatibility with various types of wayside equipment including wideband F1 operation and 25 Hz and 60 Hz traction power
- Basic system reliability.

The equipment supplier shall provide the customer with the detailed results of his design qualification tests.

2.3.2 Engineering Review

Engineering review meetings shall be held at the Contractor's facility on a periodic basis at the customer's initiative with the goals of assuring the customer that the specification technical requirements are being met and of providing the Contractor with timely information on customer evaluation of the equipment being produced.

Engineering review meetings shall include:

2.3.2.1 Preliminary design reviews to cover the exact configuration of specified equipment, any differences from the prequalified design, equipment layout, cab layout design, etc.

2.3.2.2 Final design reviews to be held in conjunction with production drawing review. This review shall be held prior to commitment to production to permit incorporation of any changes resulting from the review.

2.3.2.3 System demonstration review to be held upon completion of the first set of production equipment. The demonstration shall include a complete set of equipment to be provided under this specification, arranged to function as in an actual vehicle installation and including simulation of all required vehicle systems. A demonstration plan shall be submitted for customer approval prior to the demonstration.

2.3.2.4 Other review meetings as required to discuss technical problem areas, changes and progress.

2.3.3 Maintainability Review and Demonstation

In conjunction with the final design reviews on various portions of the system, the maintainability concepts shall be presented by the Contractor for review by the customer. In addition, a maintainability demonstration shall be held on the first complete set of production equipment and shall include component replacement, calibration, and testing techniques and troubleshooting procedures.

2.3.4 Drawing Submission

Drawings shall be submitted in a timely fashion by the Contractor as follows:

2.3.4.1 Working drawings shall provide sufficient information to permit detailed review of equipment design by the customer. These drawings shall include component layout, equipment assembly and installation information, wiring and interconnection data, and schematics and wiring diagrams. These drawings shall be submitted for review at least 30 days before the final design review concerning the equipment to which the drawings are pertinent. All subsequent changes and revisions to these drawings shall be submitted for review. Written response by the customer containing comments and required changes to these drawings and their revision will be transmitted within 30 days of receipt of the drawings by the customer.

2.3.4.2 As-built drawings shall be submitted by the Contractor within 90 days of the delivery to the customer of the last set of equipment supplied under this specification. The drawings shall be updated throughout the warranty period. These drawings shall include all information noted in section 2.3.4.1 above and such additional information as is necessary to inspect, test, troubleshoot, and repair the equipment.

All as-built drawings shall be submitted as reproducible copies on polyester film as well as on 35 mm microfilm.

2.3.4.3 No drawings shall exceed 36 inches by 24 inches. All drawings shall include complete reference to those of the next higher and lower orders of assembly.

2.3.5 <u>Manufacturing and Acceptance Tests</u>

During the manufacture of the equipment supplied under this specification, certain tests shall be performed as follows:

2.3.5.1 Component tests shall be performed to ensure conformance to component design requirements.

2.3.5.2 A system acceptance test shall be performed prior to installation on each completed set of equipment to demonstrate conformance to the requirements of this specification.

2.3.5.3 A dielectric breakdown test as specified for new equipment in Institute of Electrical and Electronic Engineers (IEEE) standard 16-300 shall be performed on each completed system prior to installation in the vehicle.

2.3.5.4 Ground resistance tests shall be performed on the following subsystems, which shall each exhibit at least 10 megohms to ground using a 500 volt DC megger after installation in the vehicle:

- Cab signal/ATC excluding power supply
- Power Supply (with appropriate grounding connection lifted)
- Train Performance Recorder.

Care shall be exercised during these tests to protect components subjected to the test voltage. These tests shall be run in cooperation with the vehicle supplier.

2.3.5.5 A functional test shall be performed in cooperation with the vehicle supplier after installation and ground resistance testing to ensure compliance with the requirements of this specification.

A comprehensive test procedure shall be submitted to the customer for review 60 days prior to the start of production manufacturing. This procedure shall include the details of each test to be run and the pass-fail criteria for each test.

A test report shall be issued for each set of equipment documenting the acceptability of the test results for that set.

2.3.6 Inspection

Inspection of the cab signal/ATC/TPR system and its components shall be the responsibility of the Contractor and his suppliers, and such inspection shall be conducted at their plants so that corrections can be made under factory conditions prior to installation.

The presence of the customer or his representatives in the Contractor's or his suppliers' plants shall not lessen the inspection or other specification requirements of the Contractor or his suppliers.

The customer shall have access during normal working hours to all plants involved in design, manufacture or testing of the specified equipment. The Contractor or his suppliers shall provide to the customer full cooperation and the necessary facilities to permit convenient inspection of all materials, work, and equipment supplied under this specification. A reasonable length of time shall be permitted for customer inspection.

The customer shall have the right to reject all material and workmanship that do not conform to this specification or accepted practice. Repetitive rejection shall be considered sufficient cause to stop work until agreement can be reached between the customer and the Contractor.

A record of the inspection and test sign off sheets and line-replacable unit (LRU) serial numbers for each set of equipment shall be delivered with the related equipment.

2.4 System Support

2.4.1 Installation Support

The Contractor shall provide engineering and field personnel as needed during the installation and test of the equipment supplied under this contract. This shall include the following:

2.4.1.1 Joint development of installation requirements with the vehicle supplier and review and approval of installation drawings relative to the function and safety of the installation.

2.4.1.2 Technical on-site liaison in the vehicle supplier's plant and test site to include prototype installation, production installation, and testing. The Contractor's engineering staff shall be on call for assistance in resolution of technical problems.

2.4.1.3 Technical on-site liaison at the customer's test site during customer test and acceptance of the vehicle. The Contractor's engineering staff shall be on call for assistance in resolution of technical problems.

2.4.2 Field Service

During the warranty period for the specified equipment, as part of the equipment delivery process, the Contractor shall make available technical field personnel to resolve problems, assist in troubleshooting and rework of equipment, and monitor the reliability demonstration. The Contractor's engineering staff shall be on call for the assistance of field technical representatives and to provide rework design effort when called for by reliability demonstration results.

2.4.3 Manuals

Manuals and parts catalogs shall be complete, well organized, and cross-indexed, and shall include no extraneous material. They shall be designed for continuous long-term service with hard covers using a good grade of paper.

The publications shall be in the following categories, produced in reinforced loose-leaf form and in the quantities noted.

2.4.3.1 Operating Instruction Manual

One hundred copies, 4 inches by 6 inches, side opening with 10 loose-leaf rings.

The operating instruction manual shall include system familiarization material; location, function and operation of all controls, switches and indicators; and other information necessary to the optimum operation of the system by the train crew. Emergency procedures and trouble diagnosis shall be included.

2.4.3.2 Maintenance Manual

Fifty copies, 8 1/2 inches by 11 inches, side opening with 10 loose-leaf rings.

The maintenance manual shall contain comprehensive troubleshooting procedures, all test and calibration procedures and values, and the detailed information necessary to service, inspect, adjust, repair, replace, overhaul and rebuild all components and subsystems of the system. Clear schematics, diagrams, and exploded drawings shall be provided to permit this maintenance.

2.4.3.3 Parts Catalog

Fifty copies, 8 1/2 inches by 11 inches, side opening with 10 loose-leaf rings.

The parts catalog shall enumerate and describe every component with its related parts, including the supplier's number, the Contractor's number, and provision for entry of the customer's stock number. Cutaway and exploded drawings shall be used to permit identification of all parts not readily identified by description. Parts common to different components for example, bolts and nuts, shall bear the same Contractor's number with a reference to the other components in which they are found. Each part or component shall be identified as being part of the next assembly. Commercially available items such as common standard fastenings, lamps, fittings, etc. shall be identified by a symbol beside the Contractor's number.

Drawings and illustrations in the publications noted above may be larger than the sizes stated but shall be foldouts, bound in a similar manner to the other pages.

The manuals and catalogs shall be delivered at the same time as the first production set of equipment. They shall be submitted for customer review and comment 60 days prior to publication. Revised pages shall be issued for these publications after initial delivery as they are required because of change in design, procedure, etc., through the warranty period.

2.4.4 Training

The Contractor shall provide a training program for the operating agency's personnel, adequate to ensure satisfactory testing, troubleshooting, servicing, repairing, and overhauling of the equipment supplied under this specification. The training shall include classroom instruction and field demonstration using actual equipment. The Contractor can assume only that the maintenance personnel have the skills pertinent to their crafts.

2.4.4.1 Program Outline

As part of the bid submission, the Contractor shall provide an outline of the planned training program including hours of classroom and field instruction, level of teacher qualification, training aids to be used, and a brief course description.

2.4.4.2 Training Plan

The Contractor shall submit for approval, within 90 days after award of contract, a detailed training plan containing an instruction outline, schedule, samples of training aids and a listing of support facilities required (classrooms, tables, etc.).

2.4.4.3 Instruction

Classroom and field instruction shall commence within 30 days after delivery of the first production equipment. They shall cover equipment functional analysis as well as all servicing and maintenance requirements. Thorough troubleshooting techniques shall be provided and demonstrated with student participation. The instructions shall be coordinated with other maintenance manuals and supplemented with the teaching and visual aids. Each student shall receive a set of classroom notes for reference at the conclusion of the training program, and the operating agency shall be given one set of classroom aids and a complete teaching guide for holding future classes as required.

All instructions and teaching aids shall be coordinated by the prime Contractor to ensure consistent and coordinated teaching standards and course material.

2.4.4.4 Class Location and Attendees

The classes and field instructions shall be held at central locations on the operating agency's property. The locations and exact schedule for classes shall be coordinated with the operating agency.

It is estimated that 50 trainees will attend each class.

3.0 CAB SIGNAL EQUIPMENT DESCRIPTION

3.1 Carrier Frequencies

The cab signal equipment shall operate using two carrier frequencies, F1, a nominal 100 Hz, and F2, a nominal 250 Hz. Operation shall be such that the equipment shall interpret the F1 carrier as specific speed commands for each coding rate and shall interpret the same F1 coding rates as separate and distinct higher speed commands when F2 carrier is present during the off coding periods of the F1 carrier.

3.1.1 Bandwidth

The cab signal equipment shall respond to and operate successfully with the following carrier frequencies and tolerances:

- F1 - 100 Hz $\pm$ 1.5 Hz
- F1 - 91.66 Hz $\pm$ 2 Hz
- F2 - 250 Hz $\pm$ 4 Hz.

3.1.2 Level

The in-rail coded carrier current ranges over which the cab signal equipment shall successfully operate are as follows (to ensure such operation the equipment shall respond to a track current of 1.8 amperes or higher and shall <u>not</u> respond to a track current of 1.5 amperes or less):

- F1 - 2.0 amperes to 20 amperes
- F2 - 1.0 amperes to 10 amperes.

Generally, the highest currents will occur at track circuit leaving ends and the lowest at the entering ends.

3.2 Code Rates

The two in-rail carriers will be coded at three code rates with F2 carrier either present or not present during the OFF portions of the F1 code. The cab signal equipment shall respond to these code rates in a manner described in section 3.5 of this specification.

3.2.1 Bandwidth

The cab signal equipment shall operate successfully with the following code rate ranges:

- Nominal 75 ppm, range 66 to 77 ppm
- Nominal 120 ppm, range 118 to 125 ppm.
- Nominal 180 ppm, range 178 to 187 ppm.

3.2.2 Duty Cycle

The cab signal equipment shall operate successfully with an F1 code on time not less than 40 percent or not more than 60 percent of the total code period.

3.2.3 Worst-Case Operation

The cab signal equipment shall respond to any upward or downward code change with no significant change in its response times with the worst-case combination of in-tolerance values of carrier frequencies and levels, code rates and duty cycles, power supply voltages, and track receiver height above rail.

3.3 Track Receivers

3.3.1 A pair of track receivers shall be mounted at each potential leading end of a car or locomotive equipped with cab signals. The receivers at a specific control end shall be connected to the carborne cab signal apparatus when and only when the controls at that end are energized. This connection shall be by double-break relay switching, and attention shall be given to balancing these circuits.

The two coils of the pair shall be electrically connected such that the voltages induced in them by the rail carried signal current shall be additive and those induced by balanced propulsion return current shall cancel.

3.3.2 The receivers shall be mounted one above each rail in front of the lead wheels of the car or locomotive. A receiver shall consist of a laminated iron core on which is mounted weatherproof coil and lead assembly. The receivers shall be mounted using nonferrous brackets, shall not use bolts in tension for support, and shall be arranged with the cores parallel to the plane of the tracks and perpendicular to the rails.

Each receiver core shall be mounted such that it is approximately 6.5 inches fron the gauge of the rail, the centerline of the core being between 6 and 9 inches above the top of rail. The receiver core shall be a minimum of 3.5 inches from any ferrous part of the car or locomotive. The mounting bracket shall include a self locking adjustment feature sufficient to maintain the receiver within the vertical range noted above within vehicle load and wear limits. The effect of car or locomotive body lateral offset in curves shall be taken into account in determining longitudinal mounting location.

3.3.3 On vehicles capable of operation over 80 mph, a nonmetallic protective enclosure shall be provided around each receiver to help protect it from wayside debris. The mounting of this enclosure can be integral with that of the receiver but in any case shall be such to maintain at least 3.5 inches clearance between the enclosure and the top of rail within vehicle load and wear limits.

3.3.4 The cable lead from each receiver shall be insulated, stranded (minimum) U.S. No. 16 copper twisted pair with a neoprene jacket. The cable lead shall be 4 feet long to allow connection in a body-mounted junction box. This junction box shall be of rugged weatherproof construction with three clamp-type weather-sealed fittings for the two receiver cable leads and the mating vehicle cable.

3.3.5. Track receivers supplied under this contract for existing rolling stock shall be mechanically interchangeable with existing receivers of similar design.

3.4 Filter/Amplifiers

Passive band-pass filters shall be used to couple the track receivers to the two amplifiers that shall drive the two decoder groups. By definition, the track receivers form an integral part of the filter network. The filter network shall be designed such that worst-case drift of component values will not result in an unsafe condition.

Filter attenuation shall be greater than that stated below if necessary to avoid interference mechanisms from traction power harmonics or other sources. The design of the filter network and the components used shall be such to minimize parameter change due to aging or normal stress of any element.

The filter elements may be in separate assemblies with portions in either amplifier assembly.

Each of the amplifiers fed by the filter network shall be designed to have as its input the coded carrier signals, and to produce as an output an alternating square wave at the input code rate.

The amplifier shall be of AC coupled design using silicon semiconductors. Adjustments for gain shall be slotted screwdriver-rotated potentiometers with positive locking features. If a fine filter adjustment is required it shall be accomplished through the use of discrete component installation or an adjustable capacitor with an adjustment locking feature.

Electrical connection shall be made by a rugged plug connector keyed to ensure correct insertion. Test jacks shall be included for measuring critical amplifier values including output current.

A visual light device shall be provided on the amplifier front panel to show the output state and coding.

3.4.1 <u>F1 Carrier</u>

Initially the F1 filter portion shall have the capability to pass both the 91.66 and 100 Hz nominal carrier frequencies with the following characteristics:

- Center frequency 96 Hz
- Attenuation of 50 db at $\pm$ 30 Hz from the center frequency (minimum) and $\overline{3}$ db at 100 Hz and 91.66 Hz (maximum) (relative to center frequency).

The capability to convert the filter network to only 100 Hz nominal carrier operation shall be designed into the equipment. This conversion shall entail only the simple replacement of the filter package. The replacement filter characteristics shall be as follows:

- Center frequency 100 Hz
- Attentuation of 50 db at $\pm$ 25 Hz from the center frequency (minimum) (relative to center frequency).

3.4.2 <u>F2 Carrier</u>

The F2 filter portion shall have the capability to pass the 250 Hz nominal carrier frequency with the following characteristics:

- Center frequency 250 Hz
- Attentuation of 50 db at $\pm$ 25 Hz from the center frequency (minimum) (relative to center frequency).

3.5 <u>Decoder Circuit and Relays</u>

3.5.1 <u>Decoder Filter and Relay Drive</u>

A decoding unit with a tuned passive filter shall be provided for each code for each carrier frequency. It is preferred that the decoders for a given code be identical and interchangeable between the two different channels for F1 and F2 carriers and that they be identical overall except for tuning differences. These units shall be of the plug-in type with connections to the plugs arranged among codes to prevent operation in the event of improper insertion.

The tuning characteristics of the decoders shall meet the following requirements:

- A code relay pickup time shall not be significantly affected under the worst-case tolerances for that code frequency and duty cycle.
- A code relay shall not be held up or its dropout time significantly affected by the presence of a neighboring code under the worst-case tolerances for the neighboring code. Allowance shall be made for future addition of a 50 ppm code.

3.5.2 Decoding Relays

The decoders shall each drive a plug-in relay that satisfies the requirements of Section 2.1.3.1 of this specification. The relays shall be identical and interchangeable among all codes and carrier frequencies. These relays shall be of a design that minimizes the effects of vehicle-induced forces.

Decoding design shall be such as to ensure that for any two carrier codes, the F2 carrier code relay precedes the F1 carrier code relay with respect to pickup and lags behind it with respect to dropout within the constraints of other response-time requirements.

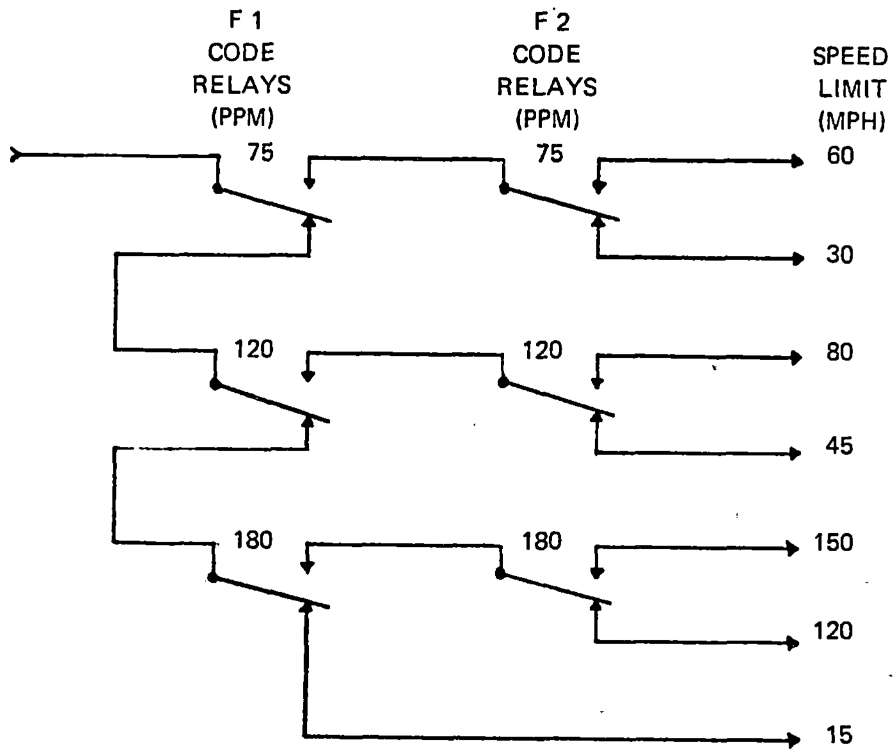
3.5.3 Arrangement of Decoding Relay Contacts

The contacts of the code relays shall be arranged in a fan to ensure that the output to the ATC subsystem and to the cab signal meets the following requirements:

- The lowest code relay that is up shall govern.
- The corresponding F1 code relay must be up to validate an F2 code output.

This fan shall conform in general to that shown in figure 3-1. Any deviation from this arrangement shall require customer approval. Cab signal output shall be arranged with two fans as noted above to form a double-break configuration for external circuitry as required.

The code relays shall provide outputs to the acknowledging circuits, overspeed protection circuits, and cab indication circuits.



FANS REQUIRED:
CAB SIGNAL 2
ACKNOWLEDGE CIRCUIT INPUT 1
ATC INPUT 2

DE LEUW, CATHER / PARSONS NECIP PROGRAM MANAGERS WASHINGTON, D.C. 20036	CAB SIGNAL DECODING RELAY CONTACT FAN FIGURE 3 - 1	LOUIS T. KLAUDER AND ASSOCIATES Consulting Engineers Philadelphia National Bank Building Philadelphia, Pa. 19107

3.6 Acknowledgment and Alarm

3.6.1 Normal ATC Acknowledgment

The acknowledging circuits shall be arranged to require the engineman's momentary operation of an acknowledging switch on any downward change in cab signal but not on an upward change. In like manner, an alarm device shall sound on any downward change in cab signal until operation of the acknowledging switch but shall not sound on an upward change in cab signal. The acknowledging switch shall be a foot pedal or manual switch located for convenient engineman actuation, dependent on cab configuration. Its design and location shall be approved by the customer. Actuation of the switch shall serve to test the alarm device but continued actuation for more than 5 $\pm$ 1 seconds shall cause a penalty brake application.

The acknowledging circuits shall be arranged in a relay tree consisting of plug-in relays and circuitry that meet the requirements of section 2.1.3 of this specification. Information shall be given to the ATC subsystem by the acknowledging circuits such that the time delay and penalty brake requirements of Section 2.2 can be met. Other methods must receive specific approval by customer.

The alarm device shall be located in each operating cab of a vehicle, shall sound only in the active cab, and shall produce a sound of sufficient intensity to be heard in this environment. The device may be electromechanical or electrically controlled pneumatic in design and shall be submitted to the customer for approval. Intensity of the whistle or alarm shall not exceed 90 dBA. Compliance shall be demonstrated using a type 2 sound-level meter as defined by American National Standards Institute (ANSI) S1.4, Specification For Sound Level Meters, using the slow meter scale.

3.6.2 Bypassed ATC Acknowledgment

When the ATC subsystem is bypassed, a separate acknowledgment penalty brake function shall be enabled, and shall be wholly part of the cab signal equipment. It shall allow operation with cab signal information and acknowledgment enforcement but without speed control in the event of ATC failure.

This function shall include electromechanical or pneumatic timing circuits and an electropneumatic brake interface such that full-service braking shall be applied if the acknowledging switch is not operated as required. This full-service brake application shall be maintained by a timing feature for a length of time sufficient to bring the train to a stop at full-service brake rate from the highest speed of which the particular vehicle is capable. This circuitry shall conform to the requirements of section 2.1.3.

A cut-out device shall be provided that shall pneumatically prevent the penalty brake application and inhibit the sounding of the alarm device. This device shall be in a location remote from the engineman's position and shall be sealed in the cut-in position (figure 4-5).

3.7 Cab Display (Combined Cab Signal and Speed Indicator)

3.7.1 The cab signal and speed indicator shall be integrated into a common group to allow a direct comparison between permitted and actual speed. It shall be designed and mounted in accordance with the anthropometric data shown in section K, The Measure of Man, Human Factors in Design; Henry Dreyfuss, 1967, Whitney Publishing Co.

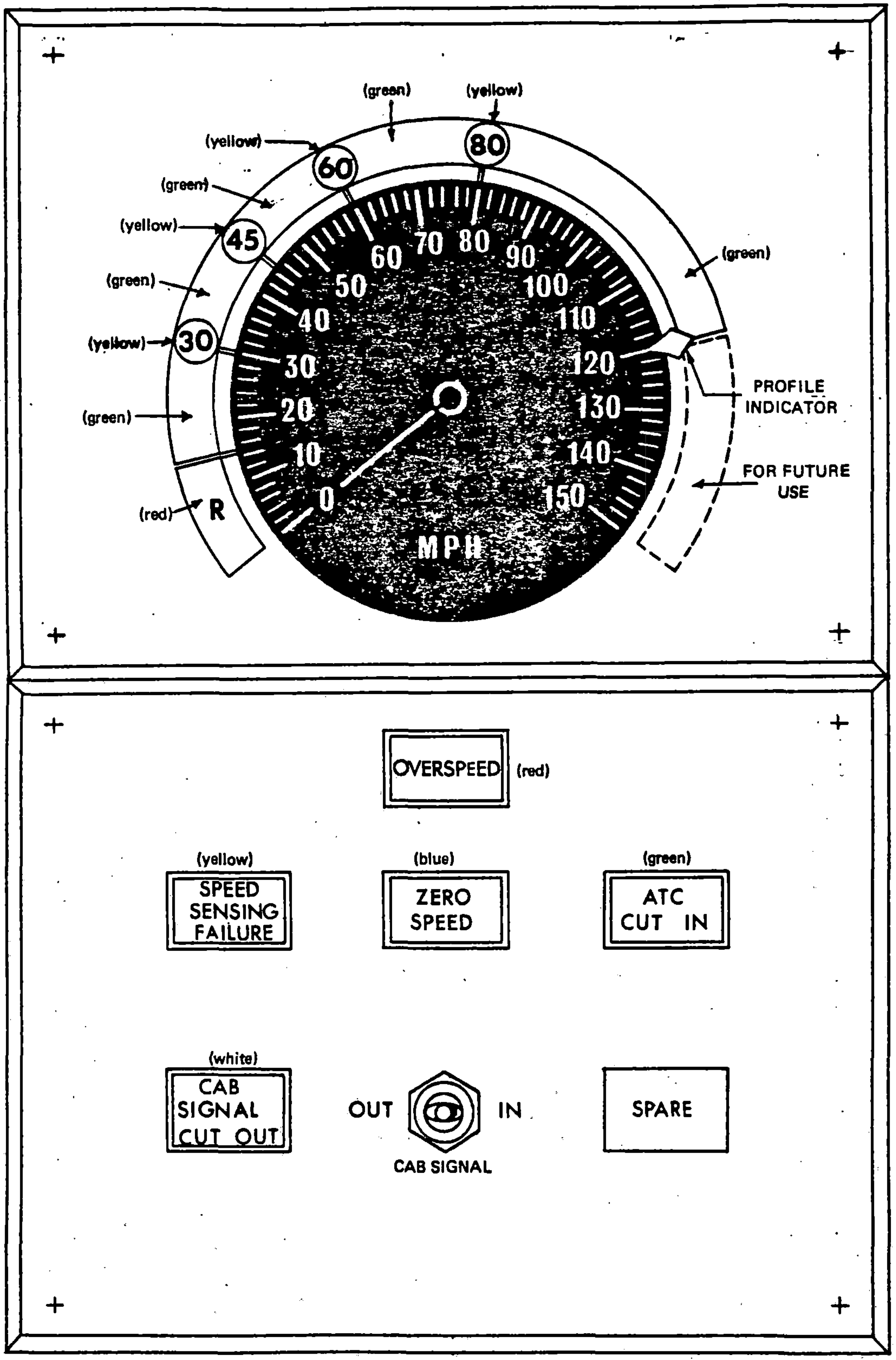
3.7.2 The speed indicator shall be an analog type, 0- to 1-milliampere meter movement made especially for transportation service. Speed indicator drive is specified in section 4.1.2.2. Zero adjustment shall be from the rear. The diameter shall be approximately 3-1/2 inches. The face shall be black with white numerals in 10 mph increments, and white graduations in 2 mph increments, with speed ranges depending on the maximum speed of the vehicle. Speed limits shall be emphasized. The face may be edge-lit plastic with graduations and numerals marked on the black face so that illuminating lamp light is reflected toward the viewer. Other innovative methods of accomplishing this function will be considered.

3.7.3 The cab signal shall be located at the circumference of the speed indicator dial and shall consist of segments which physically correspond to the permitted speed as shown on that dial. These segments shall be lighted to indicate only the maximum permitted speed. A lamp assembly near the bottom of the indicator shall be used for the red overspeed indications which shall be lighted continuously whenever vehicle speed exceeds that permitted by the cab signal. This red indicator shall flash during a penalty brake application.

3.7.4 Figure 3-2 shows the essential elements of an acceptable design for an integrated cab signal and speed indicator.

3.7.5 Important considerations in the design and construction of the combined cab signal and speed indicator are listed below:

- The speedometer pointer shall overlap the speed graduations to enable accurate readings and the possibility of misreading due to parallax or lack of contrast shall be minimized.



LOUIS T. KLAUDER AND ASSOCIATES Consulting Engineers Philadelphia National Bank Building Philadelphia, Pa. 19107	CAB SIGNAL/SPEEDOMETER/INDICATOR PANEL LAYOUT FIGURE 3-2	DE LEUW, CATHER / PARSONS NECIP PROGRAM MANAGERS WASHINGTON, D.C. 20036

- The cab signal segments shall have the maximum contrast between lighted and unlighted condition under all ambient light levels.

- Lighting of the cab signal and speed indicator shall be adequate for the function intended and must be controllable with a dimmer so as not to produce a glare within the cab or to interfere with forward vision. Ultraviolet light techniques are not permitted. The minimum dimmer position shall not extinguish the lighted segments.

- To minimize glare, the exterior finish of the cab signal and speed indicator assembly shall be finished in flat black.

- The combined unit shall be mounted at the eye level of the operator within normal vision range when looking forward. Normal vision range is defined as 30 degrees eye rotation down from the standard sight line.

- The combined unit shall be supplied with a bezel for panel mounting on a control console, or on vertical panels in vestibule control areas or in a suitable separate housing if it is not possible to mount the unit within a console or panel.

- The combined unit shall use environment resistant MS series F or R connectors in conformity with the other portions of the cab signal/ATC equipment.

- The illumination of the cab signal sectors shall be with no less than two lamps per sector. The maximum voltage applied to these lamps shall be 10 percent less than their rating and shall be supplied from a regulated source as described in section 6, Power Supply. These lamps shall be double wire fed from double-break control circuits. Lamps shall be removable from the rear of the assembly.

- In the event of failure or fault developing in the cab signal assembly, the safety of the cab signal and ATC systems shall not be affected.

- The cab signal sectors shall be mounted on the speed indicator in such a fashion as to preclude any glare on the speed indicator face.

- If possible, a clear polycarbonate face for protection shall cover the entire assembly. The face shall be separately replaceable.

- There shall be no apparent method of disassembly when viewing the front face.

3.7.6 Mounted on the same panel, but separate from the combined speed indicator cab signal unit, shall be:

- A yellow lamp to indicate the loss of one speed sensor signal
- A blue lamp to indicate zero speed
- A green lamp to indicate ATC is cut in.

The brilliance of these lamps shall be controlled by the same dimmer used with the combined speed indicator cab signal unit.

3.8 Freight-Passenger Switch

Locomotives to be used in both freight and passenger service (operation as described in sections 2.2.2.2 and 2.2.2.3, respectively) shall be equipped with a sealed changeover switch to enable the proper cab signal/ATC operation for the service being performed.

This switch, which shall be located away from the engineman's control position, shall be controlled in conjunction with the brake pipe cutoff valve on these locomotives. All equipment necessary for operation in either mode shall be installed. With this switch in the FREIGHT position, the F2 carrier receiver shall be disabled.

4.0 AUTOMATIC TRAIN CONTROL (ATC) EQUIPMENT

The ATC equipment shall initiate a visual warning to the operator if train speed is above the cab signal speed limit, and shall automatically initiate a penalty brake application if the operator fails to act to begin correction of the overspeed condition within the specified warning time. Overspeed detection shall be accomplished by electronically monitoring the actual train speed in a manner conforming to section 2.1.3 and comparing measured speed with the allowable speed received from the cab signal equipment. If an over-speed condition is detected, an indication light shall be activated and, after a 5-second delay, an automatic brake application shall be initiated unless the operator has responded properly.

The ATC equipment shall accept an input from the cab signal acknowledgment circuitry and shall in response produce the appropriate penalty-braking sequence as required by section 2.2.2. When ATC is bypassed, this action shall not occur and the cab signal lack-of-acknowledgment penalty-brake feature shall be enabled as described in section 3.6.

4.1 Speed-Determination Circuits

The speed-determination circuits shall include wheel-speed sensors and associated plug-connected printed circuit modules. These circuits may be combined on cards with other functions so that interconnections are minimized. The description and function of these items follow.

4.1.1 Wheel-Speed Sensors

The wheel-speed sensor shall be an electromechanical device coupled to an axle in such a manner that an AC waveform is produced, the frequency of which is proportional to the rotational speed of the axle (and, thus, to vehicle speed).

It may be possible or desirable in some cases, as on multiple-unit (MU) cars, to insert a speed pickup into an adapter which will in turn be inserted into the driving gearbox housing to use the bullgear for speed reference.

4.1.2 Speed Signal Conditioning

The speed signal conditioning circuits shall process the magnetic pickup signals to provide exact noise free output pulses the frequency of which is proportional to vehicle speed. These output pulses shall provide functional inputs to the velocity-zero, speedometer, and speed governor circuits.

The speed signal conditioning circuits shall be able to be calibrated for wheel wear by a multiposition switch for each channel which compensates for speed signal error due to this wear. Each switch shall have discrete marked positions in 1-inch increments of wheel diameter covering the full range of wheel size from new to fully worn.

4.1.2.1 The velocity-zero circuit shall provide a safe zero-speed output signal to indicate when the vehicle is not moving. The output signal shall operate a relay which in turn shall light a blue velocity-zero indicator on the engineman's display panel.

4.1.2.2 The speedometer drive circuit shall provide speed proportional input pulses to the speedometer signal conditioning circuit from one speed sensing channel, which shall drive the speedometer mechanism described in section 4.3. The speedometer signal conditioning circuit shall convert the input pulses to a DC signal suitable for the meter drive.

4.1.2.3 The speed governor drive circuits shall provide a series of speed proportional input pulses to the speed governor network.

4.2 Speed Governor Circuits

4.2.1 Overspeed Detection

The overspeed detector and comparator circuits shall accept logic inputs from the cab signal relay matrix corresponding to vehicle speed limits. The DC logic voltage from the relay matrix shall be provided by an isolated regulated power source within the ATC equipment. This regulated power source shall use appropriate techniques to ensure that its regulation and voltage levels remain stable so that compliance with the safety requirements of section 2.1.3 is established. The equipment shall permit future input of civil speed limit commands from a source other than the cab signal equipment. These inputs shall not affect the safety of the cab signal circuitry.

Input pulses that are frequency proportional to the measured vehicle speed shall be accepted from the speed governor drive circuits. These pulses shall be conditioned by the comparator input circuits to provide a signal for comparison with the allowable speed inputs from the cab signal relay matrix (relay fan).

The final output of the comparator circuits shall, if the actual speed exceeds the speed limit by greater than 3 mph, remove energy from the overspeed relay coil, thus energizing the cab indication light showing that an overspeed condition exists. If the operator fails to respond properly, a penalty brake application shall automatically take place as described in section 2.2.2.

4.2.2 Dual-Channel Operation

To provide system safety and to allow completion of a trip under an ATC system failure condition, complete dual-channel operation shall be provided from speed sensors to outputs. The two channels shall be arranged such that both velocity-zero outputs must be present to indicate velocity-zero and both overspeed relays must be energized to indicate a not-overspeed condition. The system shall be arranged according to the requirements of section 2.1.3.2 (figure 4-1). It shall be possible to transfer operation of the system to one channel only through the use of a switch sealed in the normal (two-channel) position. When single-channel operation is in effect, the yellow speed sensing failure indicator in the operator's cab shall be illuminated continuously.

4.2.3 Time-Delay Circuits

Reaction to an overspeed condition shall have a certain time constant associated with the penalty brake application. Normally, this shall be the time delay as described in section 2.2.2.

If a pneumatic timing valve is used as the interface, the time delay shall be one of the functions of the timing valve.

4.2.4 Throttle-Brake Control Interface

The throttle-brake control interface devices shall be determined by the requirements of each vehicle. Suitable devices for these purposes may include the P-2-A brake application valve, A-2 reduction selector valve, C-1 suppression valve, and several currently used solenoid valves and pressure switches. In general, pressure switch electrical and pneumatic portions shall conform to the safety and reliability criteria expected for cab signal relay circuits.

4.2.5 Alarm and Indication Circuits

Alarm and indication circuits shall be provided as follows.

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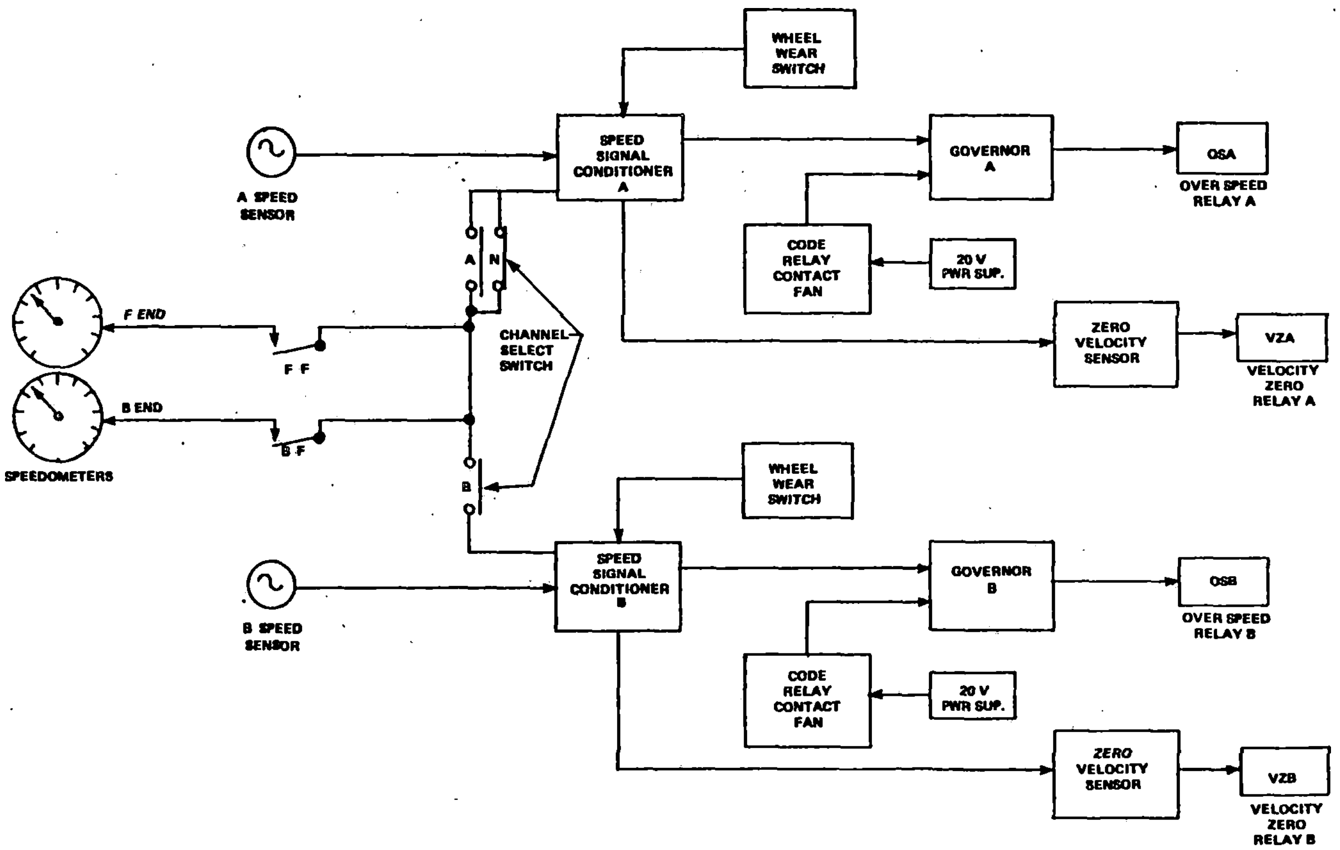

NOTE:

Channel Select Switch will cause Speedometer to be driven from the A speed signal when it is set *in the Normal position. Channel* Select Switch shall function in accorance with Section 4.2.2

DUAL CHANNEL ATC BLOCK
DIAGRAM
FIGURE 4 - 1

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4.2.5.1 Flasher Circuit

The circuit shall produce a pulsed output when steady enery is received at its input (from the overspeed logic circuits). The flasher shall be activated whenever overspeed penalty brakes have been applied and shall supply pulsed outputs to the red overspeed lamp giving a visual indication of such a brake condition.

4.2.5.2 Audible Alarm

The audible alarm shall be a Sonalert-type device (using warbling sound) or equal if electronic means are used for alarm actuation. In the event that pneumatic circuitry is used for alarm actuation, the presently used pneumatic whistle shall be provided.

OPTIONAL ADDITIONAL EQUIPMENT

4.3 Braking Profile Guidance System

On the NEC, there will be a traffic mix of trains with widely diverse performance characteristics. The NEC signal system has been designed to accommodate, in all cases, the worst-case trains from a braking performance standpoint. The net result is that block lengths will often be longer than the stopping distances required by the majority of trains. With long block lengths, throughput of the system under heavy traffic conditions will be lower than desirable. Also run times through diversions will often be adversely affected for high braking performance trains.

The objective of the braking profile guidance system is to optimize operations for all trains so that during signal initiated reductions in speed, higher performance trains may operate more optimally than would be the case if an immediate reduction to the new speed (to satisfy the ATC system) was required.

The cab signal/ATC apparatus described in other sections of this specification will provide train protection by requiring the application of full-service train air brakes until the speed is less than the new speed limit set by the cab signal. The only option given to the engineman will be the manner in which the brakes are applied; with a freight train, he may delay a full-service brake for the period temporary suppression is used. However, eventually full-service brake must be attained.

The braking profile guidance system will allow an engineman leeway in handling a train, as long as train speed is less than the speed described by a speed-distance profile curve.

4.3.1 General Requirements

The braking profile guidance system shall be furnished as an addition to the standard or block cab signal and ATC system described in other sections of this specification. The standard overspeed system shall function normally and shall automatically resume operation should the profile guidance system fail. As part of its function, the guidance system shall incorporate a profile generator which shall determine continuously variable speed limits during a reduction in speed called for by the standard block cab signal/ ATC system. The braking profile guidance system shall determine and display the absolute speed limits (at any point in time and linear space) allowed in achieving the new target speed. If the engineman controls his train so that the speed remains below the profile, a signal shall be provided to the overspeed system which shall inhibit a penalty brake application.

The system block diagram (figure 4-2) describes one suitable way of providing for the interrelation between the cab signal and profile subsystems. It is expected that the system supplier shall integrate the systems shown on figures 4-1 and 4-2 into a complete and unified system. Other system configurations using a vital profile generator and a vital profile underspeed output may also be appropriate if combined into a complete and unified system.

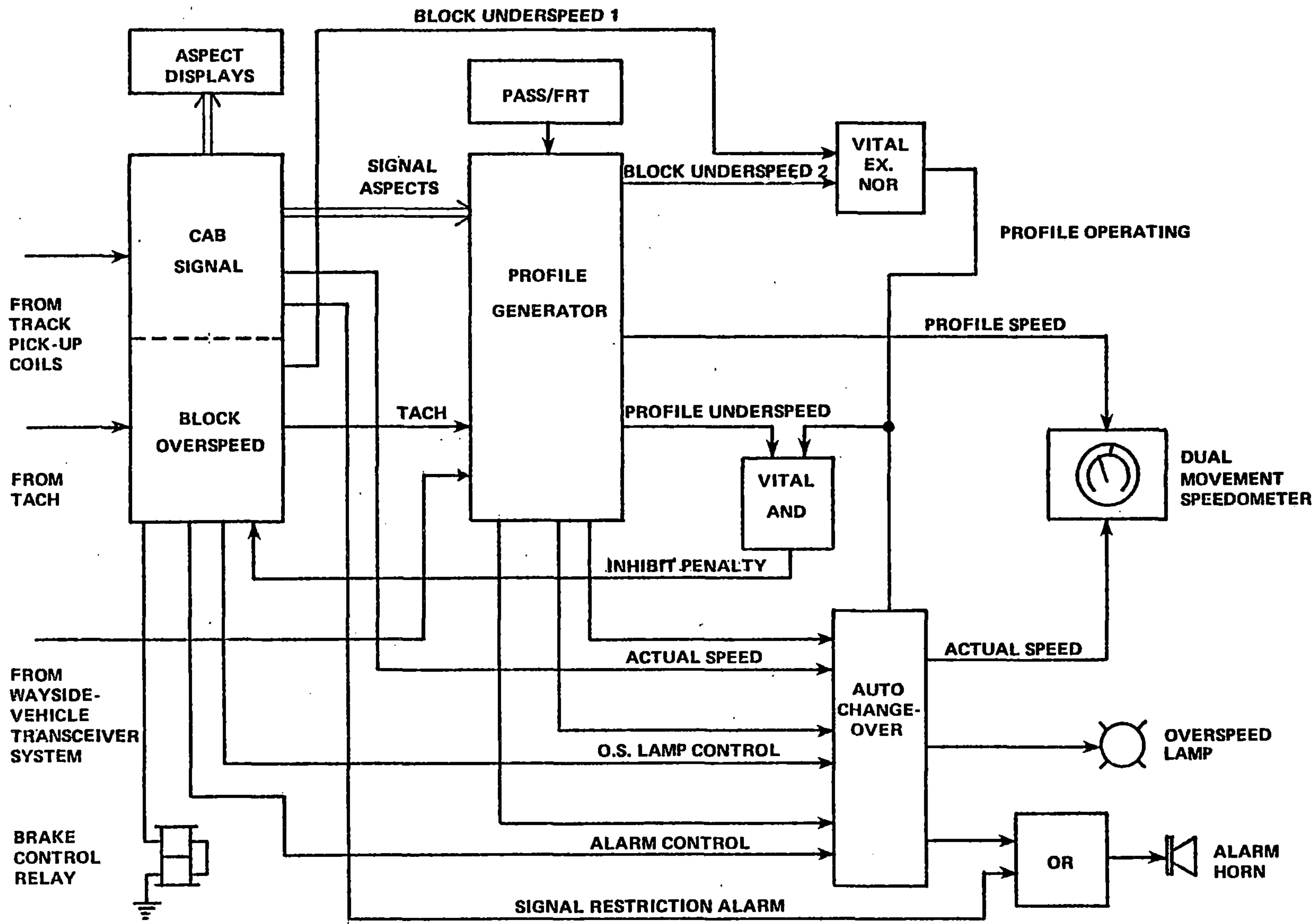
4.3.2 Profile Generator

The wheel-speed sensor and signal conditioning circuits described in sections 4.1.1 and 4.1.2 shall be used by the block overspeed to sense vehicle speed. After initial processing described elsewhere, the speed signal shall also be sent to the profile generator, which shall use it to obtain both speed and distance data.

The profile generator shall also accept input signals from the vehicle-wayside transceiver system described in section 4.4. These inputs shall represent site specific modifiers to the basic speed-distance profile such as grade, distance to go, and final speed expected.

The profile generator shall accept the various inputs and process them to develop a profile curve, which shall become the control curve for the stop in process.

FIGURE 4 - 2
BRAKING PROFILE GUIDANCE SYSTEM



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The profile generator shall process the various inputs to arrive at two results: a vital profile speed and a decision of absolute overspeed or underspeed. This absolute overspeed-underspeed output shall be considered as a vital signal and shall be interpreted identically to the block overspeed output. These two signals shall be required to always agree; therefore, they shall be compared by a vital exclusive nor logic circuit. An active output from this shall indicate that the profile generator is operating correctly. This output shall be used to control the automatic changeover circuit to provide downgrading to a standard block overspeed.

The profile speed developed shall be compared to the actual train speed; if the train is under profile speed, the profile underspeed output shall be active. This shall be applied to a vital AND gate with the profile generator operating signal. This ANDED output shall be applied to the block overspeed to inhibit penalty brake application. Again, in the absence of correct signal, the block overspeed shall have control of penalty braking.

The profile generator shall provide two analog outputs: profile speed and actual speed. These shall be applied to a dual movement meter for the engineman (figure 3-2). This shall appear as normal speedometer in the center, and an additional outer pointer to show profile speed. The intent shall be to provide the engineman with easily understood information about the speed margin remaining before braking will occur.

An alarm shall be provided to alert the engineman of an impending penalty brake application. The selection of control of this shall be made by the automatic change-over circuits. The block overspeed shall have the ability to sound this alarm for signal restriction acknowledgment.

Dual-purpose motive power shall have a passenger-freight selector to alter the braking characteristics. This information shall also be supplied to the profile generator.

4.3.3 System Operation

For an understanding of the apparatus required, the operation of the system will be described by following the sequence of events in a simulated run. Assume the train has been stopped by a signal. When the signal clears, the cab signal shall receive the change and display the new speed limit. Upon the upward change, the profile generator shall sense this change and move the outer pointer of the meter (profile speed) rapidly to indicate the new speed limit. It shall remain there until the code changes again. The inner needle shall indicate actual speed as the train accelerates. The outer pointer shall be the speed limit, so for proper operation of the vehicle the engineman must always keep the inner needle (actual speed) at a lower reading than the outer (profile).

During normal train operations, if the train enters a block with a more restrictive signal and the train speed is greater than the new speed limit, the cab signal shall change and the engineman shall be required to acknowledge to silence the alarm and prevent penalty braking. At this point, the profile generator shall begin its action. The outer pointer shall slowly begin to decrease, following a preprogrammed speed-distance (profile) curve. The engineman shall be allowed to use whatever means are available to him to slow the train; dynamic or air brakes or normal drag of the train, or he may take advantage of an upgrade by simply reducing the throttle. If he does not keep the train speed below the profile, the air brakes shall be applied in the split-reduction mode on freight trains described in section 2.2.2.3. The alarm shall sound warning of a penalty brake application. The engineman shall be required to reset after the penalty stop in the manner described in section 2.2.2.3. With passenger trains in the event the engineman exceeds the profile, the brakes shall be applied and released as described in sections 2.2.2.1 and 2.2.2.2.

4.3.4 Profile Derivation

Because the vital speed-distance profiles shall be derived from braking performance on a level track, some differences will exist when slowdowns occur on grades. When the train is going upgrade, the braking distance will be shorter than on the level, and the engineman should have no difficulty following the profile. On a downgrade, the braking performance may be degraded to the extent that the train may not be able to conform to the profile. In this case, the engineman shall have only to attain full-service braking to prevent penalty. It is expected that he will have already done this to maintain control of the train.

The following two factors will act favorably to limit the occasions where forced braking will be encountered:

- The data used to construct the speed-distance profiles will be conservative, with safety factors included.

- There are few instances in the NEC where the grades are significant enough to cause the train to exceed the profile.

Even though the profile speed may be exceeded on a downgrade, the stopping distance will still be safe because the block lengths will be grade compensated.

Individual profile curves shall be determined by a vital safety curve which shall be, in general, a parabola modified in accordance with braking distance equations described in the NECIP Signaling and Traffic Control System Standards, volume 2, Appendix G, Revised 1-8-80. The safety curve shall be a continuous group of starting points of the maximum allowable envelope or curve for stopping at a fixed point.

To account for various train braking situations, the apparatus shall be externally programmable by the wayside-vehicle transceiver system to follow at least 9 safety curves. The supplier shall be provided the desired safety curves from block layout and train performance information developed for the wayside signal system installation.

Within the vehicle apparatus, the starting or point of origin of control of the profile generator shall be determined by receipt of a more restrictive indication by the cab signal apparatus and an input from the wayside to vehicle transceiver system.

The profile control system shall be continuous and based on the principal of comparing, at each point during a speed reduction, the actual speed of the train and the theoretical maximum allowable determined by the safety curve.

4.3.5 Control Profile Curves

Profile curves shall be provided for control functions for each type of service including:

4.3.5.1 Stopping the train at a fixed point such as a home signal. In this case the profile shall be canceled below 15 mph and the engineman shall be free to complete the stop in a manner consistent with proper train handling.

4.3.5.2 Reduction of speed to a new speed limit, speed limits being defined in section 1.1, e.g., 120 to 80, 80 to 60, 60 to 45, etc. The profile shall be canceled upon achievement of the new speed limit.

4.3.6 Control Techniques

It is expected that digital control techniques will be used in the apparatus for developing the profile curve. Means shall be provided in accordance with the requirements of section 2.1.3, Train Safety, to isolate the control apparatus, provide redundancy where applicable, and provide continuous self-checking routines.

The apparatus shall be programmed in an approved language suitable for and commonly used in real-time control applications. The programming shall be fully documented, the documentation explaining the function and purpose of the various segments and code routines. Explanations shall be provided for the protection features provided in the programming. Changeable parameters related to the equipment and wayside shall be placed into unified and modularized locations, such as programmable read-only memories, so that modifications can be made if the equipment and wayside requirements change.

4.4 VEHICLE-WAYSIDE TRANSCEIVER SYSTEM

4.4.1 System Description

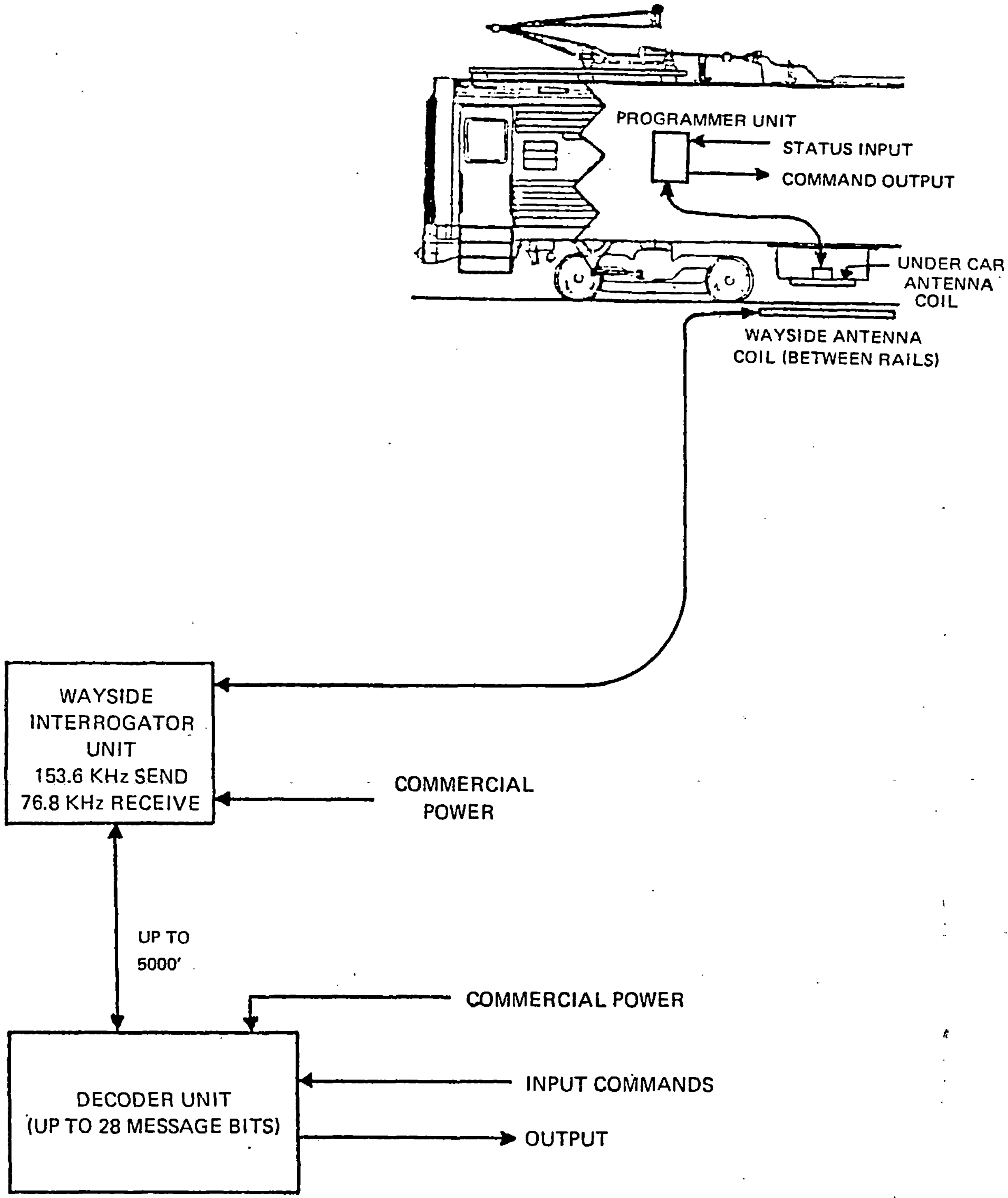
4.4.1.1 General

This system shall provide for secure two-way transmission of information between the vehicle and wayside at appropriate points along the NEC. At these points, fixed wayside transceivers will be placed to allow duplex communication of control and status information between the vehicle and wayside during the period of passage of the vehicle over the transceiver.

It is intended that this system shall be used for control of ATC activate-deactivate functions, for activation-deactivation of the F2 carrier receiver and for transfer of data to the profile guidance system. It is desirable that the system be expandable to allow for train identification and for other control functions including eventual operation of a civil speed restriction system.

Data transmission shall be in the form of high-speed digital data (figure 4.3). The carrier frequencies shown represent a suitable set.

The transmission medium shall be by inductive coupling. The signal shall be transmitted from the car or locomotive by a small loop antenna on board and will be received by a similar loop antenna located on the wayside. The signal will



DE LEUW, CATHER / PARSONS NECIP PROGRAM MANAGERS WASHINGTON, D.C. 20036	NEC GATE DATA TRANSMISSION SYSTEM FIGURE 4 - 4	LOUIS T. KLAUDER AND ASSOCIATES Consulting Engineers Philadelphia National Bank Building Philadelphia, Pa. 19107

be sent to the wayside interrogator. The interrogator, in turn, will transmit the digital information to a decoder logic unit.

4.4.1.2 Principles of Operation

The system shall work on the active-transponder principle. The vehicle-carried equipment shall contain a means of encoding information such as ATC status indication and a signal source for transmission of the information between the vehicle carried loop antenna and the wayside loop. The electronic circuitry on the vehicle shall be normally inactive when not directly over the wayside antenna. A high-frequency signal shall be continuously transmitted from the wayside loop antenna. The train-carried circuitry shall be activated and timed from the wayside antenna when the train-carried loop antenna is positioned directly over the wayside loop antenna. When the train-carried equipment is activated, it shall, in turn, transmit a phase-modulated signal at a suitable frequency different from the wayside transmitting frequency which shall contain the digital information from the train. The data rate shall be suitable for transmission of two complete messages at 150 mph train speed.

The wayside loop shall transmit command information and serve as a receiving antenna which, in turn, shall send the received signal to the interrogator where it shall be demodulated into a digital signal and retransmitted to the decoder logic unit to be converted into command outputs.

The control techniques used in the apparatus for developing the command outputs shall be provided in accordance with the requirements of section 2.1.3 Train Safety. Means shall be provided to isolate the control apparatus, provide redundancy where applicable and to provide continuous self-checking routines on both a system and major subassembly basis.

4.4.1.3 Message Format

The message format superimposed on the signal sent from the train to the wayside shall contain a minimum of 35 usable bits of information, a parity bit, and a 6-bit BCH error-checking code for message security. The usable bits of information shall be decodable as separate contact inputs and outputs or used to convey decimal number information when divided into multiple bit groups.

4.4.1.4 <u>Equipment Description, Vehicle to Wayside Programmer</u>

The programmer shall contain all of the vehicle-carried electronics and shall consist of an enclosure which shall be designed for rack mounting. Sufficient connectors shall be provided to accept inputs from and give outputs to vehicle-carried equipment which is to be monitored or controlled, and to provide inputs and outputs associated with the car-carried antenna coil. Circuit cards, wiring and various components shall be furnished in accordance with system safety standards described in other portions of this specification.

4.4.1.5 <u>Vehicle-Carried Antenna Coil</u>

The vehicle-carried antenna coil shall be mounted on the underbody of the train on a longitudinal centerline. It shall be connected only to the programmer. This coil shall provide the two-way inductive transmission path from the vehicle to the wayside loop antenna. The vehicle-carried antenna coil shall be mounted between 12 and 16 inches above top of rail. A minimum spacing of 6 inches shall be maintained between the vehicle-carried antenna coil and any metallic surface of the vehicle.

4.4.1.6 <u>Wayside Elements</u>

While not part of this specification, typical way-side elements required are described for complete-ness of understanding.

- <u>Wayside Loop Antenna</u>

The wayside loop antenna shall be designed for mounting in a position between the running rails. It shall be encapsulated in a weatherproof fiber-glass package. The unit shall be at least 48 inches long by 6 inches wide and 1-1/2 inches deep. The molded fiberglass shall be sufficiently strong that no damage results from track mainte-nance personnel walking on it. Impact resistance and other mechanical properties are described in the wayside elements specification.

- <u>Interrogator</u>

The interrogator shall provide the excitation signal required to send and receive the data. It shall be able to be installed up to 100 feet from the wayside antenna coil and housed in a weather-proof enclosure. The interrogator shall be able to send the return message up to 5,000 feet to the decoder logic unit through an appropriate cable.

- Decoder Logic Unit

  The decoder logic unit shall recover the received data from the interrogator, check the message for errors, and provide the necessary outputs. The unit shall be designed for mounting in a standard 19-inch-wide equipment rack in a weatherproof area. It shall operate from 117 VAC, 50 or 60 Hz power.

  The message output from the decoder logic unit shall be a minimum of 35 bits of parallel data over form A dry-reed relay contacts, with a capacity of 1/2 ampere maximum, 50 volts DC maximum or 10 watts maximum DC resistive load. For circuits where train safety will be involved, it shall be necessary for any relay or other logic devices to be constructed in accordance with the requirements as described in section 2.1.3.1.

4.4.2 Description of Automatic ATC Activation (NEC Gates)

Although this specification applies only to the vehicle-carried equipment, for a complete understanding of the requirements, a description of operation of the entire system is given.

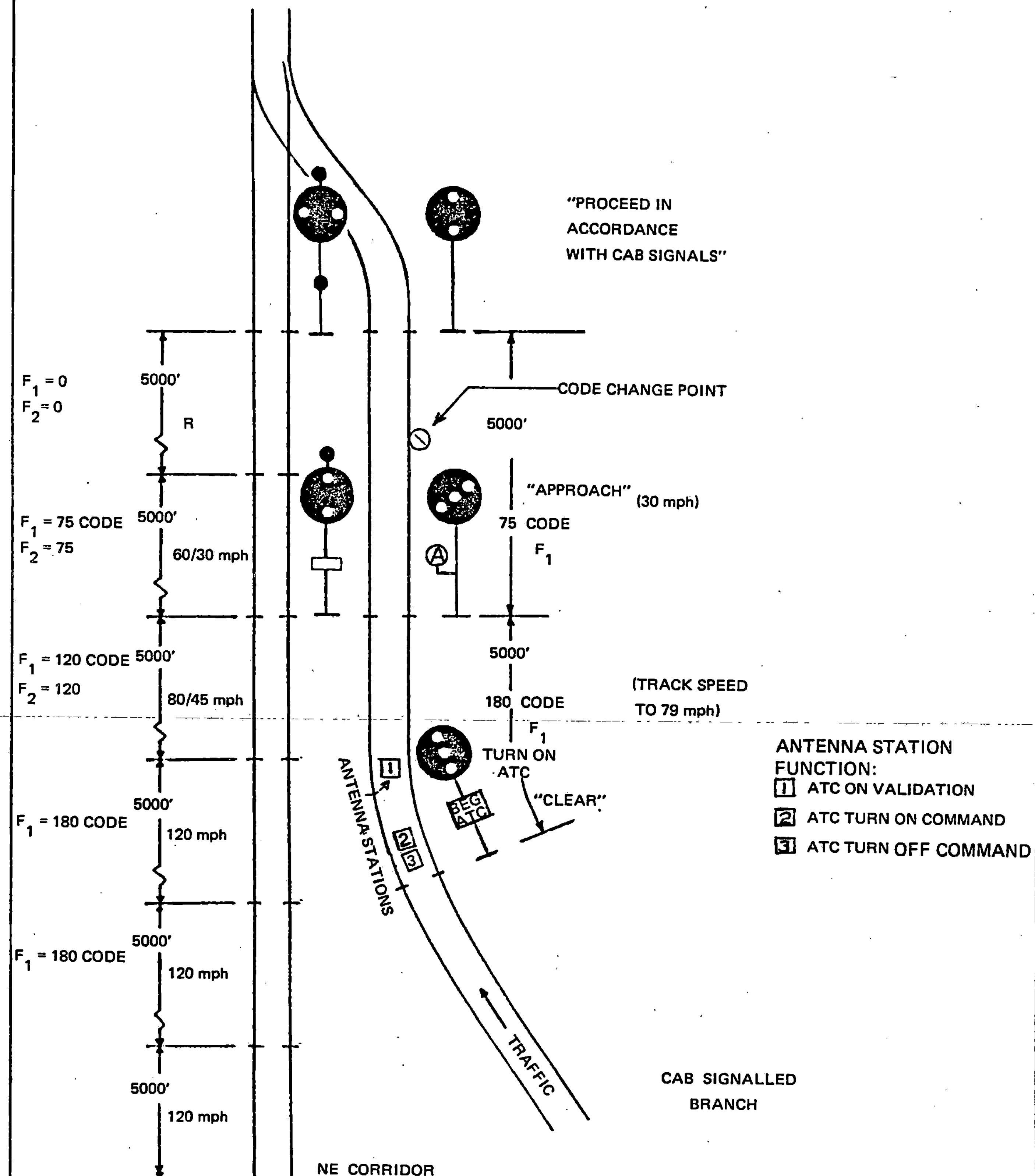
4.4.2.1 Entrance Sequence

Figure 4-4 is a diagram of a typical NEC entrance-exit sequence of operation. Antenna stations 2 and 3 are shown separately to aid in understanding system operation. With the actual apparatus, stations 2 and 3 would be different functions provided through a single antenna. As the vehicle approaches the NEC entrance on a cab-signal-equipped branch, the cab signal will indicate CLEAR and the vehicle should not exceed track speed.

- Antenna station 3 shall have no effect, because this station shall be used when leaving the NEC.

- Passing antenna station 2, the vehicle will receive an ATC ON command which shall cause the ATC apparatus to be activated. This shall be indicated to the engineman by a green ATC light being lighted within his normal field of vision.

- At antenna station 1, which is at a distance from antenna station 2 representing the time at normal speed required for the ATC system to be activated



DE LEUW, CATHER / PARSONS NECIP PROGRAM MANAGERS WASHINGTON, D.C. 20036	"NEC GATE" DIAGRAM FIGURE 4 - 3	LOUIS T. KLAUDER AND ASSOCIATES Consulting Engineers Philadelphia National Bank Building Philadelphia, Pa. 19107

and stabilized, the vehicle will receive a signal asking if the ATC system is operating. The vehicle shall verify and send back to antenna station 1 the verification information. This information will be passed on to the wayside signal system resulting in the stop indication on the entrance wayside signal changing to proceed (depending on other traffic conditions), allowing the vehicle to move into the NEC. At the approach signal, an illuminated sign shall be lighted "A", indicating to the engineman that the wayside has accepted the ATC ON signal from the vehicle.

- The lack of a verification signal shall cause the wayside entrance (home) signal to remain in stop position, prohibiting the vehicle from entering the NEC. In this event, the cab signal shall drop to RESTRICTING (or R) within stopping distance of the wayside signal.

4.4.2.2 Exit Sequence

- When leaving the Corridor, the vehicle shall receive a TURN OFF ATC command at antenna station 3. The vehicle control shall then revert to the cab-signal-only mode of operation with normal lack of acknowledgement penalty braking provided.

- When leaving the Corridor to industrial trackage or other low-speed locations, the gate apparatus shall not be used. In this case the ATC will remain activated, the cab signal shall go to R and speed shall be limited to 15 mph. Upon entry to the Corridor, the equipment shall then respond as it would to any upward change of cab signal.

4.4.3 Manual ATC Activation and Deactivation

A switch sealed in the normal position shall be provided to activate or deactivate the ATC in the event of automatic system failure. The switch shall be of three position design with momentary action either side of center (normal) for activation and deactivation. This switch and various others necessary for manual intervention in the system shall be mounted on or near the apparatus cabinet. The switches shall not be accessible to the engineman from the normal operating position. Figure 4-5 shows a proposed panel layout.

4.4.4 Non-Cab-Signal Territory Operation

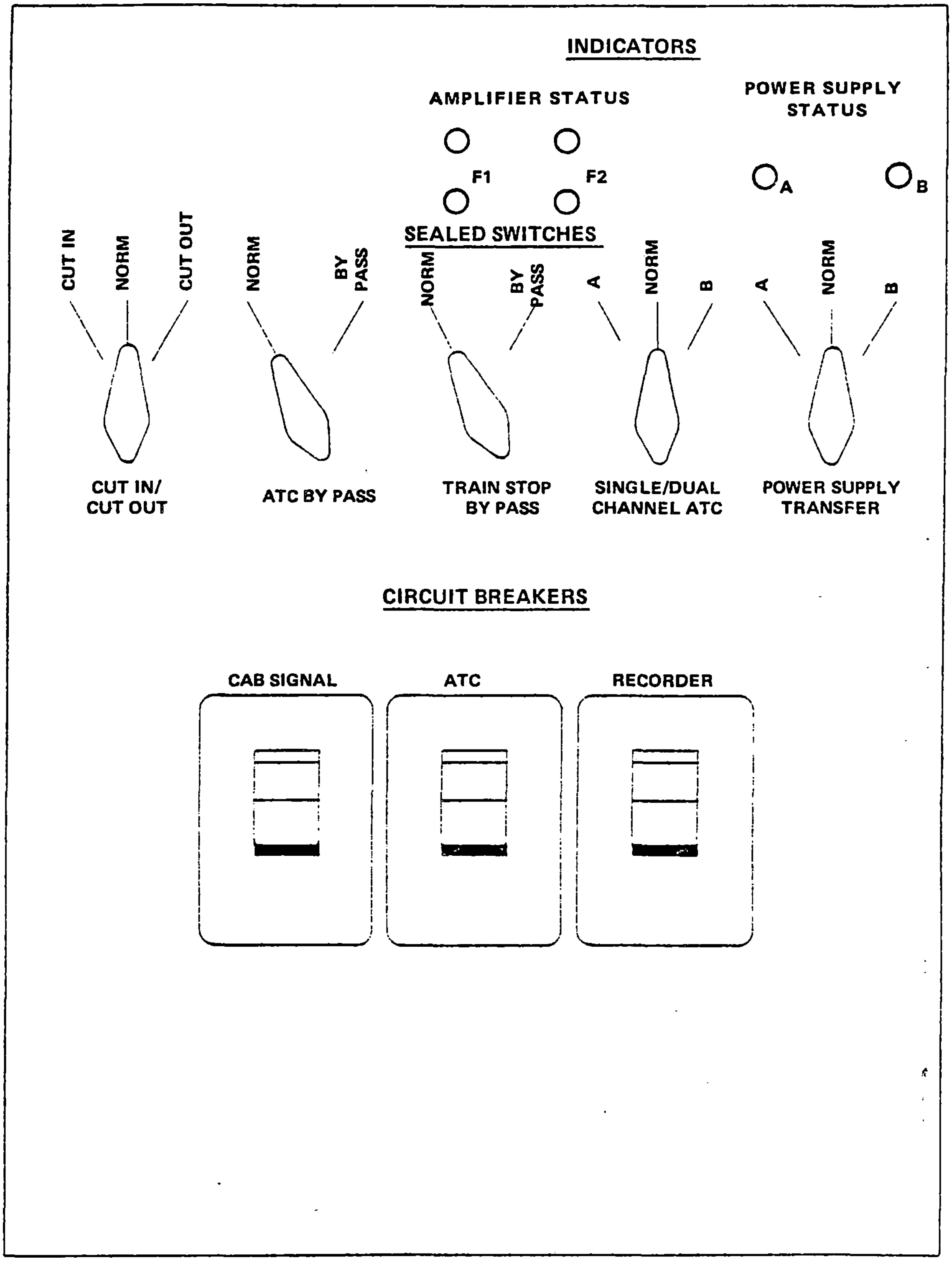
To operate in territory without cab signals, a three position, momentary-contact, center-neutral switch shall be furnished. Switch positions shall be (cab signal) CUT IN and CUT OUT. When operated to the CUT OUT position, the switch and its repeater relays shall darken all cab signal aspects and through the ATC equipment impose a 79 mph speed limit. System reaction to switch operation shall be sufficiently slow to preclude simulation of any cab signal code by its use. This switch shall be mounted near the speedometer-indicator panel.

Upon entering cab-signal-equipped coded territory, any code received shall break the stick circuits and cause the cab signal to be displayed. At this time it shall be necessary to acknowledge to reset the acknowledging circuits. The speed limit shall be removed.

Upon entering an NEC gate (with ATC activated), the above circuitry shall be arranged so that the cab signal shall remain cut in independent of switch operation.

4.4.5 F2 Carrier Receiver Activation and Deactivation

For operation in territory without the F2 carrier and where coded 200 Hz is used in certain interlockings, a two-position switch shall be located within the engineman's reach on the cab signal/speedometer/indicator panel shown in Figure 3.2. that shall activate or deactivate the F2 receiver circuits when placed in the ON or OFF position. This function also shall have the capability of being automatically activated by means of the vehicle-wayside transceiver system.



DE LEUW, CATHER / PARSONS NECIP PROGRAM MANAGERS WASHINGTON, D.C. 20036	SWITCH AND INDICATION PANEL FIGURE 4 - 5	LOUIS T. KLAUDER AND ASSOCIATES *Consulting Engineers* Philadelphia National Bank Building Philadelphia, Pa. 19107

5.0 TRAIN PERFORMANCE RECORDER (TPR) SYSTEM

5.1 Scope

This section establishes the requirements and equipment details for a multichannel magnetic-tape recording system to record important parameters of performance. This system will be required for all control vehicles (locomotives and cab cars) operating under the Northeast Corridor signaling and traffic control system.

5.2 Requirements

The operational features and technical details of the TPR are as follows.

5.2.1 Operational Features

The system shall be energized and the recorder shall operate whenever the vehicle cab signal circuits are activated.

The system shall provide for recording:

- Elapsed time in at least 1 second increments
- Speed in 2 mph increments to 160 mph (may be derived)
- Distance travelled resolved in at least 50-foot increments (compensated for wheel wear)
- Cab signal indication - seven aspects
- Independent brake on or off (freight only)
- Brake pipe pressure or analog control current, P-wire
- ATC (cut in) or (cut out)
- ATC overspeed activation (recoverable brake)
- Penalty brake application (non-recoverable)
- Throttle position - on or off
- Direction of travel.

It is assumed that some parameters will be recorded as analog functions. Where applicable, certain other parameters may be recorded as on-off or step functions. To secure the required recording capacity, a digital conversion system may be used separately, or in combination with a simple multiplexing system.

5.2.2 Functional Features

- The speed signal input shall be obtained from the active speed sensor. These sensors are specified in section 4.1 of this specification. The same speed signal shall also be supplied to the speed indicator and the ATC system. The recorder signal conditioning apparatus shall be electrically isolated from the speed sensor by optical or equivalent (from an isolation standpoint) means to ensure no interaction between the ATC and recorder systems. The isolation device must be able to withstand transients as described in section 6.2, power supply design characteristics.

- Elapsed time and distance traveled shall be recorded as functions of the recorder clock system and the output of the speed sensors, respectively.

- The regulated recorder power supply may be used to record contact-closure events. Functional isolation shall be provided between the recorder and devices being recorded.

- Events shall be recorded coincidentally with the speed signal at time of occurrence. The recorded indication shall persist for the duration of the event except for those event records which are multiplexed with others. In this case it is expected that it will be obvious upon analysis of the record, that the event was multiplexed.

- Air-to-electric transducers shall not contain sliding contact surfaces to vary the electrical output unless a service life of at least 10×10^6 cycles can be expected. Where possible, it is preferred that strain gauge type pressure transducers and appropriate signal conditioning equipment be used for analog measurement of air brake pressure parameters.

- Transducers shall withstand a 25-percent overpressure with no damage or degradation of performance.

- The case volume of the pressure element enclosure for each transducer shall not exceed 55 cc.

5.2.3 Recorder Features

The recorder shall be of the magnetic-tape type using a continuous-loop, or simulated continuous loop, self-erasing tape capable of storing information for 24 operating hours. The tape shall be installed in a cartridge that can be easily applied to and removed from the recorder.

5.2.3.1 Mechanical

The recorder case must protect the recorder from the normal railroad environment and must also include the ability to ensure survival of the stored information after the maximum credible accident.

Renewal parts for the recorder and related items of the system shall be readily available. The Contractor shall supply a parts catalog as specified in section 2.4.3.

The recorder system shall be designed so that calibration and test can be accomplished in a reasonably well-equipped railroad electronics shop. The Contractor shall provide a list of required equipment, including a portable, self-contained calibration set, and suitable instructions.

5.2.4 Playback Features

Playback and recovery of the recorded information shall be accomplished by inserting the tape magazine into a playback device, which is not covered by this specification. The recorded information shall be such that it can be readily transferred from the playback device to commercial data processing equipment. The complete recorder system shall be designed to permit an accuracy of recovered data after playback of $\pm$ 5 percent.

5.2.5 Power Supply

The TPR shall have a separate power supply integrated with the recorder unit and fed from the vehicle battery through a separate protected branch circuit.

- The case shall be designed to allow ease of access for tape replacement and recorder repair.

- Provision shall be made for locking and/or wire sealing of the case. The case shall be designed and constructed to resist unauthorized entry when locked.

- Shock mounting shall be provided to satisfy the vibration requirements specified herein.

- The design shall provide for natural convection cooling and for electromagnetic shielding from possible external radiation. The recorder shall be readily accessible for removal or replacement.

- Connection to the recorder shall be through MS F or R connectors compatible with connectors used in the other portions of the cab signal/ATC apparatus.

5.2.3.2 Electrical

- The recorder is to operate on nominal control voltages of 37 or 74 VDC. Total power consumption shall not exceed 50 watts.

- The recorder shall continue to function as specified to 60 VDC on 74 Volt systems and to 30 VDC on 37 Volt systems. Operation to specification at lower voltage is desirable. The recorder shall not be damaged by operation with low voltage (to zero) for any period of time.

- The recorder shall continue to function as specified to 80 VDC on 74 Volt systems and to 40 VDC on 37 Volt systems. Operation to specification at higher voltage is desirable. The recorder shall be disconnected automatically for equipment protection in the event of higher input voltage.

- The recorder shall start automatically upon restoration of normal operating voltage limits if operation is stopped by low or high voltage.

- The recorder shall be protected from damage caused by accidental application of reversed supply voltage polarity.

- The recorder shall be protected against input power supply transients and induced transients on sensory input lines. Expected power supply transients are described in section 6.0, Power Supplies.

- The locomotive structure is considered to be ground. Car and locomotive control systems are ungrounded. Grounding of the recorder electrical system is therefore prohibited, and isolating of inputs from ground and from each other shall be provided.

5.2.3.4 Environmental

The Contractor shall provide design and mounting to withstand the environmental requirements of section 2.1.6.

5.2.3.5 Recording Tape

Tape shall be instrument-quality magnetic recording tape enclosed in a metal or plastic cartridge, to allow removal and handling as a unit without threading. The cartridge shall be clearly marked and indexed to ensure proper insertion into the recorder.

Tape shall be in a continuous loop or simulated continuous loop, self-erasing and shall provide at least the last 24 operating hours of stored information.

The tape and tape cartridges shall have a minimum shelf life of 10 years with no degradation of performance. Date of manufacture shall be clearly indicated on the outside of the cartridge.

Provision shall be made on the cartridge for labeling for identification purposes.

5.2.3.6 Self-Test

A switch shall be provided, accessible when the recorder cover is open, to make a self-test or operating check of the recorder. It is desirable that the test show on the recording, discernible from normal recordings.

5.2.3.7 Maintenance

The recorder shall be essentially a maintenance free device. Head cleaning and demagnetizing shall be the only maintenance tasks required at monthly or quarterly periods. Heavier maintenance shall be required at intervals of not less than 6 months (preferably 12 months). The Contractor shall specify maintenance requirements.

The recorder shall be designed to allow repair by reasonably competent railroad personnel. The Contractor shall supply manuals as specified in section 2.4.3.

6.0 CAB SIGNAL/ATC POWER SUPPLIES

6.1 Configuration

The cab signal and ATC equipment shall be operated from one of two redundant power supplies. Circuit protection shall be arranged to provide a separate circuit-breaker-protected output to the ATC equipment which shall be current limited such that power to the cab signal equipment is not interrupted during the time it takes to clear an ATC fault. The feed to the cab signal equipment shall also be protected by circuit breaker. A separate circuit-breaker-protected output shall be provided to operate the cab indications and the cab signal as described in section 3.7. Control of this voltage level shall be by a cab-mounted device and shall be operable only in the active cab.

Two power supplies shall be provided, each of which shall be capable of supporting the entire cab signal/ATC load. These two power supplies shall be individually fed through separate circuit-breaker-protected branch low-voltage circuits. Only one power supply shall be functioning during normal operation. An automatic power supply selection circuit, alternating between the two power supplies, triggered by control stand energization shall be provided. A manual changeover switch shall be provided, sealed in the normal position for use in case of power supply or changeover circuit failure. Indicator lights shall be provided at the changeover switch to present power supply status.

6.2 Design Characteristics

If not included within the cab signal/ATC apparatus (the preferred method), the two power supplies shall be housed in a single rugged enclosure with the main output and input connections made by environment-resistant MS series F or R plug connectors. The two supplies shall be easily removeable from the main housing and shall have plug electrical connectors. Input circuit breakers and changeover equipment shall be mounted in the main housing in a manner to provide easy access for maintenance and inspection.

The individual power supplies shall be of the inverter-transformer-rectifier regulator type with complete DC isolation between input and output (500 megohms at 500 VDC minimum). Output voltage shall be 32 VDC $\pm$ 1 percent over the full range of input voltage (74 or 32 VDC nominal $\pm$ 20 percent) and over the full range of rated load. Output ripple shall be 1 percent maximum. The equipment shall be protected against low-voltage power transients. Transients of 2500 V peak with energy content of 50 watt-seconds are to be expected.

The final circuitry and design of the power supply equipment shall be submitted to the customer for review and approval.

7.0 CAB SIGNAL/ATC TEST REQUIREMENTS AND APPARATUS

Although this specification applies only to the vehicle carried cab signal/ATC apparatus and the test apparatus described within this section, for a more complete understanding of the requirements, a description of the proposed tests is given herein. Exact details of the test would be dependent on the type of vehicle and the final design of the apparatus.

7.1 CAB SIGNAL/ATC TESTING, GENERAL REQUIREMENTS

A test of the cab signal/ATC apparatus shall be made over track elements or test circuits controlled by test apparatus permanently installed on the wayside, or where such apparatus is not installed, with a portable test set, either on departure of a vehicle from its initial terminal or, if cab signal/ATC apparatus is disconnected from the battery supply between initial terminal and equipped territory, prior to entering equipped territory, to determine if the apparatus is in service and functioning properly. If a vehicle makes more than one trip in any 24-hour period, only one departure test shall be required in such 24-hour period.

A departure test on a single-unit vehicle equipped for forward and backward running shall be made from both ends.

When two or more vehicles or locomotive units are coupled at their initial terminal, the departure test shall be made from the front end of the leading unit. When an intermediate unit is required in relay service, this unit must also be tested and a prescribed form filled out by an authorized employee, unless test equipment is available at the relay point.

When two or more units are coupled and it becomes necessary enroute to operate from control stations from which the departure test of cab signals and ATC has not been made, the ATC and cab signals must be considered as not in operative condition.

7.1.1 Daily Test Procedures (Departure)

The test will be conducted from within the vehicle cab using the test set and the engineman's control station. If a permanent test track or loop is not available, a portable test loop must be positioned under the track receivers prior to starting the test. Carrier-current outputs on both carrier frequencies from the test set must be adjusted to 1.8 amperes with a noncoded carrier. The vehicle-mounted equipment shall respond to a track current of 1.8 amperes or higher and shall not respond to a track current of 1.5 amperes or less.

If portable loops are used, means shall be taken in their design to ensure that the use of such devices provides equivalent signal fields to that produced by the proper rail currents.

7.1.1.1 Speed-Limit Reduction Tests

The first portion of the test will determine the ability of the system to respond properly during progressive reductions of allowable speed limits, starting at the highest speed according to the following procedure.

To start the test, an allowable speed-limit test signal of 120 mph (180 code F1) will be inserted into the installed test-track section or loop to indicate 120 mph or N for normal speed. The simulated vehicle speed signal then must be dialed to 120 mph.

On vehicles with seven-aspect cab signal apparatus, the allowable speed-limit test signal will then be reduced to 80 mph (120 F1 - 120 F2 codes), and the cab signal indication must read 80. The overspeed lamp must be lighted and the audible alarm must sound. The audible alarm will be silenced by actuating the acknowledgment device. After 5 seconds, an ATC brake application (full service) must be observed on the brake-cylinder gauge. The simulated vehicle speed signal must then be slowly dialed to 80 mph. The overspeed lamp must be observed to go out below 83 mph, the controller and/or throttle and brake valve will then be moved to the suppression position, and the brake may then be released.

The speed limit test signal will then be reduced to 60 mph (75 F1 - 75 F2 codes) and the test will continue as described above and in table 7-1.

On vehicles with four-aspect cab signal equipment, the first reduction in the allowable speed-limit test signal is from 120 mph to 45 mph (rather than 80 mph), and the simulated vehicle speed signal is dialed to 45 mph (rather than 80 mph) observing that the overspeed lamp goes out at 48 mph.

Testing for both types of equipment shall continue in the same manner until the allowable speed-limit test signal is R and the simulated speed signal has been reduced to 19 mph, at which time no acknowledgment action will be taken. Five seconds after the speed test signal aspect is reduced to

TABLE 7-1
SUMMARY OF TEST PROCEDURES, PART 1

Speed-Limit Test Signal (mph)	Simulated Speed Test Signal (mph)	Cab Indications	Action
120	120	120	Release Brakes
80	120	80, alarm, and over-speed light	Acknowledge, ATC brakes will apply
80	120 to 80	80	Release Brakes
60	80	60, alarm, and over-speed light	Acknowledge, ATC brakes will apply
60	80 to 60	60	Release Brakes
45	60	45, alarm, and over-speed light	Acknowledge, ATC brakes will apply
45	60 to 45	45	Release brakes
30	45	30, alarm, and over-speed light	Acknowledge, ATC brakes will apply
30	45 to 30	30	Release brakes
R	30	R, alarm, overspeed light, and flashing light	No action taken; penalty brake application shall occur after 5 sec.
R	0	R	Acknowledge and release brakes

R, a penalty brake application will occur and the overspeed lamp will change from a continuous to a flashing indication. By moving the controller or brake handle to the suppression position, the brakes may be released when the simulated speed signal is reduced to zero and the flashing overspeed lamp is extinguished.

7.1.1.2 Train Speed Increase Detection Test

The second part of the test will determine the ability of the overspeed system to respond properly to progressive increases in train speed over that authorized by the cab signal speed-limit indications. As in the first part, the test will be conducted from within the vehicle cab using the test set and the engineman's control station. The test will consist of progressive steps, starting at the lowest speed in accordance with the following procedure.

To start the test, an allowable speed-limit test signal of 15 mph (no code) will be inserted into the test track or loop. The cab signal must indicate R for restricting. The simulated vehicle speed signal, which has been at 0 mph, will then be dialed to 18 mph and the overspeed lamp must light. After 5 seconds, an ATC brake application will be observed on the brake cylinder gauge.

The allowable speed-limit test signal will be raised to 30 mph (75 F1 code). The overspeed lamp must go out, and the brakes will be released by repositioning the controller and/or brake handle. The simulated speed signal will be raised to 33 mph and the overspeed lamp must light. After 5 seconds, an ATC brake application will be observed on the brake cylinder gauge. The allowable speed limit test signal will be raised to 45 mph (120 F1 code). The overspeed lamp must go out and the brakes may again by released by the repositioning of the controller and/or brake handle.

The testing will continue in this manner until the overspeed point for all allowable speed limits has been checked as shown in table 7-2.

The above procedures are a general outline of tests for all vehicles. Specific procedures will be developed for each class of vehicle. For example, in all cases, to properly test the vehicle it will be necessary to move the throttle, brake

TABLE 7-2
SUMMARY OF TEST PROCEDURES, PART 2

Speed-Limit Test Signal (mph)	Simulated-Speed Test Signal (mph)	Cab Indications	Action
R	0 to 18	R and overspeed light	ATC brakes will apply*
30	18	30	Release brakes
30	18 to 33	30 and overspeed light	ATC brakes will apply*
45	33	45	Release brakes
45	33 to 48	45 and overspeed light	ATC brakes will apply*
60	48	60	Release brakes
60	48 to 63	60 and overspeed light	ATC brakes will apply*
80	63	80	Release brakes
80	63 to 83	80 and overspeed light	ATC brakes will apply*
120	83	120	Release brakes
120	83 to 123	120 and overspeed light	ATC brakes will apply*
120	0	120	Release brakes

* After 5 seconds

valve, and/or master controller. The specific procedure for each class of vehicle will provide the method of accomplishing this without permitting vehicle movement under power.

When the vehicles are modified to include the test receptacles, appropriate changes shall be made to the control apparatus so that insertion of the test plug will, where possible, allow the vehicle control equipment to remain operative but cut off traction power. Where this is not possible, manual procedures shall be provided to deenergize appropriate traction control groups.

7.1.2 Periodic Tests

Periodic inspections and tests of the cab signal and ATC systems shall be made in accordance with the following outline:

- Inspect the track receivers and associated wiring for height above rail and general condition. Repair or adjust as necessary.
- Inspect the speed sensors and associated wiring for general condition. Repair as necessary.
- Calibrate speed sensors.
- Make insulation-to-ground test.
- Measure supply voltages.
- Check relay dates and replace out-of-date relays.
- Measure resistance of each decoding relay coil.
- Measure decoding relay-coil current (tuned).
- Measure decoding relay-coil current at nearest adjacent code frequency (valley current).
- Measure decoding relay dropout time.
- Measure acknowledging and ATC delay time.
- Measure system threshold track current.
- Make complete operating test (daily test).
- Inspect and clean pneumatic apparatus in accordance with the established schedule of railroad or operating agencies.

7.2 CAB SIGNAL/ATC TEST APPARATUS

7.2.1 Cab signal and ATC testing shall be accomplished with test apparatus permanently installed on the wayside or, where such apparatus is not installed, with a special portable test set. The test apparatus shall have the facility of providing the necessary track codes and a continuously variable vehicle-speed signal. The permanent test apparatus or portable test set shall have the flexibility to be used for checking all vehicles operating on the Corridor.

7.2.2 The vehicles shall be equipped with a receptacle that accepts a plug connection from the test apparatus. Plug location shall depend on vehicle design. If possible, the receptacle shall be so wired that the individual characteristics of each vehicle's speed determination circuits are matched to the test apparatus through the plug connector. By this means, the test set shall be programmed in accordance with the vehicle characteristics so that the simulated speed-signal indication, in the test set, reads directly in miles per hour for that vehicle.

7.2.3 Permanent test apparatus shall be arranged for mounting in standard 19 inch rack mountings enclosed in a weather-tight case suitable for wayside mounting. The front cover of the case shall be hinged at the top and provided with a simple mechanical means to keep the cover open during use. Indicators and controls shall be located on a front panel within the case. The assembly shall be weathertight so that, for example, a test may be made during a driving rain storm without water entering the interior of the apparatus.

7.2.4 Portable test set apparatus shall be mounted in a rugged weatherproof fiberglass suitcase-type container complete with gasketed cover. Indicators and controls shall be located on a front panel within the case. Access to the front panel shall be gained by releasing two latches, located at both sides of the carrying handle, and swinging the cover up and back from the handle. Accessory equipment may be carried in the cover and/or in an auxiliary case. Maximum weight of the test set with container shall be 30 pounds. The test set must accept input power at 110 VAC, 37 VDC, or 74 VDC. The vehicle being tested shall provide power through the test receptacle.

7.2.5 The test-set allowable-speed-signal generator shall provide the following code-rated sinusoidal carrier output signals to the test track or loop at continuously variable levels from 0 to 3 amperes on both carrier frequencies. The selection of allowable speed-signal output shall be by interlocked pushbuttons.

Speed Limit (mph)	Code Rate: Carrier Frequency 100 Hz	Code Rate: Carrier Frequency 260 Hz
R	0	0
30	75	
45	120	
60	75	75
80	120	120
120	180	
150	180	180

7.2.6 A speed-sensor simulator (to simulate both of the vehicle speed-sensor outputs) shall be provided, capable of producing continuously variable speed-test signals by dial setting in the range of 0 to 155 mph. The speed signal output of the test set shall be displayed in miles per hour with a digital indicator.

7.2.7 Included as part of the test-set equipment shall be a portable detachable test loop connected through cables to the set. Where permanent built-in wire loops or track circuits are installed, they may be used in place of the portable loop. In this case, the test set shall act to control the wayside circuits. Standardized cable connectors will be provided on the wayside test-track circuits and loops to connect to the portable test sets.

7.2.8 The test set shall provide self-calibration modes where possible. Where self calibration is not possible, means shall be provided for calibration of the test set instrumentation and functions to laboratory standards traceable to the National Bureau of Standards.

8.0 REFERENCES AND EXHIBITS

8.1 References

- AAR Communication and Signal Section - American Railway Signaling Principles and Practices.
- AAR Signal Manual, volumes 1 and 2.
- IEEE #16, American Standard for Electric Control Apparatus for Land Transportation Vehicles.
- NECIP Task 205: Signaling and Traffic Control System Standards, volumes 1 and 2.

8.2 Exhibits

8.2.1 Reliability and Maintainability

The Contractor shall provide the following documentation to satisfy reliability and maintainability (R&M) requirements:

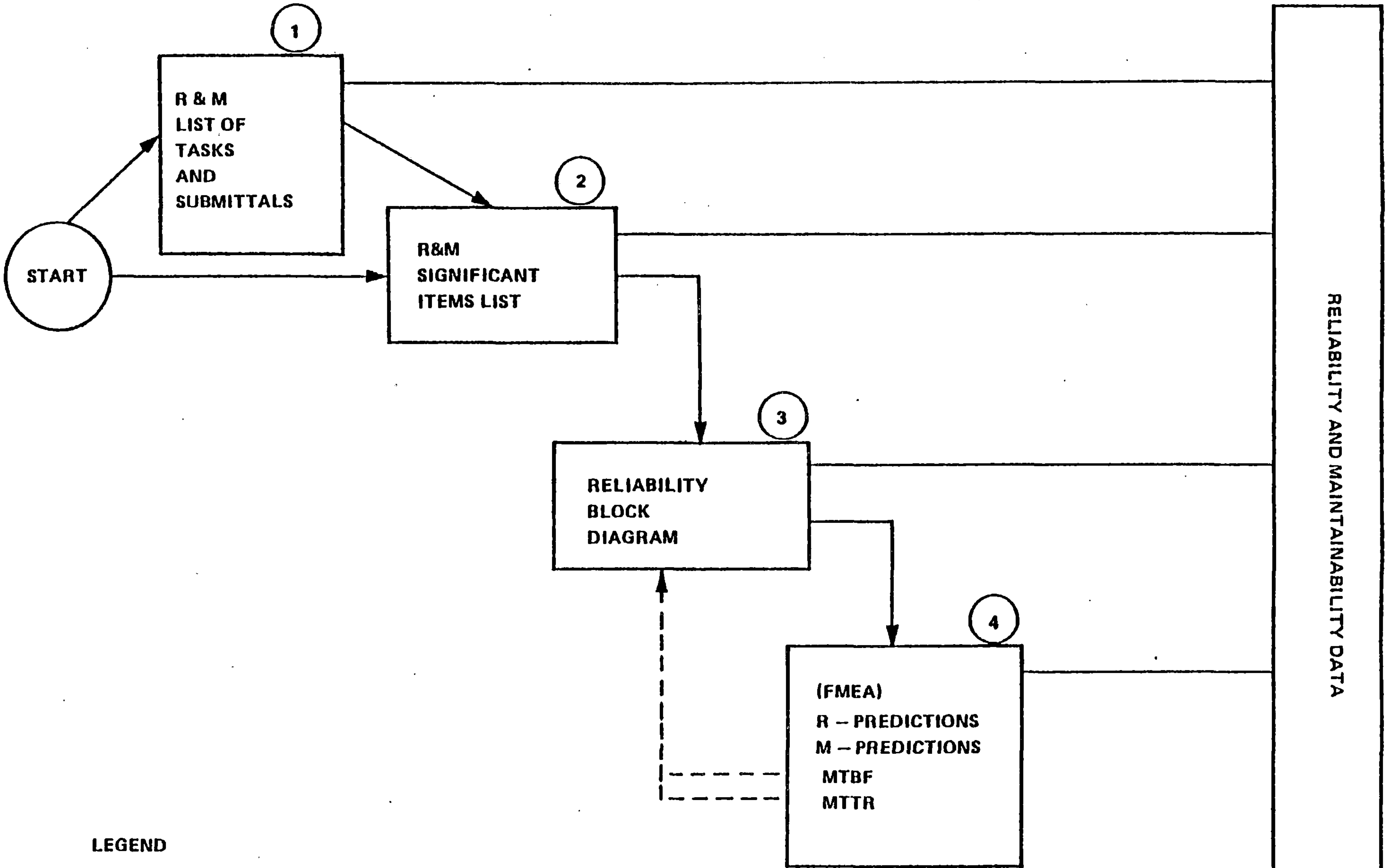
- R&M significant-items list
- Reliability block diagrams
- Failure mode and effects analysis (FMEA). FMEA shall include R&M predictions which shall be developed into the mean-time-between-failure (MTBF) and the mean-time-to-repair (MTTR) for all significant items.
- R&M list of tasks and submissions.

The four R&M documentation requirements are interrelated and supply basic information for defining the R&M characteristics for equipment design. Figure 8-1 illustrates the interrelationships of R&M documentation.

8.2.1.1 R&M Significant-Items List

The R&M significant-items list shall identify those items whose failure is potentially critical to the reliability and maintainability of the indicated systems or whose failure could have a severe safety impact. Significant items are those whose failures may have design features that would compromise R&M or would have a safety-critical impact on personnel or system hardware.

Figure 8-2 is a sample of the form to be used for the R&M significant-items list. This form shall be completed for significant items. R&M significant items shall be



LEGEND

R = RELIABILITY
M = MAINTAINABILITY
FMEA = FAILURE MODE AND EFFECTS ANALYSIS
MTBF = MEAN TIME BETWEEN FAILURES
MTTR = MEAN TIME TO REPAIR

RELIABILITY AND MAINTAINABILITY INTERRELATIONSHIPS

Figure 8 – 1

RELIABILITY AND MAINTAINABILITY SIGNIFICANT ITEMS LIST

(1) PROJECT ____________________

(2) DATE ____________________

(3) PREPARED BY ____________________

(4) ITEM	(5) FUNCTION	(6) BASIS FOR SELECTION AS A SIGNIFICANT ITEM

Figure 8 – 2

identified at the highest identifiable subassembly level. The basis for selection of each significant item shall be identified on the form (item 6).

The Contractor shall develop the reliability block diagram and perform an FMEA including all R&M significant items. R&M significant items require approval by the customer prior to initiating further R&M analytical tasks.

Referring to Figure 8-2, the following information shall be supplied on the R&M significant-items list (the numbers correspond to those on the form):

1. Project - NECIP project

2. Date - date prepared

3. Prepared by - name of person preparing form

4. Item - name of item or system element within the project

5. Function - function of item

6. Basis for selection - information regarding the determination of an item as a significant item.

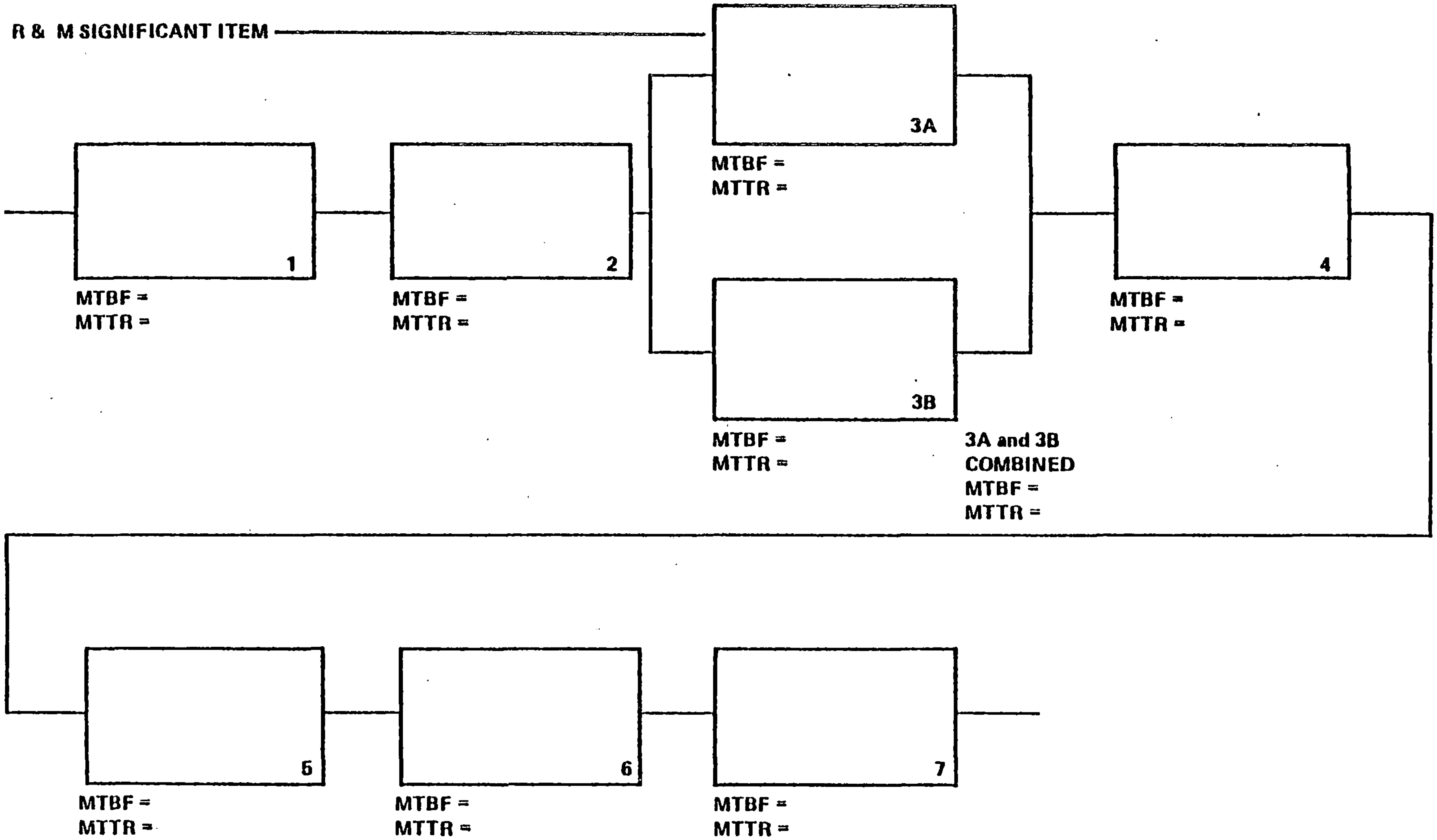
8.2.1.2 Reliability Block Diagram

This diagram shall show the R&M dependency between the various elements of the system. In addition, details on the project, assembly, and part level shall be shown.

The reliability block diagram shall show the effect of failure of items of equipment on the system's functional capability. Items whose failure causes system failure shall be shown in series with other items. Items whose failure causes system failure only when some other item has also failed shall be shown in parallel with the other items. The reliability block diagram shall be initiated to show how the R&M significant items fit in the project design.

The block diagram shall show the first-level breakdown of project. Separate block diagrams shall then be constructed for each of the first-order subdivisions shown to the lowest line repairable unit.

When the FMEA is completed, the calculated MTBF and MTTR values shall be made to determine the overall MTBF and MTTR for each R&M significant item identified. Figures 8-3 and 8-4 indicate the format to be used for the reliability block diagrams.



LEGEND:

R & M = RELIABILITY AND MAINTAINABILITY

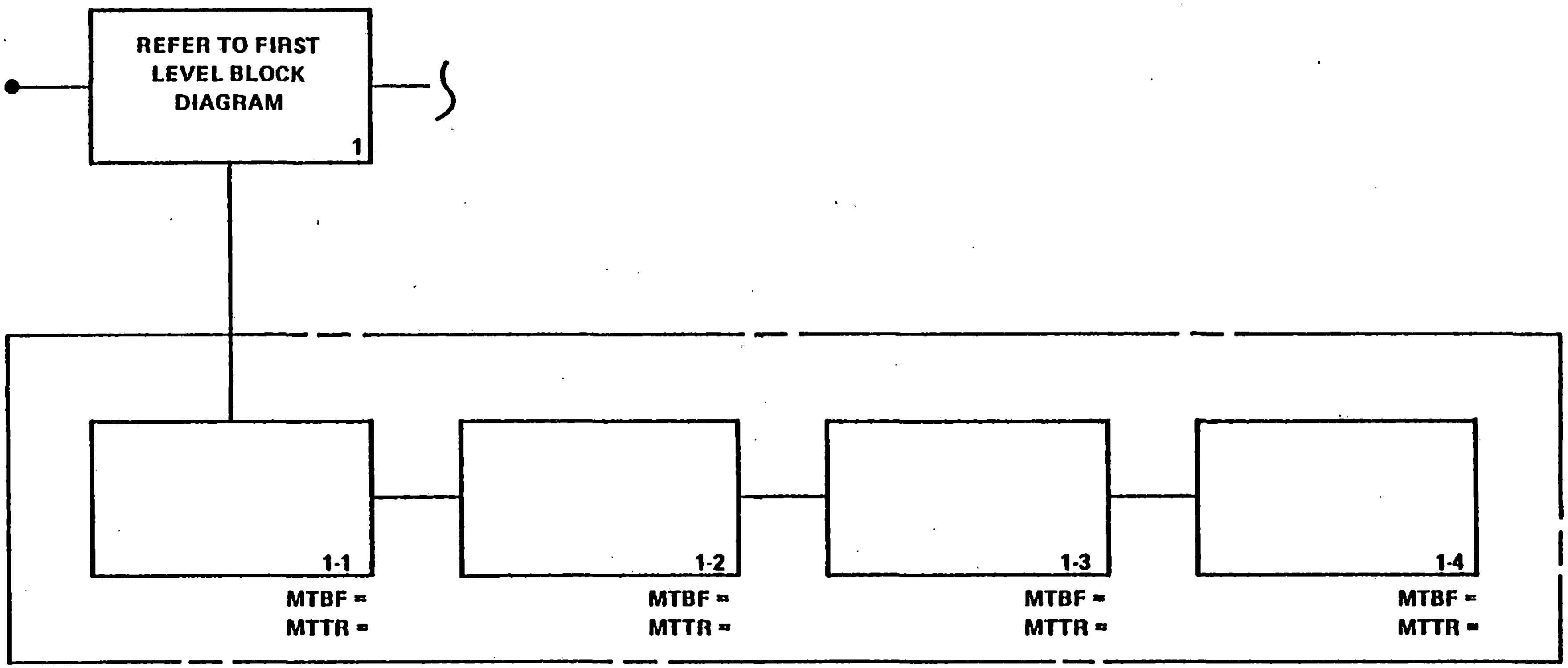
MTBF = MEAN TIME BETWEEN FAILURE

MTTR = MEAN TIME TO REPAIR

Figure 8 – 3

RELIABILITY FIRST LEVEL BLOCK DIAGRAM

R&M SIGNIFICANT ITEM – ______________________



LEGEND

R&M = RELIABILITY AND MAINTAINABILITY
MTBF = MEAN TIME BETWEEN FAILURE
MTTR = MEAN TIME TO REPAIR

RELIABILITY SECOND LEVEL BLOCK DIAGRAM

Figure 8 – 4

8.2.1.3 Failure Mode and Effects Analysis (FEMA)

FMEA shall be performed on all items identified on the R&M significant-items list and to the highest assembly levels possible, or to the line replaceable unit (LRU) level.

The FMEA shall identify the failure modes of all mechanical, electrical, electronic, and control systems equipment, and the results of this analysis shall be used by the Contractor to optimize the reliability and maintainability of design. The Contractor shall perform a prediction analysis to determine the system failure and repair rates as a part of this task. Overall failure rates (expressed as MTBF) and repair rates (expressed as MTTR) shall be determined using information from R&M predictions and other source data (including manufacturer, vendor, and state-of-the-art accepted rates).

Figure 8-5 indicates the form to be used for the failure mode and effects analysis for the unit or subassembly level, and for either a functional or hardware analysis. The following information shall be supplied on the FMEA format.

1. Project - name of NECIP project
2. Unit - name of unit
3. Date - date prepared
4. Prepared by - name of person preparing form
5. FMEA item number - the number of the item block on the reliability block diagram
6. Item nomenclature - the item or circuit name or a brief description of the item if the name is not self-explanatory
7. Function - each enumerated function, numbered consecutively
8. Failure mode - entry describing all possible failure modes leading to loss of the function listed in entry (7), numbered consecutively
9. Failure effects on project - for each failure mode entered in (8), the effect this failure has on the input-output interfaces at the next higher level leading to its effects on the project. Each entry for a given failure mode shall be numbered consecutively.

FAILURE MODE AND EFFECTS ANALYSIS

(1) PROJECT ____________________

(2) UNIT ____________________

(3) DATE ____________________

(4) PREPARED BY: ____________________

(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
FMEA ITEM	ITEM NOMENCLATURE	FUNCTION	FAILURE MODE	FAILURE EFFECT	OBSERVABLE SYMPTOMS	CONTROLS TO REDUCE	FAILURE RATE

Figure 8 – 5

10. Observed symptoms - how the failure mode would manifest itself in readings from instrumentation and/or other indicators. This entry together with entry (9), is to be used in the test and operational phases for failure diagnosis to determine possible causes.

11. Controls to reduce effects - provisions in the design to eliminate the failure or minimize the failure effect on functional performance, such as redundancy, bypasses, and safety margins

12. Failure rate - failure rate occurring under the operational condition to which it is assigned. The reliability prediction worksheet is to be used to provide failure rate information for this entry.

8.2.1.4 <u>Reliability Prediction</u>

Reliability predictions shall form the baseline for calculation of the assembly-level and unit-level failure rates and corresponding MTBF values. Manufacturers' data are the usual basis for the failure rate, augmented by data from standard manuals and specifications.

Figure 8-6 indicates the format to be used for the reliability prediction analysis. The worksheet for the analysis shall include the following information (the numbers correspond to the numbers in the figure):

1. Project - name of NECIP project

2. Subassembly - name of subassembly

3. Item - name of item (when applicable)

4. Part number - part number of the item of subassembly

5. Revision - number indication of the latest revision

6. Prepared by - name of the person preparing work sheet

7. Date - date prepared

8. Item or circuit symbol - name of item or circuit symbol

9. Element or part name - Identifying element or part name of the item or circuit

10. Manufacturer - name of manufacturer.

RELIABILITY PREDICTION WORKSHEET

(1) PROJECT ________ (2) SUBASSEMBLEY ________ PAGE ____ OF ____

(3) ITEM NAME ________ (4) PART NUMBER ________ (5) REVISION ________ (6) PREPARED BY ________ (7) DATE ________

(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
ITEM OR CIRCUIT SYMBOL	ELEMENT OR PART NAME	MANUFAC-TURER	RATED STRESS	APPLIED STRESS	STRESS RATED	QUANTI-TY	K – FACTOR	BASIC FAILURE RATE X 10^6 HRS	ADJUST-ED FAIL-URE RATE X 10^6	REFER-ENCE	REMARKS

Figure 8 – 6

11. Rated stress - maximum allowable wattage that element or part is rated for

12. Applied stress - the identified wattage that will be applied to element or part

13. Stress ratio - ratio of applied to rated stress in decimal form

14. Quantity - number of elements within the subassembly

15. K-Factor - the actual field application number reflecting additional factors, such as humidity, vibration, shock, handling, turn-on, and turn-off. Consult handbooks such as Military Standard 217B (MIL-STD-217B)

16. Basic failure rate - the manufacturer or industry standard failure rate of the element

17. Adjusted failure rate - the adjusted failure rate of the element for stress ratio, K-factor, and temperature usage

18. Reference - the basic reference used to determine basic failure rate and adjusted failure rate

19. Remarks - as appropriate

Reliability is expressed as the mean-time-between-failures, which is simply equal to 1/failure rate (λ). The failure rate (λ) is expressed as failure per unit-hours.

8.2.1.5 Maintainability Prediction

Maintainability predictions shall form the baseline for calculation of the assembly-level and unit-level repair rates and corresponding MTTR values. The information obtained from the predicted failure rate (λ) shall be used with identifying data on the time to:

- Isolate the failure to unit
- Remove unit
- Replace unit
- Repair in place
- Perform a verification test.

Figure 8-7 indicates the format to be used for the maintainability prediction analysis. The worksheet for the analysis shall include the following information (the numbers correspond to the numbers in the figure):

1. Project - name of NECIP project

2. Element - name of element

3. Prepared by - name of person preparing worksheet

4. Date - date prepared

5. Replacement unit - name of replacement unit within element

6. Current predicted failure rate (λ) - failure rate as determined by Reliability Prediction Worksheet

7. Isolate failure to unit - time to isolate failure to unit

8. Remove unit - time to remove unit

9. Replace unit - time to replace unit

10. Repair in place - time to repair unit in place

11. Verification test - time to verify unit replacement functions properly

12. t - minutes for maintenance tasks times conversion factor

13. t - failure rate times the time for maintenance

14. Summation of the failure rates for that element

15. Summation of time for the element

16. MTTR - the total mean time to repair for that element.

8.2.1.6 <u>R&M List of Tasks and Submissions</u>

The submissions for the R&M tasks shall be as follows or as identified in the project scope of work.

The 30 percent submission shall include the R&M significant items list, initial reliability block diagrams, and failure mode and effects analyses, including R&M predictions with MTBF and MTTR analyses. The significant items list will be reviewed, and the Contractor shall then perform the remaining R&M requirements responding to the customer's comments.

The 60 percent submision shall include details of all R&M data.

MAINTAINABILITY PREDICTION WORKSHEET
(ESTIMATED MEAN TIME TO REPAIR)

(1) PROJECT ____________________ (3) PREPARED BY ____________________

(2) ELEMENT ____________________ (4) DATE ____________________

REPLACEMENT UNIT	CURRENT PREDICTED FAILURE RATE	AVERAGE TIME TO PERFORM MAINTENANCE TASKS (IN MINUTES)						
		ISOLATE FAILURE TO UNIT	REMOVE UNIT	REPLACE UNIT	REPAIR IN PLACE	VERIFICATION TEST	$M \times .0166 = t$	$\lambda \times t = \lambda t$
(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	$\sum \lambda =$ (14)							$\sum \lambda t =$ (16)

LEGEND

M = IN MINUTES

t = IN HOURS

λ = FAILURE RATE PER HOUR

$\sum$ = SUMMATION

MTTR = MEAN TIME TO REPAIR

(16)

$$MTTR = \frac{\sum \lambda t}{\sum \lambda} = \_\_\_\_\_\_ = \_\_\_\_\_\_ \text{ HOURS}$$

Figure 8-7

The 90 and 100 percent submissions shall include all updated R&M documentation.

Figure 8-8 summarizes the submissions required at the various design review levels.

8.2.2 System Safety

The Contractor shall provide documentation to satisfy the following requirements.

Preliminary Hazard Analyses and Hazard Mode and Effects Analyses. A preliminary hazard analysis (PHA) shall be performed as early as possible during the initial design phase and submitted for review no later than the 30 percent design review. The analysis shall be performed using the procedure described in the following paragraphs and the format indicated on figure 8-9. The results of this analysis shall identify those major project elements that may have potential safety-critical failure modes for which component-level hazard mode and effects analyses (HMEAs) will be required. In general, HMEAs will be required for category 3 and 4 review, the results of the PHA will be evaluated, and the project components for which more detailed HMEAs are required will be established by the customer. The results of the HMEAs shall be submitted for review no later than the 60 percent design submission. These analyses shall identify component hazardous failure modes and specify actions to be taken or proposed to eliminate or minimize their effects. The acceptability of these actions will be established as a result of the review. A final analysis summary which shall include documentation of the disposition of all safety-critical failure modes shall be submitted at the 90 percent review.

Hazard Categorization. The categories that define the hazard levels of failure modes shall be established in accordance with the following rationale: conditions such that personnel error, environment, design deficiencies, subsystem or component failure, or procedural deficiencies:

- Will not result in personnel injury or system damage (category 1 failure - safe)
- Can be counteracted or controlled without personnel injury or major system damage (category 2 failure - marginal)
- Will cause personnel injury or major system damage thereby requiring immediate corrective action (category 3 failure - critical)

RELIABILITY AND MAINTAINABILITY TASK LIST	SUBMITTAL 30%	SUBMITTAL 60%	SUBMITTAL 90%	SUBMITTAL 100%
● RELIABILITY AND MAINTAINABILITY SIGNIFICANT ITEMS LIST	△		△	△
● RELIABILITY BLOCK DIAGRAM	△	△	△	△
— MEAN TIME BETWEEN FAILURE AND MEAN TIME TO REPAIR LISTING	△	△	△	△
● FAILURE MODES AND EFFECTS ANALYSIS	△	△	△	△
—RELIABILITY PREDICTION	△	△	△	△
—MAINTAINABILITY PREDICTION	△	△	△	△

Figure 8–8

RELIABILITY AND MAINTAINABILITY LIST OF TASKS AND SUBMITTALS

- Will cause death or serious injury to personnel or major system loss (category 4 failure - catastrophic).

Figure 8-9 indicates the format to be used for the PHAs and HMEAs. The following information shall be supplied on the analysis format:

1. Project

2. Major element - the major element of the project being analyzed

3. Component - the component of the major element of the project

4. Performed by - the name of the person performing the analysis

5. Date - date prepared

6. Item number - sequentially number each item

7. Description - brief descriptive title of major element (for PHA) or component (for HMEA) being analyzed

8. Function - brief description of the function of the item

9. Failure mode - listing of the various possible failure modes

10. Failure effect on system - briefly describes the consequences of the failure on system performance

11. Category - Assigned hazard category - a measurement of the system safety criticality of the failure (e.g., categories 1 through 4)

12. System safety assessment - a qualitative assessment of the consequences of the failure (e.g., acceptable, requires testing, requires training, requires redesign, requires redundancy)

13. Corrective action - actions taken to eliminate or minimize the hazard.

8.2.2.1 System Safety Test Requirements

The system safety test requirements shall be included with the 60 percent design submission and the final requirements shall be included with the 90 percent design submission. This information shall be noted on the form for System safety test, operating procedures, and training requirements. (See figure 8-10 for format.)

PRELIMINARY HAZARD ANALYSIS
AND/OR
HAZARD MODE AND EFFECTS ANALYSIS

(1) PROJECT ____________________
(2) MAJOR ELEMENT ____________________
(3) COMPONENT ____________________

(4) PERFORMED BY ____________________
(5) DATE ____________________

(6) ITEM NO.	(7) DESCRIPTION	(8) FUNCTION	(9) FAILURE MODE	(10) FAILURE EFFECT ON SYSTEM	(11) HAZARD CATEGORY	(12) SYSTEM SAFETY ASSESSMENT	(13) CORRECTIVE ACTION

Figure 8 – 9

SYSTEM SAFETY TEST, OPERATING PROCEDURES, AND TRAINING REQUIREMENTS

PROJECT COMPONENT	SAFETY CRITICAL – FAILURE MODE	TEST REQUIREMENTS	OPERATING PROCEDURES	TRAINING REQUIREMENTS

Figure 8 – 10

8.2.2.2 System Safety Operating Procedures

A draft of the system safety operating procedures shall be included with the 60 percent design submission and the final procedures shall be included with the 90 percent design submission. This information shall be noted on the form shown in figure 8-10.

8.2.2.3 System Safety Inputs to the Training Program

A draft of the system safety inputs to the training program shall be included with the 60 percent design submission. This information shall be noted on the form shown in figure 8-10.