SECTION 8 –SIGNAL SYSTEM

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8.1.0 GENERAL

Railway signaling techniques shall be applied at various LRT locations to enhance safety in the movement of trains and to improve the overall efficiency of train operations. These functions include the protection and control of track switches; the protection and control of bi-directional train operation where applicable; the protection for following trains operating with the normal current of traffic; and highway grade crossing warning. The need for signaling, and the type of signalization provided, shall be determined by the specific requirements of each line segment.

8.2.0 AUTOMATIC BLOCK SYSTEM

Automatic Block System (ABS) shall be installed at certain locations along the LRT right-of-way to permit higher operating speeds than would be possible by relying on line-of-sight operation without signals. The ABS system shall provide information to train operators concerning the condition and occupancy of the track ahead, and provide sufficient stopping distance, when required. Automatic Train Stop (ATS) shall be provided if a train passes a stop signal. A violation of a stop signal shall be reported to the Operations Control Center by means of the SCADA system.

Unless limited by operational constraints, all signals shall comply with a “double red” philosophy. Cab signals functioning in a “go-no-go” environment shall provide enforcement for all signaled moves, including those against the normal direction of traffic. There shall be no overlap where the next signal in advance is an "END ABS" sign.

All signals shall be controlled, in regard to any track switch in the block, to display a red aspect when:

- The switch points are not in position for safe train movement.
- A hand operated switch is not in the normal position.
- A switch-and-lock movement is not fully locked.
- An electric switch-locking movement is not fully normal.
- The selector lever of a dual-control switch-and-lock movement is not in the "MOTOR" position.
- A manual switch electric lock access door is not fully closed.

No signal shall display an aspect less restrictive than approach, when the next signal, in advance, displays an aspect requiring a stop. Three-aspect, non-interlocked signals shall display a proceed aspect when the next signal, in advance, displays an approach aspect.

8.3.0 INTERLOCKINGS

Interlockings shall be provided for all power switches used on the mainline in open track. Interlocking signals shall be provided to govern train movements into and through interlocking limits.

Detector, time, route, and approach locking shall be provided at all interlockings. Detector locking shall not be released until five seconds after the slow pick-up track repeater relays have closed their front contacts.

All non-interfering train movements, through interlockings, shall be permitted simultaneously.

Interlocking design shall comply with principles and accepted practices of the Association of American Railroads (AAR).

8.4.0 HIGHWAY GRADE CROSSING WARNING

Warning devices for highway grade crossings shall be installed at certain locations. Each such crossing shall include automatic gates, LED flashing lights, bells, signs, approach and island track circuits, emergency batteries and associated circuitry, cabling and cases as required. Crossing gates shall be Western-Cullen-Hayes model number 3593-131 with "Gate Keeper" protective devices or approved equal.

The design of each crossing shall be specific to that site and shall provide a minimum of 20 seconds warning time, from the time that the lights first begin to flash until the time that a train traveling at track speed enters the crossing. The design of the crossing circuitry shall avoid unnecessary delays to motorists. Where necessary, the grade crossing warning system shall preempt adjacent traffic lights to avoid automobiles forming a queue across the tracks.

Center lane divider island shall be installed at all grade crossings to aid in the prevention of traffic gate runarounds. Crossings with permitted train speeds in excess of 30 mph shall have warning signs "High Speed Trains" with flashing yellow lights facing highway traffic. Provisions for the installation of video monitoring equipment shall be installed at each grade crossing. Highway grade crossing warning devices will be installed consistent with AAR Signal Manual and the Manual on Uniform Traffic Control Devices Standards (MUTCD).

8.5.0 TRAIN-TO-WAYSIDE COMMUNICATIONS (TWC) SYSTEM

RTD's LRVs are equipped with a Train-to-Wayside Communication (TWC) system. The carborne portion of the TWC system consists of two transponders (one for each end of the LRV), and two car control units (one for each cab). The wayside portion shall consist of an inductive loop antenna and a wayside transceiver. The wayside transceiver, through the wayside loop antenna, shall constantly transmit a message asking that any carborne TWC transponder, in the immediate area, identify itself. A carborne TWC transponder receiving this message shall respond by transmitting a serial 19-bit message, identifying the LRV's car number, the train number, route number (destination), and other information. Thumb-wheel switches and push buttons in each cab are provided to train operators to enter the route number and train number of their consist and other requests such as switch call and preempt call.

A TWC system, compatible with the LRV equipped TWC system, shall be installed at all interlockings, at all passenger stations adjacent to highway crossings and provisions made for all passenger stations in street running, and at all power switches in street running, to allow train operators to enter switch call and route requests. Use of the TWC system shall be the primary method of entering route, switch requests, and SCADA train identification at those locations.

A TWC loop and handhole shall be installed at all highblocks for improved SCADA control of LRV movements. It shall include a TWC antenna and conduits to a nearby signal case for future utilization.

The TWC wayside interrogator operating frequency shall be 100 Khz. It must be capable of recording and storing data history to include all inputs and outputs for download and review for a backlog of at least 48 hours from the time of download. Data acquisition and unit programming must be easily accomplished by a signal technician with moderate laptop computer skills. Installation shall include one interrogator per loop. The wayside loop shall be a single wire loop mounted between the rails with the end to end dimension of the loop being 15 feet. The loop shall be mounted no higher than top of rail and no lower than 6 inches below top of rail. In open track areas the loop shall be housed in a pre-fabricated protective non-metallic enclosure.

Assignment of destination codes shall take into consideration future expansion plans of the LRT system. Assignments shall be developed to provide a logical progression of destination codes throughout RTD's LRT expansion plans.

8.6.0 STANDARDS AND CODES

The signal system shall be designed, constructed and tested in accordance with ~~to~~ the latest revision at the time of award of contract of the following codes and standards:

- U.S. Code of Federal Regulations (CFR), Title 49, Part 236
- American Railway Engineering and Maintenance Association (AREMA)
  - Signal Manual of Recommended Practice
  - American Railway Signaling Principles and Practice
  - Communication Manual of Recommended Practice
  - Typical Circuits Representing Current Practice for Railway Signaling
- Rules and Regulations of the Colorado Public Utilities Commission (PUC)
- National Electrical Code (NEC)
- National Electrical Safety Code (NESC)
- Insulated Cable Engineers Association (ICEA)
- American Society for Testing and Materials (ASTM)
- American National Standards Institute, Inc. (ANSI)
- Underwriters Laboratories, Inc. (UL)
- U.S. Department of Transportation, Federal Highway Administration, Manual on Uniform Traffic Control Devices (MUTCD)

- Institute of Electrical and Electronic Engineers (IEEE)

8.7.0 SAFETY DESIGN

Train safety shall be the prime consideration in the design of the signal system and in the selection of its components, including relays and other devices with moving parts, insulated wire, wire terminals, binding posts, housings, conduits, resistors, capacitors, transformers, inductors and other similar items. The entire signal system shall meet the requirements of this section. Circuit design shall conform to the "American Railway Signaling Principles and Practices" of the AAR Communication and Signal Section.

The following requirements shall govern the design of the portions of the system or a subsystem which affect train safety:

- Only components which have high reliability and predictable failure modes and rates and which have been proven in conditions similar to the projected service shall be utilized.
- Components shall be combined in a manner that ensures that a restrictive rather than a permissive condition will result from component failure.
- All circuits which are not confined to one housing and which affect safety shall be double-wire, double-break, except signal and switch indicator light circuits.
- The design shall be based on closed circuit principles.
- Component or system failures shall cause a more restrictive signal indication than that permitted with no failure. The built-in fault detection and alarm generation capability are preferred.
- System safety design shall be such that any single independent component or subsystem failure will result in a safe condition. Failures that are not independent (those failures which in turn always cause others) shall be considered in combination as a single failure and will not cause an unsafe condition.
- Any latent failure of the equipment, that is a failure, which by itself does not result in an unsafe condition, but which in combination with a second or subsequent failures could result in an unsafe condition, must be detected and negated within a stipulated time period.
- Electronic circuit design shall insure that the following types of component failures have a restrictive rather than a permissive effect:
    - Two terminal devices: open, short, partial open or short
    - Multi-terminal devices: combination of opens, shorts, partial opens and/or partial shorts
- Wherever possible, built-in checks shall be included that impose a restriction and/or actuate an alarm whenever a device fails to assume its most restrictive position when conditions require that it should.
- Redundant design by itself shall not be considered an acceptable method of achieving design safety.

8.8.0 HEADWAYS & BLOCK LAYOUT

The design of the LRT signal system shall provide for minimum train headways of 130 seconds, or less. Headway is defined as the length of time taken for a given automatic block signal to upgrade to a permissive (restricting or approach) aspect after a leading train has passed that signal at normal track speed. Maximum train length will be 4 cars under normal conditions. Three-aspect signals are required to provide information about the aspect displayed by the next signal ahead so as to avoid the necessity for always approaching it while prepared to stop.

Wherever it is displayed, a stop indication shall be an absolute signal, requiring that train operators bring their trains to a full stop and call the LRT controller for authorization to pass the signal at restricted speed (i.e., prepared to stop, within one-half the range of vision, short of anything that may so require).

Signal system design headways are calculated without regard for variations in vehicles, weather conditions or individual operators. Signal system design headways will provide for sustained five minute scheduled headways.

8.9.0 SAFE BRAKING DISTANCE

Safe braking distances shall be calculated using a 2 second vehicle reaction time, a minimum adhesion which would allow a deceleration rate on level tangent track of 1.95 MPHPS and a 35% (distance) safety margin. The assumed deceleration rate shall be reduced on downhill grades to compensate for the effects of gravity. In addition, all safe braking distance calculations in open-track territory shall assume a LRV entry into the governed area at a maximum authorized speed plus 10 mph to a maximum of 60 mph.

8.10.0 ENVIRONMENTAL CONSIDERATIONS

All equipment shall be designed to operate from a minimum temperature of -40°C (ambient) to a maximum temperature resulting from a combination of an ambient temperature, maximum sun loading and maximum normal internal heat generation, of 70°C.

8.11.0 SERVICE PROVEN EQUIPMENT AND DESIGN

All signal equipment shall be proven in similar North American railroad or transit service. The signal system shall have an expected service life of 40 years at the specified level of service. Achievement of this useful life shall be through the use of off-the-shelf proven hardware. Each major component shall incorporate provisions to allow for functional and physical interchangeability of replacement spare parts.

8.12.0 TRAIN DETECTION

Train detection in the ABS sections and at interlockings shall be accomplished by using one of the following types of track circuits.

- Two-rail, shunt type 60 Hz, phase selective track circuits with impedance bonds and two-element vital vane relays.
- Solid state electronic, coded track circuits suitable for use in overhead propulsion territory.

Single-rail (not to exceed 60 feet in length) or double rail, shunt-type 60 or 100 Hz AC track circuits shall be used to detect train presence in embedded track.

Audio-frequency, overlay, shunt-type track circuits shall be used for train detection in the control of highway grade crossing warning equipment.

The design of the LRV propulsion and traction systems and selection of track circuit frequencies and modulation schemes shall be coordinated to preclude interference between the LRV and the signal system.

A shunt with a resistance of 0.2 ohm or less at any point between the two rails of any track circuit shall cause the track circuit to indicate train occupancy. Shunt fouling shall not be allowed, and multiple track relays or series fouling shall be used for all turnouts, with the exception of the two (or four) turnouts used in crossovers between mainline tracks. Voltage regulating transformers in the feed to the track may be used or additional track circuits may be installed, if necessary, to provide this shunting capability. Impedance bonds shall be used to enhance track circuit stability.

8.13.0 SIGNALS & SWITCH INDICATORS

8.13.1 Color Light Signals

With the exception of those signals noted below and two-aspect interlocking signals, standard railway color light, high signals, including backgrounds and split base junction boxes shall be provided for ABS sections and interlockings in open-track sections. Signals at station platforms which do not have to be viewed from a distance may be dwarf-type railway color light signals on pedestal bases. Low, dwarf-type railway color light signals may be used for non-normal moves.

8.13.2 Signal Aspects

Each signal aspect shall have an indication (meaning), which is the same wherever it is displayed throughout the LRT system. The system shall have two-aspect and three-aspect signals.

Fundamental aspects of color light signals shall consist of the following:

TABLE 8A - FUNDAMENTAL ASPECTS OF COLOR LIGHT SIGNALS

Name	Aspect	Indication
Stop	Red Light	Stop
Approach	Yellow Light	Proceed on primary route prepared to stop at next signal
Proceed	Green Light	Proceed on primary route at permitted speed
Diverging	Flashing Yellow Light	Proceed on secondary route prepared to stop at next signal
Diverging	Flashing Green Light	Proceed on secondary route at permitted speed
Exit	Red over Yellow	Proceed out of signalized territory into yard or storage track

TABLE 8B - STREET RUNNING AREA SIGNALS

Name	Aspect	Indication
Stop	Red	Stop
Proceed	Yellow	Divergent track clear; proceed in street running rules
Proceed	Green	Proceed on primary route at permitted speed

TABLE 8C - POINT INDICATORS

Name	Aspect	Indication
Stop	Dark	Stop
Reverse	Yellow Light	Switch Lined Reverse
Normal	Green Light	Switch Lined Normal

8.13.3 Light-Out Protection

"Light-out" protection shall be provided on all three-light interlocking signals to prevent a signal from displaying a more permissive aspect from that intended because of a burnt-out lamp or broken wire. Light out protection shall cascade to the rear as required to provide an orderly arrangement of signal aspects.

8.13.4 Signal Locations

Signals shall be located to the right of the track governed. There may be locations where there is no room for signals to the right; however, if site conditions permit, every effort shall be made to adjust clearances so that the signals can be located on the right.

8.13.5 Signal Height

All signals governing normal movements shall be close to the train operator's eye level depending upon civil interference constraints.

8.13.6 Signal Lighting

Approach lighting shall be used and signal lights shall be extinguished when there are no trains in position to view the signal. Exceptions to this will include the first signal approached when leaving non-signaled and entering signaled territory. These signals shall be lighted continuously. Lamp voltage shall be from 85% to 90% of rated voltage in order to extend lamp life and to retain proper light color. LED signal light assemblies are an acceptable substitute to the incandescent bulb type.

8.13.7 Signal Numbering

All LRT signals shall have number plates attached to facilitate identification and simplify record keeping. Signals shall be assigned numbers coinciding with the signals physical track distance from the northern terminus of the Downing Street station and a suffix letter indication of the associated corridor. Signal numbers shall reflect this distance rounded to the nearest 100th of a mile. Example: Signal 379 in the Central Corridor is approximately 3.79 track miles from the Downing Street terminal and would be labeled S379CC. Signal plates will have black background with white reflective lettering.

8.13.8 Red Signal Violation

All signals shall be equipped with a positive means of detecting a red signal violation. Red signal violations shall be recorded on the local event recorder, as well as being sent to the central office via the SCADA system.

8.13.9 Cab Signals

All signals shall have an associated enforcement function provided by a “go/no-go” cab signal system. All moves in both the normal and reverse directions of traffic shall be protected by this system.

8.14.0 MAINLINE TRACK SWITCHES

8.14.1 Track Switches in Open-Track

a) Manual Track Switches

Manually operated switches in signaled territory shall be equipped with switch and lock movements with operating rods, lock rods and point detectors, and electric switch locks as required by Federal Railroad Administration (FRA) requirements. Removing a padlock from the electric switch lock and opening the front access door shall put neighboring signals to stop and shall start a timer to ensure clearance of trains that may have just passed the controlling signals. Expiration of the 30 second timer shall permit the switches to be unlocked and hand lined.

b) Powered Track Switches

Ballasted

Switches shall be powered by dual control (motor driven/manual) switch machines on open trackwork. Power for the dual control switch machines shall be from the signal power line or from commercial 120 VAC power source, rectified to 110 VDC. Switch machines shall be equipped with operating rods, lock rods and point detectors. Electric switch and lock movements shall be US & S Type M23-A, GRS model 5F, or approved equal.

c) Switch Heaters/Snow Melters

Switch heaters are to be provided and installed by the Signal Contractor at designated locations where the presence of ice and snow could affect rail service. Switch heaters shall be operated automatically or manually and an indicator shall be provided at the control equipment enclosure to indicate that the unit is on. Snow melters shall be powered from a 208 or 240 VAC source with heater pads wired in parallel sufficiently rated to keep the switch points and stock rails free of snow and ice.

8.14.2 Track Switches in Paved Track

a) Manual Track Switches

Manual track switches shall be equipped with toggle type switch movements. Facing-point switches shall be equipped with switch circuit controllers and switch indicator as determined by RTD

b) Powered Track Switches

Embedded

For in street running switches designed for embedded in street applications shall be utilized. Switches shall be powered off a rectified AC source originating from the control enclosure. Power shall be a nominal 120 VAC. Switch machines shall be equipped with operating rods and point detectors. Switches shall be Western Cullen Hayes, electro-hydraulic, or approved equal.

A successful operating record shall require a minimum of 3 years of successful operation on a comparable North American transit system or railroad, as determined and approved by RTD.

8.15.0 CONTROL CIRCUITRY

All safety circuits or logic shall be designed using vital relays and/or Vital Processors (solid state interlocking) of proven design and successful operating record.

Non-vital logic circuits may be controlled either by non vital relays or non vital solid-state logic controller or emulator.

All relays shall plug into separate relay bases. All non-vital relays shall be identical. All relays shall be furnished with at least one spare independent front-back contact.

The use of diodes, capacitors, or resistors to change a vital relays timing characteristics shall not be allowed for vital relays. All such timing characteristics shall be accomplished magnetically.

8.16.0 VITAL MICROPROCESSOR INTERLOCKING SYSTEMS

If interlockings are not controlled by vital relays, then Vital Microprocessor Interlocking Systems (VMIS) shall be employed to execute all vital safety signal system functions. The VMIS system shall be compatible with the existing microprocessor equipment currently in service on the RTD light rail system.

The VMIS shall be capable of operating in a light rail transit environment including exposure to temperatures, humidify and vibration. The VMIS shall be capable of operation at temperature of -40°C to +70°C at 90% humidity non-condensing.

The VMIS software systems shall be segregated into two independent software levels as follows:

- Executive Software shall consist of the coding that performs the input, internal and output operations that is defined within the individual interlocking application logic. The executive software shall be configured on a closed loop principle to ensure that the individual vital microprocessors operate in a fail-safe manner. The executive software shall reside in a read only memory.

- Application Software shall be segregated from the executive software and consists of the vital signal logic defining a specific interlocking configuration. The application software shall derive its safety from signal circuit design practices similar to that used for relay logic. The application software shall be capable of being modified to reflect changes in a specific interlocking configuration by RTD signal engineering staff with basic computer skills. To perform these software modifications, the VMIS system shall incorporate an application software development system and software simulator in order that the modifications can be tested and verified prior to final implementation.

For large interlockings (more than four power switches and/or movable point frogs), the VMIS system shall be segregated into zones and configured in a manner that failure in one zone will not affect the operation of an adjacent zone. Redundant microprocessors (normal and hot standby) shall be provided at selected microprocessor interlocking locations and configured such that shut down of the primary microprocessor would automatically permit seamless transfer to the standby unit.

Individual VMIS units shall include both vital serial ports to interface with adjacent VMIS unit, and non-vital serial ports for interface with the non-vital control system. Interface connections to wayside signal equipment shall be designed to function with existing RTD signal equipment operating at a standard voltages for the type of equipment in service. Where necessary, the VMIS system shall include vital relays to provide interface to wayside signal appliances.

The VMIS shall be equipped with a data recorder and diagnostic system capable of being accessed on-site at the VMIS location, or remotely over telephone or dedicated data lines using a diagnostic terminal or standard laptop personal computer. Data shall be capable of being accessed remotely from the data recorder and in real time on-site directly from the VMIS equipment. The diagnostic system shall be capable of identifying a failure, the nature of the failure and failure location. In addition to the diagnostic system, individual cards including; input/output boards, central processor cards and internal power supply boards shall be equipped with indicator lights that illuminate when respective input/output devices or ports are active.

The VMIS system shall be configured to operate from local available signal system power supply sources. Individual VMIS units shall be equipped with protection against unwarranted power surges at the power supply input terminals. The VMIS units shall also be protected against high levels of electric noise transmitted from external sources including radio, vehicle propulsion systems and hi-tension commercial power lines. Lightening protection including appropriate lightening arresters and equalizers shall be provided at all input terminals interfacing with wayside signal appliances.

VMIS units shall be modular and consist of stand alone card files capable of being mounted in standard instrument racks. Included in the instrument rack shall be all signal equipment required to provide a complete stand alone system.

8.17.0 PROGRAMMABLE LOGIC CONTROL SYSTEM

A Programmable Logic Control (PLC) system shall be employed for control and indication of the signal system. The PLC system shall interface with the VMIS at individual field locations. The PLC system shall perform all entrance-exit functions, receive inputs from various sub-system components (including; individual local control panels and central control) and transmit the appropriate command to the VMIS system. Status indications received from the VMIS shall be processed and transmitted to the local control panel and central control. The PLC system shall be compatible with equipment currently in-service on RTD's LRT system.

The PLC system shall consist of a fault tolerant microprocessor based control system, utilizing either a single unit or fully redundant normal and standby microprocessors. The RTD shall determine which locations require redundant systems based upon the affects a failure of the microprocessor would have on overall system operations. The normal and standby units shall exchange information on operations and health of each respective unit over a serial link. Automatic switch over to the standby unit shall occur if a failure is detected in the hardware or through diagnostic routines of the on-line unit.

The system software shall be field proven, commercially available and prevalent in the industry. The software system shall be designed in a manner that will permit future expansion. The application programs shall be stored on Erasable Programmable Read Only Memory (EPROM), with temporary data (controls and indications) stored in Random Access Memory (RAM). The software shall be capable of being modified to reflect changes in system configuration by RTD signal engineering staff with basic computer skills. To perform these software modifications, the non-vital PLC system shall incorporate a software development system and software simulator in order that the modifications can be tested and verified prior to final implementation.

The PLC units shall be capable of operation in a light rail transit environment including exposure to temperatures, humidify and vibration. The PLC shall be capable of operation at temperatures of -40°C to +70°C at 90% humidity non-condensing. The PLC unit shall be protected against high levels of electrical noise transmitted from external sources including radio, vehicle propulsion systems and hi-tension commercial power lines. In addition, appropriate lightening protection shall be provided where the PLC unit interfaces with external cable systems.

The PLC units shall consist of modular card files capable of being mounted in standard instrument racks. Individual cards including; input/output boards, central processor boards and internal power supply boards shall be equipped with indicator lights that illuminate when functions on the boards are active.

8.18.0 SIGNAL POWER

8.18.1 Power Line

Primary power will be provided to the various signal locations by individual power drops provided by the local utility. Because the track relays shall be of

the phase-selective, two-element type, it shall be necessary for a fixed-phase relationship to be maintained between adjacent track circuits and between the two ends of each individual track circuit. Reference voltage between locations may be required to be provided via line wire.

8.18.2 Frequency Converters

If 100 Hz (rather than 60 Hz) track circuits are determined to be necessary as the result of electromagnetic interference studies, 60 Hz to 100 Hz converters of solid state design shall be provided.

8.18.3 Batteries

All grade crossing warning equipment shall be provided with emergency batteries. Nickel-cadmium or sealed lead-acid batteries, with a minimum capacity of 240 Ampere-hours shall be provided. Separate battery banks for logic and gates flashers shall be provided. Battery backup shall provide sufficient power to allow the crossing to operate for a minimum of 8 hours under normal operating conditions.

8.18.4 Redundant Signal Power

Redundant signal power shall be provided at junctions.

8.19.0 SCADA INTERFACE

Each signal equipment room/case shall be equipped with a SCADA interface to provide the following controls and indications to the SCADA system:

- TWC Indications for all Passing Trains
- Track Circuit Occupancy Indications
- Switch or Crossover Position Indications
- Electric Switch Lock Indications
- Switch Heater Indications and Controls
- Signal Aspects Indications
- Route Request Indications and Controls
- Interlocking Mode of Operation Indications and Controls
- Commercial Power Status Indications
- Signal Power Status Indications
- Signal Power Line Indications and Controls

8.20.0 LIGHTNING AND TRANSIENT PROTECTION

Track circuits shall be protected from lightning per AAR Signal Manual Part 11.1.10. Grounding electrodes rods shall be provided and installed in the signal rooms/case. Connections between arresters, other signal equipment, and grounding electrodes shall be

per AAR Signal Manual Part 11.1.1, except that all connections to grounding electrodes shall be by exothermic welding.

All electronic and solid state devices shall have effective internal and separate external surge protection. High-voltage lightning arresters shall be applied to commercial power connections.

8.21.0 WIRE AND CABLE

Station-to-station and signal-room-to-field equipment signal wires in the signaled areas shall not be combined in the same cable or conduit with signal power or communication circuits. In general, conduit located in an underground duct bank shall be provided.

Station-to-station and signal-room-to-field equipment signal conductors shall be #14 AWG or larger conductors with 5/64" of 90°C ethylene-propylene rubber compound insulation. Multiple conductor cables shall have an outer jacket of extruded, black, low density, high-molecular weight polyethylene.

Case wiring shall be #16 AWG or larger and shall have either 90°C ethylene-propylene rubber compound or Teflon insulation. Wire, cable and its installation shall comply with the applicable requirements of the AAR Signal Manual. A minimum of 10%, but not less than 2 spare conductors, shall be required in each cable.

8.22.0 LOCATION OF SIGNAL EQUIPMENT

Signal system equipment shall be located in wayside houses. Wayside cases shall be used only in the event it is physically impossible to locate a house at the required location.

All signal equipment, including signals, switch machines, switch indicators, cases and houses shall clear the LRV dynamic outline by a minimum of 6 inches.

Doors of signal equipment cases and houses shall be restrained from opening to a position less than 6 inches from the LRV dynamic outline.

Equipment cases shall be located in such a way as to not obstruct the train operators or motorists (insofar as grade crossing warning equipment is concerned) view of the governing signal.

To the maximum extent possible, all signal relays shall be located in signal equipment rooms/cases at each passenger station.

So far as possible ABS signals shall be located approximately 50 feet from the exiting end of station platforms.