

ROCKWELL AUTOMATION

PROCUREMENT SPECIFICATION

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Ethernet Network System

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Section XX XX XX

Ethernet Network System

Part 1 General

1.1 Summary

The Ethernet Network System section covers the furnishing of all network hardware and software for the Control System. Principal components of the Ethernet Network System shall be as described below.

The Contractor shall furnish all necessary equipment, interconnecting cables, and accessories for proper network operation and to meet the functional requirements specified herein.

Equipment and services provided under the Ethernet Network System section shall be subject to the general requirements specified in the Control System section. Supplementing this section, network data, special requirements, and options may be indicated on the drawings.

1.2 General

The Contractor shall install all equipment in accordance with the manufacturer's instructions. Equipment and materials used shall be subject to review and shall comply with the following requirements.

- a) If requirements in this specification differ from those in Section XX, the requirements specified herein shall take precedence.
- b) Supplementing this section, the drawings indicate locations and arrangement of hardware and enclosures, provide mounting details, and may show other information regarding the connection and interaction with other equipment.
- c) Unless otherwise specified, electric power supply to the network equipment shall be 24 volts DC or 120 volts AC as required by the equipment, and UPS backed up. Any required power supplies, special cable, special grounding, and isolation devices shall be furnished for proper performance of the equipment.
- d) To the extent possible, components used for similar types of functions and services shall be the same brand and model line. Similar components of different network hardware shall be the products of the same manufacturer to facilitate maintenance and stocking of repair parts. Whenever possible, identical units shall be furnished.

1.3 References

- TIA/EIA-568-B/C (Series): Commercial Building Telecommunications Cabling Standards.
- TIA/EIA-569 (Series): Commercial Building Standard for Telecommunications Pathways and Spaces.
- TIA/EIA-526 (Series): Standard Test Procedures for Fiber Optic Systems.

- TIA/EIA-604 (Series): Fiber Optic Connector Intermateability Standard (FOCIS).
- IEC 11801 (Series): Cabling for Customer Premises.
- IEC 24702: Information technology - Generic cabling- Industrial premises.
- IEC 60068 (Series): Environmental Testing.
- IEC 60529: Degrees of protection provided by enclosures (IP Code).
- IEC 60603-7: Connectors for electronic equipment - Detail specification for 8-way, unshielded, free and fixed connectors.
- IEC 61000 (Series): Electromagnetic compatibility (EMC).
- IEC 61076 (Series): Connectors for electronic equipment - Product requirements.
- IEC 61131-2: Programmable controllers - Equipment requirements and tests.
- IEC 61326: (Series): Electrical equipment for measurement, control and laboratory use - EMC requirements.
- ANSI/ISA-99: Security for Industrial Automation and Control Systems.
- IEEE 802 (Series): Standards for Local and Metropolitan Area Networks.
- IEEE 1588: Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems
- Internet Engineering Task Force (IETF) RFC documents (various).

1.4 Submittals

Submittals shall be made in accordance with the requirements of this section. Each submittal shall be complete, with all required information provided together at one time, and submitted in a sequence that allows the Owner to have all of the information necessary for checking and approving a particular document at the time of the submittal. The Contractor shall be responsible for planning and making all submittals as necessary to avoid delays or conflicts in the work.

The complete Ethernet Network System design shall be submitted together, allowing a complete review of the design and components. The Ethernet Network System Design submittal shall include:

- a) Product data for all networking hardware, including:
 - Manufacturer's operation and installation instructions.
 - Data sheets, technical product brochures or bulletins.
- b) Complete installation, operation, calibration, and testing manuals.
- c) Complete set of drawings including but not limited to:
 - System block diagram showing relationship and connections between devices, including manufacturer and model information, and address settings.
 - Detailed physical network topology diagram detailing all hardware and the interconnections, including physical media type and cabling distances.
 - Network riser diagram.

- Network port diagram that shows physical location of all ports within the facility and identifies their patch panel and switch port.
 - Construction drawings for all equipment cabinets, including dimensions, identification of all components, preparation and finish data, nameplates.
 - Electrical connection diagrams including complete grounding requirements.
- d) A detailed description of the configuration requirements for all components that are to be configured by the Contractor.
- e) Complete and detailed bills of materials for the cabling infrastructure and network infrastructure broken up by each cabinet.
- f) A report on the projected bandwidth usage of the Ethernet network and each of the individual nodes on the network to ensure there are no bottlenecks and that there is the required percentage of bandwidth available for expansion
- g) Network Testing Plan, Procedures, and Test Reports in accordance with Part 3 of this section, that shall include:
- Narrative describing the test procedures followed.
 - Block diagram of test set up.
 - Manufacturer's information on test equipment used.
 - Detailed test results.
 - A narrative summarizing the results of the testing and identifying any further action required.

1.5 Functional Requirements

1.5.1 Network standard compliance

The network system shall be based on existing IEEE 802.3 Ethernet standards. There shall be no modifications of Ethernet protocol that create incompatibility with commercial off-the-shelf Ethernet products.

The network system shall use standard unmodified TCP, UDP and IP protocols for Ethernet frame encapsulation and transport across the network, as specified in the IETF RFC documents.

The network system shall be able to integrate into other parts of the manufacturing network and to communicate with the enterprise network equipment using open-standard non-proprietary protocols. The network components shall be interoperable with standard network equipment, such as switches, routers, firewalls.

1.5.2 Industrial Protocol Requirements

The network system shall utilize a common industrial application layer protocol, using a single media-independent network technology, enabling interoperability across a broad range of vendors and devices. This protocol shall be managed by a vendor neutral organization that maintains conformance testing to ensure vendor interoperability and specification compliance.

1.5.3 Network design requirements

The network system shall be designed to meet the following requirements:

- a) The network shall be able to meet real-time communication requirements of the industrial control equipment.
- b) The network shall have resources available to support the required number of network nodes and amount of traffic they generate, with additional capacity for future expansion.
- c) The network shall provide high availability for all critical components by using redundant network hardware, power supplies and power sources, cabling infrastructure and network data paths.
- d) The network shall be compliant with the ANSI/ISA-99 standards for industrial automation and control system security.

Part 2 Products

2.1 Network Cabling

2.1.1 Ethernet media support

The following Ethernet physical media standards shall be supported in the network:

- a) 100Base-TX copper
- b) 100Base-FX fiber (multi-mode and single mode)
- c) 1000Base-SX fiber (multi-mode)
- d) 1000Base-LX fiber (single mode)

2.1.2 Environmental considerations

Environmental factors of each area of the IACS network shall be assessed using M.I.C.E. analysis as recommended by the ANSI/TIA-568-C.0 standard. Cabling components and forms of mitigation shall be selected based on this assessment.

2.1.3 Commercial copper media cables

2-pair and 4-pair twisted pair cables (shielded or unshielded) shall meet the transmission performance requirements of ANSI/TIA/EIA-568-B standards.

2.1.4 Commercial RJ-45 connectors

Commercial non-sealed RJ-45 connectors shall conform to ANSI/TIA/EIA-568-B.2 standards and meet the mechanical and electrical requirements of IEC 60603-7 series standards.

2.1.5 Commercial fiber media cables

The following fiber optic cable shall be supported and meet the requirements of ANSI/TIA/EIA 568-C.3 standards:

- a) Multi-mode 50/125µm
- b) Multi-mode 62.5/125µm

- c) Single mode 9/125µm

2.1.6 Commercial fiber connectors

Commercial non-sealed fiber connectors shall be limited to the LC, SC, SCRJ, and ST variants. Fiber connectors shall conform to ANSI/TIA/EIA-568-C.3 and TIA/EIA-604 FOCIS standards. The LC connector variants shall be used for all new installations. LC transceivers shall have duplex jacks with center spacing compatible with the FOCIS standard.

2.1.7 Industrial cabling components

Copper and fiber industrial cabling components shall support the minimum environmental recommendations of IEC 60068-2 standards, and EMI requirements for IEC light industrial (IEC 61000-4, 61000-6, 61131-2, 61326-1).

2.1.8 Industrial copper media cables

The following industrial Ethernet cabling shall be available for installation in harsh environments:

- a) Cat5e unshielded twisted pair cable (UTP), four- and eight-conductor styles
- b) Shielded twisted pair cable (STP), four- and eight-conductor styles
- c) 600V STP cable, four- and eight-conductor styles, for use in a cable tray shared with high voltage power cables

Cabling shall be designed to IEC 24702 standards and be suitable for high noise M3I3C3E3 (industrial) environments. Industrial cabling components should meet the minimum environmental recommendations of IEC 60068-2 series standards.

2.1.9 Industrial copper connectors.

The industrial non-sealed RJ-45 connectors shall meet the following requirements:

- a) Cat5e tested connector
- b) Designed to withstand IP20 industrial applications
- c) Suitable for M1I1C2E2 (light industrial) environments
- d) Meet IEC 60603-7 specifications

The industrial sealed RJ-45 connectors shall meet the following requirements:

- e) Cat5e tested connector
- f) Designed to withstand IP67 industrial applications
- g) Suitable for M3I3C3E3 (industrial) environments
- h) Meet IEC 61076-3-106 specifications

The industrial sealed M12 “D”-coded connectors shall meet the following requirements:

- i) Cat5e tested connector
- j) Designed to withstand IP67 industrial applications
- k) Suitable for M3I3C3E3 (industrial) environments
- l) Meet IEC 61076-2-101 specifications

2.1.10 Industrial fiber media cables.

Ruggedized IP-rated fiber cables shall be used for indoor and outdoor industrial applications.

2.1.11 Industrial fiber connectors and SFP modules

Sealed industrial LC, M12, and SCRJ fiber connectors shall meet the requirements of the corresponding ANSI/TIA/EIA documents and be fully compatible with off-the-shelf fiber optic plugs and jacks.

2.1.12 Network Equipment Enclosures

Network equipment enclosures shall be used to house networking devices and patch panels in harsh environments, unless the network hardware is designed for mounting in such environment.

Network equipment enclosures shall provide a wire duct for communication cables and fiber optic cables between the communication devices in control panel and communication raceways. Plastic wire duct design shall take into account minimum bend radius of communications cable.

2.1.13 Patch Panels

Cabling systems shall utilize patch panels, surface mount box, or other enclosure, which allows the cable to be permanently terminated and tested. Direct cabling to switches shall be avoided. Connections between switches and patch panels will be made with patch cables not exceeding 3 meters in length and shall conform to ISO/IEC 11801 standards.

2.2 Industrial Ethernet switches

2.2.1 Environmental and power specifications

Industrial Ethernet switches shall meet the following environmental and power specifications:

- a) IEC 60529 IP20 or IP30 environmental rating.
- b) Industrial DIN-rail enclosure.
- c) Passive cooling with no moving parts.
- d) Operating temperature 0°C...+60°C.
- e) Ambient relative humidity 5% to 95% (non-condensing).
- f) Redundant power source 12...48V DC.
- g) Two front panel connectors for DC power and alarm signals.
- h) Internal temperature sensors.
- i) Two independent alarm relays.

Extended temperature, vibration, shock and surge, and noise immunity ratings shall comply with specifications for industrial environments.

2.2.2 Certifications

- a) UL Listed Industrial Control Equipment for Class I, Division 2 Group A, B, C, D Hazardous Locations, certified for US and Canada.

- b) European Union 2004/108/EC EMC Directive, compliant with EN 61326-1 Meas./Control/Lab., Industrial Requirements; EN 61000-6-2 Industrial Immunity; EN 61000-6-4 Industrial Emissions; EN 61131-2 Programmable Controllers (Clause 8, Zone A & B).

2.2.3 Ethernet media support

Industrial Ethernet switches shall support one or several of the following media types for end device connectivity:

- a) 100Base-TX copper with RJ-45 ports.
- b) 100Base-FX multi-mode fiber with small form-factor pluggable (SFP) slots or built-in ports.
- c) 1000Base-TX copper with RJ-45 ports.

Industrial Ethernet switches shall support one or several of the following media types for connectivity to other industrial switches and distribution layer devices:

- d) 100Base-TX copper with RJ-45 ports.
- e) 100Base-FX multi-mode and single mode fiber with SFP slots.
- f) 1000Base-TX copper with RJ-45 ports.
- g) 1000Base-SX multi-mode fiber with SFP slots.
- h) 1000Base-LX single mode fiber with SFP slots.

2.2.4 Ethernet port configurations

Industrial Ethernet switches shall have one of the following numbers of ports:

- a) 6 ports, fixed configuration.
- b) 6 ports expandable up to 24 ports with extension modules.
- c) 10 ports, fixed configuration.
- d) 10 ports expandable up to 24 ports with extension modules.
- e) 20 ports, fixed configuration.

The switches with Gigabit speed capabilities shall have one of the following:

- f) Two copper ports (RJ-45)
- g) Two SFP slots.
- h) Two dual-purpose ports (RJ-45 or SFP).

2.2.5 Switching hardware specifications

Industrial Ethernet switches shall meet the following switching hardware characteristics:

- a) Line rate / non-blocking ports
- b) Wire-speed switching with 16 Gbps switching fabric
- c) Forwarding rate based on 64-byte packets: 6.5 Mpps
- d) 128 or 256 MB DRAM, 64 MB on-board flash memory
- e) Configurable up to 8000 MAC addresses and 255 IGMP multicast groups (Layer 2 switch)

- f) Configurable up to 2000 MAC addresses and 1000 IGMP groups (Layer 3 switch)

2.2.6 Hardware alarms

Industrial Ethernet switches shall be able to trigger an alarm when the following fault conditions occur:

- a) Power supply fault
- b) Low and high temperature
- c) FCS bit error rate exceeded
- d) Link fault (loss of signal)
- e) Port not forwarding
- f) Port not operating (startup self-test fault)

The alarms shall be configurable in software and be able to use these methods for notifications:

- g) System message to a logging facility (syslog)
- h) Simple Network Management Protocol (SNMP) traps to a server
- i) Use of alarm relays to trigger an external alarm device

2.2.7 LED indicators

Industrial Ethernet switches shall have LED indicators displaying hardware and network link status:

- a) Module status indicator with the following states:
 - Switch is operating properly.
 - A recoverable minor fault has occurred.
 - A non-recoverable major fault has occurred.
 - The switch is performing a power-on self-test (POST).
- b) Network status indicator with the following states:
 - The device has at least one established connection to a control system.
 - Control system connection has timed out.
 - Duplicate IP address.
 - The switch is performing a POST.
- c) Setup status indicator with the following states:
 - Switch is configured as a managed switch.
 - Switch is in initial setup.
 - Switch is in recovery state or initial setup is incomplete.
 - Switch failed to start initial setup or recovery.
 - Power status indicator.
- d) Port status indicators with the following states:
 - No link.

- Link present.
- Port is sending or receiving data.
- Link fault.
- Port is disabled due to an address violation, Ethernet loop detection, or manual configuration.

2.2.8 Removable storage

Industrial Ethernet switches shall have a hot-swappable storage device (CompactFlash or SD flash memory card). The switch shall continue to operate while the storage device is being replaced. All configuration and firmware files shall be saved on the removable storage device for quick field replacement of the failed switch.

2.2.9 Control System Integration

Industrial Ethernet switches shall support a common application layer protocol used for the control system for configuration and monitoring purposes. The switch shall have the ability to be added as an I/O device to a programmable logic controller (PLC) and provide an application protocol interface for read-only and read-write access to switch parameters. This interface shall provide the following information and configuration capabilities:

- a) Port status and enable/disable configuration
- b) Port error and media counters
- c) Port bandwidth utilization
- d) Port security configuration and violations
- e) Switch alarm status
- f) Multicast group information
- g) Port enable/disable
- h) Power supply and temperature status
- i) Firmware and hardware identity information
- j) Control system connection information
- k) IP address information and configuration
- l) Switch configuration save and restore

2.2.10 Diagnostic and monitoring

Industrial Ethernet switches shall support the following methods of diagnostic and monitoring:

- a) Web interface (HTTP).
- b) System message logging (syslog).
- c) SNMP protocol version 2c and 3.
- d) Port mirroring.
- e) Application protocol interface to a control system.

2.2.11 Configuration

Industrial Ethernet switches shall have the following configuration options:

- a) Initial setup procedure with a web browser that configured basic parameters for typical industrial applications.
- b) Web browser configuration.
- c) Built-in global or interface-level macros (command templates) that allow easily set up the switch in a configuration optimized for the specific application.
- d) Application protocol interface using the same software and tools as for a control system.
- e) SNMP configuration.
- f) Command line configuration (CLI) via serial console line, Telnet, or SSH protocols.

CLI configuration shall NOT be required for a switch to operate in a typical industrial network, and shall be reserved only for advanced configuration.

Preconfigured templates (macros) shall be available to enable global and interface level features for a typical industrial automation applications.

2.2.12 Network standard compliance

Industrial Ethernet switches shall implement existing IEEE 802.3 Ethernet standards with no modifications of Ethernet protocol that create incompatibility with commercial off-the-shelf Ethernet products.

Industrial Ethernet switches shall be able to integrate into other parts of the manufacturing network and to communicate with the enterprise network equipment using open-standard non-proprietary protocols.

2.2.13 Network protocol support

Industrial Ethernet switches shall be available with standard and advanced software set.

Industrial Ethernet switches with standard software set shall include the following networking functionality based on open standards protocols:

- a) VLAN and trunking support: IEEE 802.1q.
- b) Rapid Spanning Tree protocol (RSTP): IEEE 802.1w
- c) Multiple Spanning Tree protocol (MSTP): IEEE 802.1q-2005
- d) Multicast traffic management with IGMPv3 snooping, filtering and querier: RFC 4541.

Industrial Ethernet switches with advanced software set shall include additional functionality:

- e) Link aggregation (Etherchannels) LACP: IEEE 802.3ad.
- f) DHCP server and DHCP persistence (port-based allocation): RFC 2131.
- g) Quality of Service (QoS).

2.2.14 Prioritization (QoS) support

Industrial Ethernet switches with advanced software set shall be able to prioritize automation control traffic using Quality of Service (QoS). The following standards shall be supported:

- a) Layer 3 QoS based on DSCP classification (DiffServ).
- b) Layer 2 QoS: IEEE 802.1p.

Switches shall have at least two ingress and four egress packet queues and shall be able to configure priority queue for handling critical traffic. Switches shall have built-in macro commands for simplified configuration of QoS mapping, classification, and scheduling. The following classes of traffic shall be prioritized:

- Time synchronization
- Motion control
- Safety I/O and messaging
- Standard I/O and messaging

2.2.15 Time synchronization

Industrial Ethernet switches with time synchronization capabilities shall support IEEE 1588 Precision Time Protocol (PTP). Switches shall support end-to-end transparent and boundary PTP modes.

2.2.16 Switch ring topology

Industrial Ethernet switches shall include a loop-prevention network protocol with the ability to support large number of switches in a ring topology. The protocol convergence time shall meet the requirements of typical industrial applications.

2.2.17 Security features

Industrial Ethernet switches shall include the following security features:

- a) Username and password for remote and local (console) access.
- b) Password for the read-write access to parameters from a control system.
- c) Authentication protocol support: AAA, RADIUS.
- d) Secure management protocols: SSHv2, SNMPv3, HTTPS.

Industrial Ethernet switches with advanced software set shall support the following:

- e) Port-based authentication and VLAN assignment: IEEE 802.1x.
- f) MAC ID port security
- g) DHCP snooping and IP source guard
- h) Dynamic ARP inspection and rate limiting
- i) Port-based IP and MAC access lists (ACL)
- j) Port-based broadcast, multicast, and unicast storm control

2.2.18 Layer 3 routing

Industrial Ethernet switches with Layer 3 routing capabilities shall include the following functionality:

- a) Inter-VLAN IP routing.
- b) Static routing and dynamic routing protocols.
- c) IP multicast routing with PIM protocol.
- d) First hop redundancy protocol support.

2.3 Embedded Switch Devices

2.3.1 General Requirements

Ethernet devices with embedded switch technology shall have two Ethernet ports to connect to a linear or device-level ring topology (DLR). Such devices shall meet the following requirements:

- a) Support of a DLR topology with a resiliency to a single point of failure.
- b) Support of fast recovery time after a single fault that is sufficient for high demand control applications.
- c) Ability to operate with non-DLR switches and devices in the common network infrastructure.
- d) QoS support consistent with the rest of the control network, with a high priority queue for DLR frames and strict priority scheduling for the critical automation traffic.
- e) Broadcast rate limiting to host CPU.
- f) Incoming unicast and multicast traffic filtering to host CPU.
- g) IEEE 1588 support for time synchronization.

Embedded switch devices shall be able to operate using standard IEEE 802.3 technology. There shall be no modifications of Ethernet protocol that create incompatibility with commercial off-the-shelf Ethernet products.

2.3.2 Supervisor Node Requirements

In the DLR network, ring supervisor shall have the following features:

- a) Verification of the integrity of the ring.
- b) Reconfiguration of the ring to recover from a single fault.
- c) Ability to provide diagnostic information about ring status and fault location via HTTP or using a control system application protocol.

2.3.3 Ethernet Tap Requirements

Ethernet taps shall be used to connect devices that do not support embedded switch technology, and shall meet the following requirements:

- a) Two 100 Mbps copper or fiber ports connect to a linear or a DLR network.
- b) One 100 Mbps copper port for end device connectivity, or to provide port mirroring capabilities.
- c) IGMP snooping and IGMP querier functions.
- d) Ring supervisor capability.
- e) Ring diagnostics via HTTP and control system application protocol interface.

2.4 Ethernet communication modules

2.4.1 General requirements

Ethernet communication modules provide network interface for control system components such as programmable controllers and I/O devices. Ethernet communication modules shall be

able to operate using standard IEEE 802.3 technology. There shall be no modifications of Ethernet protocol that create incompatibility with commercial off-the-shelf Ethernet products. Ethernet communication modules shall have a functional TCP/IP and UDP protocol suite and transport mechanism, as covered in RFC 1122, 1123, 1127 and the subsequent documents. Any new features or protocols shall be implemented in accordance to the appropriate RFC documents.

2.4.2 LED indicators

Ethernet communication modules shall have LED indicators displaying module, network port and control system connection status:

- a) Module status indicator with the following states:
 - Module is operating properly.
 - A recoverable minor fault has occurred.
 - A non-recoverable major fault has occurred.
 - Module is performing a power-on self-test (POST).
- b) Network status indicator with the following states:
 - Module has at least one established control system connection.
 - Control system connection has timed out.
 - Duplicate IP address.
 - Module is performing a POST.
- c) Port status indicator with the following states:
 - The module is not ready to communicate on the port.
 - The module is ready to communicate.
 - The module is communicating over the network.

2.4.3 Ethernet interfaces and media support

Ethernet communication modules shall support either one of the following Ethernet media standards:

- a) 100Base-TX copper with RJ-45 connector.
- b) 100Base-TX copper with M12 D-coded connector.
- c) 100Base-FX multimode fiber with LC connector.

2.4.4 Diagnostic and monitoring

Ethernet communication modules shall have the following methods of diagnostic and monitoring:

- a) Web interface (HTTP).
- b) Application protocol interface to a control system.
- c) LED indicators and diagnostic displays.

The following information shall be available for diagnostic and monitoring:

- a) System resource utilization

- b) Current network settings
- c) Ethernet statistics
- d) I/O connection information
- e) Diagnostic messages

2.4.5 Configuration methods

Ethernet communication modules shall at least support the following configuration methods:

- a) Full configuration using Ethernet port and control system application protocol.
- b) Automatic IP address configuration using Ethernet port and BOOTP/DHCP protocol.

The following methods may also be supported:

- c) Manual IP address configuration with rotary switches on the module.
- d) Full configuration using USB port and control system application protocol.
- e) HTTP interface configuration.

If configuration via a web browser interface is implemented, it shall be password protected.

2.4.6 Network configuration

Ethernet communication modules shall satisfy the following network configuration requirements:

- a) Static or BOOTP/DHCP IP address configuration shall be supported.
- b) Any valid IP address and subnet mask configuration shall be supported. There shall be no limitation on mask length or IP subnet range.
- c) The module shall have default gateway configuration option.
- d) The module shall have primary and secondary DNS server, and domain name configuration options.
- e) Auto-negotiate or manual speed and duplex port settings shall be supported. Half or full duplex and 10 Mbps or 100 Mbps operation shall be supported.

2.4.7 Network protocol support

Ethernet communication modules shall at a minimum support the following protocols and standards:

- a) Internet Protocol (IP version 4): RFC 791
- b) User Datagram Protocol (UDP): RFC 768
- c) Transmission Control Protocol (TCP): RFC 793
- d) Address Resolution Protocol (ARP): RFC 826
- e) Internet Control Messaging Protocol (ICMP): RFC 792
- f) Internet Group Management Protocol (IGMP): RFC 1112, 2236
- g) IEEE 802.3 (Ethernet): RFC 894
- h) HTTP protocol for diagnostic and configuration purposes.

2.4.8 Address Conflict Detection

Ethernet communication modules shall implement IP address conflict detection (ACD) mechanism and display the conflict mode via LED indicators and diagnostic messages.

Part 3 Execution

3.1 Network installation

The Contractor shall follow these requirements when installing network equipment and cabling:

- a) All racks shall be level and plumb.
- b) All cable bundles within the network rack/enclosure shall be secured and tied with Velcro wrap.
- c) All cables and equipment shall be installed in strict conformance with the manufacturer's recommendations:
 - Cables shall be installed avoiding sharp bends.
 - Install cable using lubricant designed for cable pulling.
 - Cable ties or other cable supports shall be installed without crimping the LAN cables.
 - Install LAN cables without splices.
 - Installed bend radii shall not exceed 4 times the cable diameter.
 - Terminate all pairs at the jack and the patch panel.
 - Install cables a minimum of 40 inches away from electrical motors and transformers.
 - Install cables a minimum of 12 inches away from fluorescent lighting.
 - Individual pairs will be untwisted less than 1/2 inch at termination points.
- d) All cables and terminations shall be labeled with cable designations.
- e) Each data port shall be individually labeled with its patch panel/switch port ID.
- f) At the completion of the wiring installation, provide the following documentation:
 - A plan-view of the premise(s) showing the jack numbering scheme.
 - A printed certification report for the entire wiring installation showing compliance with all ANSI/EIA/TIA specifications for data cable.
- g) Each device with a unique IP address shall be individually labeled with its IP address.

3.2 Network configuration

The Contractor shall provide a configuration report to the Owner detailing all the configuration parameters for all Contractor-configured devices that connect to the network, including but not limited to the following:

- a) IP address, subnet mask, default gateway assignments.
- b) DNS hostname, domain, and server assignments.

- c) Speed and duplex configuration for each network interface.
- d) Access VLAN configuration or trunking mode for each switch port.
- e) User access passwords for network device management.
- f) Switch configuration files in text (CLI) format.

3.3 Network testing

3.3.1 Specifications and Guidelines

All tests, verifications, checks, and recommendations shall be in conformance with the ANSI/TIA or ISO/IEC specifications. ANSI/TIA or ISO/IEC specifications define electrical and mechanical parameters that are the basis for all tests and test equipment usage defined in this section.

All tests, verifications, checks, and recommendations shall be in conformance with all applicable vendor specifications and guidelines. Manufacturers' specifications and guidelines may define additional electrical and mechanical parameters beyond ANSI/TIA or ISO/IEC specifications, and must be included in the basis for all tests and test equipment usage defined in this section.

3.3.2 Ethernet Network Testing Equipment

The Contractor shall utilize any required test equipment, equipment management tools, and additional tools as needed to validate the network installation. All test equipment shall bear current calibration certification from a certified calibration laboratory, as appropriate.

3.3.3 Testing of installed twisted-pair cabling links

The installed twisted-pair copper cabling links shall be tested to meet the requirements of the ANSI/TIA/EIA 568-B standards and to the maximum rating for the grade of the installed cable. The following parameters shall be tested for each cable pair and/or for both ends (where applicable):

- a) Wire Map: Presence of opens, shorts, crossed, reversed, transposed, and split pairs.
- b) DC Loop Resistance.
- c) Length.
- d) Propagation Delay.
- e) Delay Skew.
- f) Insertion Loss.
- g) Return Loss measured from both ends.
- h) Near-End Cross Talk (NEXT).
- i) Power Sum Near-End Cross Talk (PSNEXT).
- j) Attenuation to Crosstalk Ratio Near-End (ACR-N).
- k) Power Sum Attenuation to Crosstalk Ratio Near-End (PSACR-N).
- l) Attenuation to Crosstalk Ratio Far-End (ACR-F).
- m) Power Sum Attenuation to Crosstalk Ratio Far-End (PSACR-F).

- n) Alien Near-End Cross Talk (ANEXT).
- o) Power Sum Alien Near-End Cross Talk (PSANEXT).
- p) Alien Far-End Cross Talk (AFEXT).
- q) Power Sum Attenuation to Alien Crosstalk Ratio Far-End (PSAACR-F).
- r) Average PSANEXT loss.
- s) Average PSAACR-F.

3.3.4 Testing of installed fiber cabling links

The installed fiber cabling links shall be tested to meet the requirements of the ANSI/TIA/EIA 568-C and IEC 11801 standards. Measurements shall be done according to EIA/TIA-526-7, -526-14, and -TSB140 standards. The following parameters shall be tested for all fibers in each cable and for all splices, termination, and connections:

- a) Fiber continuity and length at both ends.
- b) Attenuation (optical power loss) in both directions from the ends of each cable.
- c) Polarity.
- d) Splice loss.
- e) Fiber termination endface inspections.
- f) End-to-end optical quality test with Optical Time Domain Reflectometer (OTDR).

3.3.5 Ethernet Network Test Requirements

The Contractor shall perform a network walk-through to verify that all applicable installation specifications and environmental classifications were followed. The Contractor shall perform a visual inspection of all cable terminations (fiber and copper).

The installed Ethernet Network System shall be tested for performance and functionality according to the IETF RFC 2544 recommendations. The performance of each network link shall be measured in both directions. The duration of each test trial shall be at least 60 seconds. The following minimum tests shall be performed:

- a) Throughput – the maximum rate at which frames can be transmitted from the source to the destination with zero lost frames or errors.
- a) Latency – the total time it takes for a frame to travel from source to destination. The minimum, average, and maximum latency values for each frame size shall be reported.
- b) Frame Loss – the percentage of frames transmitted that are not received at the destination.
- c) Back-to-Back Frames (burstability) – the maximum number of frames that can be sent from the source to the destination within a specified interval with zero lost frames.
- d) Jitter – the variation in the arrival time of frames received at the destination.
- e) Bit Error Rate – the percentage of bit errors measured at the destination relative to the number of bits sent by the source.
- f) Verification of the Link Integrity Status LED on both sides of each link.

- g) Verification of proper operation and failover of each redundant component and links.
- h) Verification of alarming of each link failure.
- i) Verification of configuration parameters for each network component (IP addressing, VLAN and port assignment, speed/duplex settings).
- j) Verification of the necessary network services including but not limited to DHCP, DNS, FTP, and HTTP.

Upon completion and testing of the installed network, the Contractor shall submit test reports in printed form. Test reports shall show all test results performed by the Contractor for each port and piece of equipment. Date of test equipment calibration shall also be provided.

3.3.6 Network Troubleshooting

The Contractor is responsible for trouble-free and reliable network installations. The Contractor shall employ any means necessary to ensure operational networks. The Contractor shall obtain any needed test equipment, including but not limited to time-domain reflectometers, protocol analyzers and network sniffers, to troubleshoot any problems. The Contractor shall utilize the services of a trained and certified Network Engineer that is regularly involved in troubleshooting network problems, in the event that operational or reliability problems exist.

End of Section