TABLE OF CONTENTS
SECTION 8 – SIGNAL SYSTEM

SECTION 8 SIGNAL SYSTEM

8.1 GENERAL

Current state-of-the-art railway signaling techniques and products shall be applied throughout the Commuter Rail Transit (CRT) system to enhance safety in the movement of trains and improve the overall efficiency of train operations. The functions of the signal system shall include the protection and control of track switches; the protection and control of bi-directional train operation; and highway-rail grade crossing warning. The signaling needs and the type of signalization to be provided shall depend on whether the line is electrified or not. On electrified lines, the signalization to be provide shall be suitable for a 25kV, 60Hz AC traction power environment. On non-electrified lines, the signalization to be provided shall be a conventional system. The signal technology to be employed shall be a bi-directional, double track, cab signal type system. The signal system must comply with the Positive Train Control (PTC) requirements of the Railway Safety Act of 2008, and provide interoperability with Union Pacific Railroad (UPRR), Burlington Northern Santa Fe (BNSF), Amtrak, and as required, other existing private carriers where their trains operate on RTD controlled lines.

8.2 AUTOMATIC BLOCK/CAB SIGNAL SYSTEM

An Automatic Block Signal (ABS) System shall be designed that utilizes a series of consecutive blocks/track circuits governed by cab signals that are controlled by conditions that affect the use of a block. The cab signal system shall be the continuous inductive type. If the line is used only by cab equipped commuter rail vehicles, wayside signals will only be required at interlocking limits. The cab signal system shall be supplemented with additional wayside signals at intermediate locations, spaced to meet the scheduled headways. The intent is that freight trains will not have to be equipped with cab signal equipment in order to operate on the line and commuter trains with equipment failure will not block the line.. But in no case shall any trains operating on the lines not be PTC compliant.

At a minimum, the signal system design shall comply with the following:

- U.S. CFR, Title 49, Part 236, Subpart B – Automatic Block Signal System
- U.S. CFR, Title 49, Part 236, Subpart E – Automatic Train Stop, Train Control, and Cab Signal Systems
- AREMA C&S Manual, Part 2.2.1 – Recommended Functional/Operating Guidelines for Automatic Block Signal Circuits and Systems
- AREMA C&S Manual, Part 16.4.50 – Recommended Design Guidelines for Automatic Speed Control with Continuous Cab Signaling

A cut-in/departure test circuit shall be provided at all entrances to Cab signal territory by means of which the carborne equipment shall be tested to prove it is in operative condition before the train enters signaled territory.

Each Commuter Rail cab car shall be equipped with a Cab Signal carborne package that is compatible with that of the Cab Signal wayside design. The cab shall have both an audible indicator (to sound under a predetermined condition or conditions) and a visual indicator (to indicate a condition affecting the movement of a train or engine).

8.3 INTERLOCKINGS

Interlockings shall be provided at all mainline turnouts and crossovers. In conjunction with cab signals, wayside signals shall be provided at interlockings and controlled points.

Approach or time locking, route locking, and traffic locking shall be provided. Detector locking/loss of shunt of not less than five (5) seconds shall be provided on each route within interlocking limits.

All non-conflicting train movements shall be permitted simultaneously. If applicable, sectional releasing shall be permitted.

At a minimum, the interlocking design shall comply with the following:

- U.S. CFR, Title 49, Part 236, Subpart C – Interlocking
- AREMA C&S Manual Part 2.2.10 – Recommended Functional/Operating Guidelines for Interlockings

8.4 HIGHWAY-RAIL GRADE CROSSINGS

Warning devices for highway-rail grade crossings shall be installed; and at a minimum shall include gate arms and mechanisms, gate arm lights, LED flashing light units, electronic bells, signs, approach and island track circuits, standby/backup battery, and associated control circuitry as required. High wind guards and gate keepers shall also be provided.

The design of each highway-rail grade crossing shall be determined based upon site specific requirements. The total warning time shall be based upon the maximum authorized speed (MAS), a minimum warning time of 25 seconds (30 seconds if rail or highway-rail grade crossing shared with freight), and additional warning time that may be required for buffer time, clearance time and/or advance traffic signal preemption time. Constant warning time devices shall be provided if applicable for the system. Where a station platform is within the start of a highway-rail grade crossing, location of the approach circuits shall take into consideration a station dwell time of 30 seconds, and shall be provided with circuitry to prevent unnecessary activation/operation of the highway-rail grade crossing warning devices and interconnected traffic signal control devices.

All locations shall be equipped with a data recorder, and space allocated for the installation of video monitoring equipment.

The standard highway-rail grade crossing configuration shall be two (2) gates with flashers and two (2) median flashers. In the event that highway constraints prevent the use of a median, four-quadrant gates (two entrance and two exit gates) shall be provided.

In the event that the highway-rail grade crossing warning system does not activate or is activated but one or more crossing gates are not horizontal, the crossing signal house shall interface with the appropriate signal relay house(s) to ensure that the cab signal is downgraded to the most restrictive cab rate.

At a minimum, the following interface circuits shall be provided at all shared highway-rail grade crossings:

- Crossing Control (XR)
- Gate Up (GPR)
- Gate Down (GDR)
- Exit Gate Down (EGDR – if applicable)

At a minimum, the design shall comply with the AREMA C&S Manual, Section 3 – Highway-Rail Grade Crossing Warning Systems and the MUTCD, Part 8 – Traffic Controls for Highway-Rail Grade Crossings.

8.5 STANDARDS AND CODES

8.5.1 Regulatory Documents

The signal system shall be designed to the latest revision of the following regulatory documents, at the time of contract award:

- U.S. Code of Federal Regulations (CFR), Title 49, Part 236
- American Railway Engineering and Maintenance-of-Way Association (AREMA) Communications & Signals Manual
- 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)
- Institution of Electrical and Electronic Engineers (IEEE)

8.6 RTD GENERAL STANDARDS

In addition to the regulatory documents listed in 8.5.1, the following are some general RTD specific standards that shall be incorporated in the design:

The ID for a relay house/case shall be related to the nearest tenth of a milepost from DUS.

- The ID for track circuits outside of interlocking limits shall be related to the nearest tenth of a milepost and track number at the normal entering end, with track circuits on the northbound track 1 tied to the nearest odd tenth of a milepost, and track circuits on the southbound track 2 tied to the nearest even tenth of a milepost. For example for track circuit 91-1T the south end of the circuit would be 9.1 miles from DUS on track 1, and for track circuit 92-2T, the north end of the circuit would be 9.2 miles from DUS.

- The ID for automatic signals outside of interlocking limits shall be related to the nearest tenth of a milepost and track number, with northbound signals tied to the nearest odd tenth of a milepost, and southbound signals tied to the nearest even tenth of a milepost. For example signal 91-1EC would be on track 1 on the East Corridor 9.1 miles from DUS.

- The ID for interlocking signals shall be based on even numbers starting with 2 for track 1 and 4 for track 2 and adding N for northbound signals and S for southbound signals that oppose each other. For example, 2N would be the first interlocking signal on track 1 at the south end of the interlocking, with 2S being its opposing signal.

- The ID for interlocking track circuits shall be tied to the number of the signal controlling movements over the track circuit with A B C etc. added from the south end of the circuit to the north end of the circuit. For example 2T would be the track circuit associated with signals 2N and 2S. If there were two circuits, they would be 2AT and 2BT.

- The ID for interlocking switches shall be odd numbers beginning with 1 from the south end of the interlocking and proceeding to the north end of the interlocking. For switches with more than one end add A B C etc. for different ends of the switch again beginning at the south end of the switch and proceeding to the north end of the switch. For example and interlocking with two universal crossovers would have switches 1A and 1B at the south end of the interlocking and 3A and 3B on the north end of the interlocking.

- The ID for a relay house/case and an automatic signal shall include a two letter suffix which indicates the corridor that each relay house/case and signal is associated with (i.e. East Corridor suffix is EC, Gold Line suffix is GL, North Metro suffix is NM and Northwest Rail suffix is NW).

8.7 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 signal circuit design shall conform to the regulatory standards and codes listed in Section 8.5.1.

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

- Only components which have high reliability, 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 results from any 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 results 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 shall 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 failure 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 HEADWAYS AND BLOCK LAYOUT

Headway is defined as the time separation between two trains both traveling in the same direction on the same track. It is measured from the time the rear of the leading train passes a given reference point to the time the front of the train immediately following passes the same reference point at a minimum speed of 30 MPH. The design of the CRT signal system shall provide for a minimum signal design headway of 5 minutes for all line segments with a scheduled headway of 10 minutes or more. On line segments with a scheduled headway of less than 10 minutes, the planned signal design headway must be approved by RTD. Maximum train length for the commuter rail network will be eight (8) cars under normal conditions, though not all corridors are required to accommodate this length.

Signal system design headways are calculated without regard for variations in vehicles, weather conditions, or train operators. Headway calculations shall assume that stops are made at all stations, and a station dwell time of 90 seconds maximum.

8.9 SAFE BRAKING DISTANCE

Safe braking distances shall be calculated using a vehicle reaction time of five (5) seconds, a minimum adhesion which would allow a deceleration rate on level tangent track of 1.95 MPHPS, and a 35% (distance) safety margin. In addition, the calculation shall assume an overspeed of 2 MPH and a runaway acceleration time as defined by the manufacturer of the cab equipment. The assumed deceleration rate shall be reduced on downhill grades to compensate for the effects of gravity. In addition, all safe braking distance calculations shall include the maximum authorized speed (MAS) of 79 MPH or the MAS for the governed area.

8.10 ENVIRONMENTAL CONSIDERATIONS

All signal equipment installed on the wayside or housed in wayside signal enclosures shall be designed and manufactured for a minimum operating temperature of -40ºF and a maximum operating temperature of +160ºF at 0% to 95% relative humidity, non-condensing; and a minimum storage temperature of -67ºF and a maximum storage temperature of +185ºF at 0% to 95% relative humidity, non-condensing.

8.11 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.

8.12 TRAIN DETECTION

Train detection shall be accomplished by using one of the following types of track circuits.

- Within interlocking limits on electrified lines, double-rail, shunt type 100 Hz, phase selective track circuits with impedance bonds and solid state electronic vane relays.

- Within interlocking limits on non-electrified lines, double-rail, shunt type DC relay track circuits.

- Outside of interlockings on electrified lines, solid-state electronic, coded track circuits suitable for use in 25 kV AC propulsion territory with impedance bonds.

- Outside of interlockings on non-electrified lines, solid-state electronic, coded track circuits.

On electrified lines, Audio Frequency Overlay (AFO), shunt-type track circuits shall be used for train detection in the control of highway grade crossing warning equipment.

On non-electrified lines, Microprocessor controlled Grade Crossing Predictors shall be used for train detection in the control of highway grade crossing warning equipment.

On electrified lines the design of the commuter rail rolling stock propulsion and traction systems and selection of track circuit frequencies and modulation schemes shall be coordinated to preclude interference between the rolling stock design and the signal system.

A shunt with 0.06 ohm resistance 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. On electrified lines 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. On electrified lines, tuned impedance bonds shall be used to enhance track circuit stability and power consumption. All track circuits and associated bonding shall be designed to provide broken rail protection.

8.13 WAYSIDE SIGNALS

8.13.1 Color Light Signals

Standard railroad LED color light signals, including backgrounds and hoods, and split junction box bases shall be provided at all interlockings and any intermediate signals needed to comply with the requirements of this specification. The final design shall determine which type of color light signal shall be provided.

8.13.2 Signal Aspects

Each signal aspect shall have an indication (meaning/operating instructions), which is the same wherever it is displayed throughout the CRT system.

8.13.3 Light-Out Protection

"Light-out" protection shall be provided on wayside signals to prevent a signal from displaying a more permissive aspect from that intended because of a burnt-out lamp or broken wire.

8.13.4 Signal Locations

Signals shall be located to the right of the track governed. There may be locations where space constraints do not permit right-hand signals. However, every effort shall be made to adjust clearances so that the signals can be located on the right. Signals should be located to provide a non-obstructed view from the operator's cab, and should be viewable from a distance not less than 1,000 feet in approach to the signal.

8.13.5 Signal Height

All wayside signals governing normal movements shall be close to the Train Operator's eye level depending upon possible interferences and constraints.

8.13.6 Signal Lighting

Approach lighting shall be used and signal lamp(s) shall be extinguished when the track circuits in approach to a signal are unoccupied. Approach lighting shall be activated at least two blocks in advance of a signal. Exceptions to this will include the first signal approached when leaving non-signaled territory and entering signaled territory (these signals shall be lit continuously). Under all circumstances the over-riding requirement shall be to provide a clear and unmistakable aspect at least 1000 feet in advance of the approaching train.

8.13.7 Signal Numbering

All CRT signals other than interlocking signals shall have number plates attached to facilitate identification and simplify record keeping. Interlocking signals shall be numbered on the plans, but not on the wayside signal itself. Signals shall be assigned numbers (See Section 8.6) which coincide with the physical track distance from Denver Union Station to the signal. Signal numbers shall reflect this distance rounded to the nearest 100th of a mile.

8.13.8 Red Signal Violation

Where applicable, signals shall be equipped with a positive means of detecting a red signal violation. Red signal violations shall be recorded at the local data recorder, as well as being sent to the CRT OCC via the SCADA system.

8.13.9 Cab Signals

Each cab signal shall have an indication (meaning/operating instructions), which is the same throughout the commuter rail fleet. The system shall have multiple cab rates, each used to indicate a different cab signal.

8.14 MAINLINE TRACK SWITCHES AND TURNOUTS

Switches shall be dual control (motor driven/manual) switch machines. Power for the dual control switch machines shall be from the signal power line or from commercial 120 VAC power source with rectifiers and 110 VDC batteries. Switch machines shall be equipped with operating rods, lock rods and point detectors. Limiting speeds through turnouts can be found in the CRT Design Criteria Section 4-Trackwork. A helper rod assembly and associated switch circuit controller shall be provided for all #15 turnouts or greater.

Switch heaters/snow melters shall be provided at all power and spring switch locations where the presence of ice and snow could affect rail service. Heater pads, wired in parallel, shall be sufficiently rated and provide sufficient coverage of the switch points, rods, and stock rail to keep them free of ice and snow. Switch heaters shall operate automatically and manually. An indicator shall be provided at the control equipment enclosure and on the exterior of the signal house/case (amber lamp) to indicate that the unit is on. Switch heaters shall be powered from a 208 or 240 VAC source.

8.15 CONTROL CIRCUITRY

All safety circuits or logic shall be designed using vital relays and/or vital microprocessors of proven design and successful operating record.

Non-vital logic circuits may be controlled either by non-vital relays and/or non-vital logic controllers or emulators.

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 the timing characteristics of a vital relay shall not be allowed. All such timing characteristics shall be accomplished magnetically.\

8.16 VITAL MICROPROCESSOR INTERLOCKING SYSTEMS

Vital Microprocessor Interlocking Systems (VMIS) shall be employed to execute all vital signal system safety functions. The VMIS system shall be compatible with the existing microprocessor equipment currently in-service on the RTD rail system.

The VMIS shall be capable of operating in a commuter rail transit environment including exposure to temperatures, humidify, and vibration. The VMIS shall be

capable of operating at a temperature range of -40F to +160F at 0% to 95% relative 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.

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.

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

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 apparatus.

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 SIGNAL POWER

8.17.1 Power Line

Primary power should be provided to the various signal locations by individual power drops provided by the local utility. Provisions shall be considered for alternate or backup power in the event that there is a loss of primary power or commercial power is unavailable. On electrified lines as 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.

8.17.2 Frequency Converters

On electrified lines, as 100 Hz (rather than 60 Hz) phase selective track circuits are necessary within interlocking limits due to 60 Hz traction power, 60 Hz to 100 Hz converters of solid state design shall be provided at interlockings.

8.17.3 Batteries

All signal equipment shall be provided with standby/backup battery. Nickel-cadmium or sealed lead-acid batteries, with a minimum capacity of 240 Ampere-hours shall be provided. At highway-rail grade crossings, separate battery banks for the operations of gates and lights and other signal equipment shall be provided. Battery backup shall provide sufficient power to allow the signal equipment to operate for a minimum of eight (8) hours under normal operating conditions.

8.17.4 Redundant Signal Power

Redundant signal power shall be provided at all locations.

8.18 SCADA

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

8.19 CONTROLS (FROM THE OCC)

- Central Control – Allows the OCC to take control of a controlled signal location.
- Switch Heat – Allows the OCC manual operation of the switch heaters. In no case shall this control override the safety control (over current, over heat, etc.).

- Switch Control – Allows the OCC to take control of a switch. Each power switch shall have two associated controls. One shall be used to request the switch normal and the other shall be used to request the switch reverse. Circuits shall be arranged such that it is not necessary for a switch to be in a valid route in order for it to be requested. Requesting both positions simultaneously shall generate no new switch request.

- Switch Blocking – Allows the OCC to block a switch to prevent operation

- Route Request – Allows the OCC to request a route (requests the switch or switches that are associated within the requested route and requests the entering signal for the associated route). Each operative signal shall have one or more associated route request, depending on whether there are one or more routes associated with the signal. At a minimum, each operative signal shall have a "normal" or "reverse" route request, or both. Additional controls may be required if there are several "normal" or "reverse" routes.

- Route Cancel – Allows the OCC to cancel a cleared signal. Each operative signal shall have an associated Route Cancel.

- Traffic Request – Allows the OCC to change the direction of traffic on a track between two interlocking or controlled point signals without requesting a route or a signal.

- Track Blocking – Allows the OCC to block a track between two interlocking or controlled point signals to prevent any signal from displaying a route into that track.

- Fleet – Allows the OCC to fleet a cleared signal. Fleeting shall be initiated by first clearing a signal and then selecting the associated Fleet control. Fleeting shall be canceled by operating the Fleet Cancel for the fleeted signal. Each operative signal, for a primary revenue route, shall have the capability of being fleeted.

- Fleet Cancel – Allows the OCC to cancel a fleeted signal without canceling the Route Request. Each operative signal shall have an associated Fleet Cancel.

8.20 INDICATIONS (TO THE OCC)

- Track Circuit – Each track circuit shall indicate occupancy.

- Switch Position – Each power switch shall have three associated indications.

  - Switch is in correspondence in the normal position.

  - Switch is in correspondence in the reverse position.

  - Switch is electrically blocked.

  - Switch is electrically locked.

- Signal Aspect – Each signal aspect shall have an associated indication.

- Signal Time – Each signal shall have an indication that shall indicate when the signal/route has been canceled and the ASR is de-energized.

- Lamp Out – Each signal shall have an associated indication that shall indicate whenever a lamp is burned out.

- Overrun – If applicable, each signal shall have an associated indication that shall indicate whenever a train has bypassed a red signal.

- Track Blocking – Each track section between two interlocking or controlled point signals shall indicate blocked or unblocked.

- Traffic - Each track section between two interlocking or controlled point signals shall indicate the direction of established traffic and whether that traffic is locked or not.

- Mode of Operation – Each controlled location shall provide three indications which shall indicate the current mode of operation: Auto, Central/Office, or Local.

- Fleet – Each signal shall have an indication which shall indicate whenever the associated signal is fleeted.

- Route Stacking – Each interlocking that has route stacking logic shall provide the necessary indications identifying the positions of each of the route requests that have been initiated.

- Faults/Warnings – There shall be a series of indications to indicate fault/warning conditions. These indications shall not be under the control of the mode of operation and shall indicate whenever the fault/warning is present. These indications shall include:

    - AC Power Off – Indicates whenever the primary AC power source is off. This indicates that the interlocking is operating on the alternate AC power source. This indication shall be omitted at locations with a single source of AC power.

    - DC Power Off – Indicates whenever one or more of the DC power supplies is not producing DC power. At locations with standby power supplies, this indication shall monitor both the on-line and standby power supplies.

    - DC Ground – Indicates whenever one or more ground detectors indicates a positive or negative ground fault greater than 50% of the drop away current of any vital relay used in the system. This shall monitor all of the DC power supplies in the associated relay house.

    - Link Fail – Indicates whenever serial communications between redundant processors (if applicable), and/or remote signal locations is lost. There shall be a separate indication for each link used.

    - Blown Fuse – Indicates whenever one or more of the indicating fuses or breakers are in the blown or tripped position.

- Switch Heat – Indicates whenever switch heat is “on”, regardless of the source of switch heat activation.

- Redundant Processor Statuses – There shall be a series of indications to indicate the health status of redundant processors (if applicable) and the VTP (Vital Transfer Panel). These indications shall not be under the control of the mode of operation and shall indicate whenever a status change is present. These indications shall include:

  - Health Status (Main) – Indicates whenever the “Main” or “A Unit” has experienced a failure and is not in control or not able to take control.

  - Health Status (Standby) – Indicates whenever the “Standby” or “B Unit” has experienced a failure and is not in control or not able to take control.

  - VTP Status – Indicates whenever the VTP selector switch is not in the “auto” position.

- Highway-Rail Grade Crossing indications:

  - Gate Down – Indicates whenever the crossing gates are in the horizontal position.

  - Crossing Active – Indicates whenever the XR is de-energized.

  - Crossing Alarm – Indicates whenever the crossing gates have been in the horizontal position for greater than 3 minutes.

  - Gate Alarm – Indicates whenever the XR is energized and the crossing gate(s) are not in the vertical position.

8.21 LIGHTNING AND TRANSIENT PROTECTION

Track circuits shall be protected from lightning. Grounding electrode rods shall be provided and installed in the signal relay house/case. Connections between arresters, other signal equipment, and grounding electrodes shall be protected, except that all connections to grounding electrodes shall be by exothermic welding. All protection provided shall be per AREMA C&S Manual, Section 11 – Circuit Protection.

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.

8.22 WIRE AND CABLE

Station-to-station and signal relay house-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 house-to-field equipment signal conductors shall be #14 AWG or larger conductors. Multi-conductor cables shall have an outer jacket of extruded, black, low density, high-molecular weight polyethylene.

House/case wiring shall be #16 AWG or larger (TEFZEL).

Wire, cable, and the installation of both shall comply with the applicable requirements of the AREMA C&S Manual, Section 10 – Wire and Cable. A minimum of 10%, but not less than two spare conductors, shall be required in each cable.

8.23 LOCATION OF SIGNAL EQUIPMENT

Signal system equipment shall be located in signal relay houses.

All track mounted signal equipment, including switch machines and impedance bonds shall clear the rolling stock clearance envelope by a minimum of six inches.

All signal equipment mounted on the right-of-way (ROW), including signals and signal relay houses shall clear the rolling stock clearance envelope by a minimum of two feet.

Doors of signal relay houses shall be restrained from opening to a position clear the rolling stock clearance envelope by a minimum of four feet.

Signal relay houses/cases shall be located in such a way as to not obstruct a train operators' or motorists' (in the case of highway-rail grade crossing warning equipment) view of the governing signal.

All signal relay houses shall be located to allow easy access for maintenance.

END OF SECTION