3. Detail Design

4. Develop Network-Level Schematic Diagram Identify Exact Physical Infrastructure Components

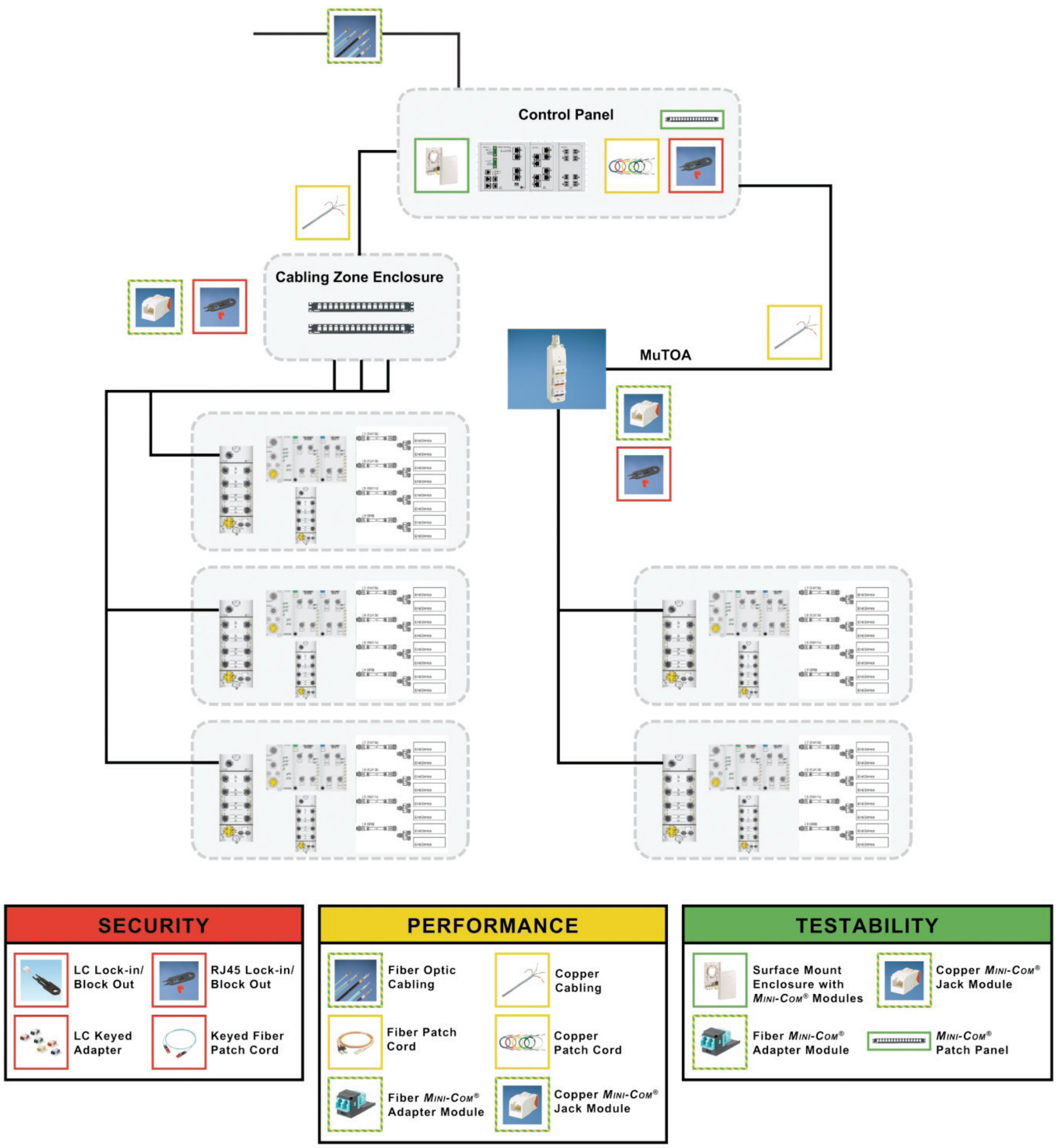


Fig 2.9-3. Network Detail design for On Machine distributed network

5. Review the Levels of the Architecture in the Diagram and Identify Solutions to Address Your System Needs.

Zone Area Physical Infrastructure	Zone Issues	Panduit Solution
On Machine	Security: Control of ports	Color coded fiber and copper jacks or keyed connectivity solutions can provide means to segregate critical systems
	Performance: ESD, Noise issues	Bond machine sections and control panel systems for low impedance ground plane.
	Reliability: Mitigate failures due to vibration and motion	Abrasion protection to prevent cable damage
	Maintainability	Identification and wire management products that improve ability to change, modify, debug
	Performance: Throughput, Latency	Connectivity solutions that exceed standards for copper and fiber connectivity. Pre-tested patch cords deliver long term performance reducing risk
	Testability: Verify during startup, preventative maintenance	Patching for testing fiber, copper uplinks and critical external connections. Pre-tested copper and fiber patch cords to mitigate risks
	Deploying wireless access points securely without expensive power runs	Utilize lockable, environmentally rated enclosures designed for Cisco Wireless Access Points and antenna systems and Power over Ethernet (PoE) to distribute power
	Mixture of Office and IE network in zone cabling enclosures	Color coded, keyed jacks can prevent crossing networks inadvertently. Lock-in connectors can secure connections in switches or patching to control who can make changes
	Maintainability: Dynamic production floor - equipment relocation, additions, expansions, removal	Zone enclosure solutions to cost effectively distribute cabling with consolidation points. Wire management and identification products. Expandable, high density patch panels
	Arc Flash, Voltage hazards identified	Warning labels, lock out solutions

6. Review the Recommended Solution Component List of Materials and Specify your Infrastructure:

Copper Cables/Connectors/Outlet boxes

Panduit Part#	Description
IAEBH6	Category 6 RJ45 IP67/IP65 rated bulkhead connector. UTP type.
IAEBH6S	Category 6 RJ45 IP67/IP65 rated bulkhead connector. STP type.
IAEBHC6	Category 6, RJ45 bulkhead coupler, IP67/IP65 rated.
CM6PIW	MuTOA 6-port outlet box for Mini-Com modules

Required for higher MICE levels

PANDUIT®

IndustrialNet Products

Panduit Part#	Description
IAEBH5E	Category 5e, RJ45, 8-position, 8-wire black industrial connector with protective cover
IAEBH5ES	Category 5e, RJ45, 8-position, 8-wire shielded black industrial connector with protective cover
IEABHC5E	Category 5e, RJ45, 8-position, 8-wire black industrial bulkhead coupler with protective cover
MPI588T	Category 5e, RJ45 industrial plug with protective cover
MPSI588T	Category 5e, RJ45 shielded industrial plug with protective cover
IUTPCH*BLY	Category 5e UTP patch cord constructed of industrial grade UTP category 5e solid cable with dust caps
ISTPCH*MBLY	Category 5e STP patch cords constructed of industrial grade STP category 5e solid cable with dust caps

Fiber Optic Parts

Panduit Part#	Description
IAEF7JMA	Industrial LC fiber optic bulkhead adapter
IAEF617P-7PM1*	Industrial duplex multimode 62.5μm LC to LC patch cord
IAEF617P-NM1**	Industrial duplex multimode 62.5μm LC to pigtail

Fiber Raceway Parts

Panduit Part#	Description
FR4X4**6	FIBERRUNNER 4x4 Solid Wall Channel.
FRHC4**6	FIBERRUNNER 4x4 Snap-On Hinged Cover.
FRBC4X4**	FIBERRUNNER 4x4 QuikLock Coupler.
FRT4X4**	FIBERRUNNER 4x4 Horizontal Tee Fitting.
FRTSC4**	FIBERRUNNER 4x4 Horizontal Tee Cover.
FRFWC4X4**	FIBERRUNNER 4x4 Four Way Cross Fitting.
FRFWCSC4**	FIBERRUNNER 4x4 Four Way Cross Cover.
FRRA4X4**	FIBERRUNNER 4x4 Horizontal Right Angle Fitting.
FRRASC4**	FIBERRUNNER 4x4 Horizontal Right Angle Cover.
FREC4X4**	FIBERRUNNER 4x4 End Cap.
FRSP**	FIBERRUNNER Spill-Over Fitting with 2x2 Exit.
FRSP4C**	FIBERRUNNER Spill-Over Fitting with 2x2 Exit Cover for 4x4 Channel.
FBC2X2**	FIBERRUNNER 2x2 QuikLock Coupler.
FIDT2X2**	Single Port Spill-Out t 1.5” ID Split Corrugated Loom Tubing.
FR6TRBN58	FIBERRUNNER QuikLock New Threaded Rod for 5/8” Threaded Rod
FR6TB12	FIBERRUNNER QuikLock Trapeze Bracket
FR6ALB	FIBERRUNNER Adjustable Ladder Rack Bracket

*** Replace with desired color, YL for yellow, BL for Black or OR for Orange*

Gridrunner wireway Parts

Panduit Part#	Description
GR21X4X24PG	GRIDRUNNER 21"W x 4"D x 24"L Wire Basket Section
GR21X4X48PG	GRIDRUNNER 21"W x 4"D x 48"L Wire Basket Section
GR12X4X24PG	GRIDRUNNER 12"W x 4"D x 24"L Wire Basket Section
GR12X4X48PG	GRIDRUNNER 12"W x 4"D x 48"L Wire Basket Section
GRFWC21PG	GRIDRUNNER Universal Intersection
GRPBPG	GRIDRUNNER Pedestal Bracket
GRCLAMPPG-X	GRIDRUNNER Pedestal Clamp
GRBR4PG	GRIDRUNNER Bend Radius Control Corner

Duct Parts

Panduit Part#	Description
DRD33LG6	PanelMax DIN Rail Wiring Duct (base, cover, rail fasteners),PVC,7.25" x 3.16"X6',White
DRDWR3-X	3" wire retainer for PanelMax™ DIN Rail Wiring Duct.
DRDCS-X	3" corner transition strip for PanelMax™ DIN Rail Wiring Duct.
H3X3LG6	Hinged Cover Slotted duct,PVC,3"X3"X6',LGray
HC3LG6	Hinged Cover, PVC, 3"W X 6', Lgray
CSPC3LG-Q	1" bend radius corner strip pre-cut for 3" wall height.
WR3-X	Duct Wire Retainer, Type G or H, 3"

Cable Ties

Panduit Part#	Description
PLT1M-M	Pan-Ty Cable Tie - Nylon 6.6, 1" Bundle Diameter Miniature
PLT1.5M-M	Pan-Ty Cable Tie - Nylon 6.6, 1.5" Bundle Diameter Miniature
PLT1.5I-M	Pan-Ty Cable Tie - Nylon 6.6, 1.5" Bundle Diameter Intermediate
PLT2I-M	Pan-Ty Cable Tie - Nylon 6.6, 2" Bundle Diameter Intermediate
PLT3I-M	Pan-Ty Cable Tie - Nylon 6.6, 3" Bundle Diameter Intermediate
PLT2S-M	Pan-Ty Cable Tie - Nylon 6.6, 2" Bundle Diameter Standard
PLT3S-M	Pan-Ty Cable Tie - Nylon 6.6, 3" Bundle Diameter Standard
PLT4S-M	Pan-Ty Cable Tie - Nylon 6.6, 4" Bundle Diameter Standard
PLC2S-S10-M	Pan-Ty Clamp Tie - Nylon 6.6, 2" Bundle Diameter Standard
PLC2S-S10-M30	Pan-Ty Clamp Tie - Heat Stabilized Nylon 6.6, 2" Bundle Diameter Standard
PLT1M-M30	Pan-Ty Cable Tie - Heat Stabilized Nylon 6.6,1" Bundle Diameter Miniature
PLT2S-M30	Pan-Ty Cable Tie - Heat Stabilized Nylon 6.6, 2" Bundle Diameter Standard
PLT4S-M30	Pan-Ty Cable Tie - Heat Stabilized Nylon 6.6, 4" Bundle Diameter Standard
PLM2S-M	Pan-Ty Marker Tie - Nylon 6.6, 2" Bundle Diameter Standard
PLM2S-M30	Pan-Ty Marker Tie - Heat Stabilized Nylon 6.6, 2" Bundle Diameter Standard
PFX-0	Marking Pen
PLWP1M-C	Pan-Ty Push Mount Tie - Nylon 6.6, 1" Bundle Diameter Miniature
PLWP2S-C	Pan-Ty Push Mount Tie - Nylon 6.6, 2" Bundle Diameter Standard
PLWP1M-D30	Pan-Ty Push Mount Tie - Heat Stabilized Nylon 6.6, 1" Bundle Diameter Miniature

(Cable Ties continued next page)

Panduit Part#	Description
PLWP2S-D30	Pan-Ty Push Mount Tie - Heat Stabilized Nylon 6.6, 2” Bundle Diameter Standard
PLT2S-M702Y	Pan-Ty Cable Tie - HALAR, Plenum Rated, Flame Retardant, 2” Bundle Diameter Standard
PLT3S-M702Y	Pan-Ty Cable Tie - HALAR, Plenum Rated, Flame Retardant, 3” Bundle Diameter Standard
GTS	Cable Tie Tool - Manual Install-SM,M,I,S
GTH	Cable Tie Tool - Manual Install-S,HS,LH,H
PTH	Cable Tie Tool - Pneumatic Install-S,HS,LH,H
PLT1M-M0	Pan-Ty Cable Tie - Weather Resistant Nylon 6.6, 1” Bundle Diameter Miniature
PLT1.5I-M0	Pan-Ty Cable Tie - Weather Resistant Nylon 6.6, 1.5” Bundle Diameter Intermediate
PLT2I-M0	Pan-Ty Cable Tie - Weather Resistant Nylon 6.6, 2” Bundle Diameter Intermediate
PLT3I-M0	Pan-Ty Cable Tie - Weather Resistant Nylon 6.6, 3” Bundle Diameter Intermediate
PLT2S-M0	Pan-Ty Cable Tie - Weather Resistant Nylon 6.6, 2” Bundle Diameter Standard
PLT3S-M0	Pan-Ty Cable Tie - Weather Resistant Nylon 6.6, 3” Bundle Diameter Standard
PLT4S-M0	Pan-Ty Cable Tie - Weather Resistant Nylon 6.6, 4” Bundle Diameter Standard
PLWP1M-D0	Pan-Ty Push Mount Tie - Weather Resistant Nylon 6.6, 1” Bundle Diameter Miniature
PLWP2S-C0	Pan-Ty Push Mount Tie - Weather Resistant Nylon 6.6, 2” Bundle Diameter Standard
PLT1M-C186	Pan-Ty Cable Tie - Metal Detectable Polypropylene, 1” Bundle Diameter Miniature
PLT2S-C186	Pan-Ty Cable Tie - Metal Detectable Polypropylene, 2” Bundle Diameter Standard
PLT3S-C186	Pan-Ty Cable Tie - Metal Detectable Polypropylene, 3” Bundle Diameter Standard
PLT4S-C186	Pan-Ty Cable Tie - Metal Detectable Polypropylene, 4” Bundle Diameter Standard
PLT1M-M109	Pan-Ty Cable Tie - Polypropylene, 1” Bundle Diameter Miniature
PLT2S-M109	Pan-Ty Cable Tie - Polypropylene, 2” Bundle Diameter Standard
PLT3S-M109	Pan-Ty Cable Tie - Polypropylene, 3” Bundle Diameter Standard
PLT4S-M109	Pan-Ty Cable Tie - Polypropylene, 4” Bundle Diameter Standard
PLT4H-TL109	Pan-Ty Cable Tie - Polypropylene, 4” Bundle Diameter Heavy
PLT1M-M76	Pan-Ty Cable Tie - Tefzel, 1” Bundle Diameter Miniature
PLT2I-M76	Pan-Ty Cable Tie - Tefzel, 2” Bundle Diameter Intermediate
PLT2S-M76	Pan-Ty Cable Tie - Tefzel, 2” Bundle Diameter Standard
PLT4S-M76	Pan-Ty Cable Tie - Tefzel, 4” Bundle Diameter Standard
PLT4H-TL76	Pan-Ty Cable Tie - Tefzel, 4” Bundle Diameter Heavy

PANDUIT®

Abrasion/Mounting Parts

Panduit Part#	Description
ABM112-A-C	Adhesive Backed Mounts
ABMQS-A-Q	Multiple Bridge Adhesive Backed Mounts
ACC38-A-C	Adhesive Cord Clip
MACC62-A-C	Metal Adhesive Cord Clip
LWC50-A-L	Latching Wire Clip
BEC62-A-L	Beveled Edge Clip
VCC25-A-C	Vertical Cord Clip
HSTT50-C	Heat Shrink Thin Wall
HSTT4A47-48-Q	Heat Shrink (4:1)
T50F-C	Spiral Wrap
PW75F-C20	PAN-WRAP™ Split Harness Wrap
CLT100-C20	Corrugated Loom Tubing
SE75P-CR0	Braided Sleeving
CPM87S-C	Control Panel Mounts
TM3S8-C	Cable Tie Mounts
TA1S10-C	Tie Anchor Mounts
PUM100-D30	Push Mounts with Umbrellas
PUM-071-2S-D30	Push Mount Assemblies
CCS25-S8-C	Standard Fixed Diameter Clamps
CCH50-S10-C	Heavy-Duty Fixed Diameter Clamps

PANDUIT®

Grounding/Bonding

Panduit Part#	Description
PV*-14RX	Ring Terminal, 1/4" stud hole, * PV14 to PV6 - 16awg-6awg. For terminating Ground wires from various components. Other sizes and styles available up to 1000 Kcmil
BS10**45U	Braided Bonding Strap, 1" Width, #4 AWG (38,400 CMA) Tin Copper Braid, one-hole terminals, 3/8" bolt hole. For bonding multiple sub-panels together and other equipment. ** Sizes 04 - 12 in inches
BS10**45	Braided Bonding Strap, 1" Width, #4 AWG (38,400 CMA) Tin Copper Braid, one-hole terminals, 3/8" bolt hole, green/yellow insulation. For bonding of doors to enclosures and where abrasion protection is required. ** Sizes 04 - 12 in inches.
RGW-100-1Y	3/8" bolt hole, Paint Piercing Grounding Washers, pack of 100. For bonding sub-panels to enclosures at the mounting studs.
RGTBSG-C	Green Bonding Screws, #12-24 x 1/2", box of 100. Bonds equipment with painted flanges to sub-panels.
RGTBSM6G-C	Green Bonding Screws, M6 x 15mm, box of 100. Bonds equipment with painted flanges to sub-panels.
TRBSK	Bonding Stud Kit, #12-24 fasteners, box of 25. For bonding various components to sub-panels, on-machine applications
TRBSM6K	Bonding Stud Kit, M6 fasteners, box of 25. For bonding various components to sub-panels, on-machine applications
BGN-C	Bonding Nuts, #12-24, box of 100. For bonding various components to sub-panels, on-machine applications
BGNM6-C	Bonding Nuts, M6. For bonding various components to sub-panels, on-machine applications
RGTS-CY	Thread Forming Screw, #12-24 x 1/2"
RGTSM6-C	Thread Forming Screw, M6 x 12mm

Safety/Security Parts

Panduit Part#	Description
PVS0305W2102Y	Arc Flash Label, 3"x5"
PVS0305W2201Y	Short Circuit Current Rating Label, 3"x5"
PSL-CBNT	"No" Tool Circuit Breaker Lockout Device
PSL-P	Individual Plug Lockout Device
PSL-WS	Toggle Switch Lockout Device
PSL-4RED	XENOY™ plastic body padlock with steel shackle
PSL-1	Lockout Hasp with 1" diameter jaw and overlapping tabs
PVT-41	"DO NOT OPERATE" Lockout/Tagout tag with cable tie

Identification Parts - LS 8E printer items only shown

Panduit Part#	Description
C200X100YPC	Printable Label for Enclosure Identification
H100X044H1C	Printable Label for 2mm/3mm Fiber Cable Identification
H100X084H1C	Printable Label for MTP Fiber Cable Identification
H100X084H1C	Printable Label for Cat 5/6 Copper Cable Identification
H100X084H1C	Printable Label for 10Gig Copper Cable Identification
T100X000VPC-BK	Printable Label for Fiber Port Identification
C061X030FJC	Printable Label for Single Port Identification
C252X030FJC	Printable Label for Copper 4 Port Identification
C379X030FJC	Printable Label for Copper 6 Port Identification
C100X000VUC-BK	Printable Label for Duct Identification

M12 Connectivity - From Rockwell Automation

1585D-F4DC-SH	Rockwell M12 EtherNet connector, 4 pin straight female, IP67, shielded
1585D-M4DC-SH	Rockwell M12 EtherNet connector, 4 pin straight male, IP67, shielded
1585D-D4AC9-0M5	Rockwell M12 Ethernet receptacle, 4 pin female, IP67 with M16 x1.5 threads
1585D-DD4JD	Rockwell Female M12 receptacle to right angle RJ-45 receptacle, Pg 9 threads

Required for higher MICE levels

2.10 Process Plant Application

Process industries continue to show dynamic growth by leveraging technology advancements for greater efficiency, productivity, and safety in global deployments. Process plant control systems are now integrated solutions that leverage the capabilities that today's computing and networking capabilities can bring to their operations.

By replacing outdated analog control loops and labor intensive manual steps with advanced process control strategies, fieldbus and asset management systems process plants are realizing higher outputs, greater reliability, and improved safety. The successful implementation of these new architectures and capabilities creates new dependencies on the industrial Ethernet network infrastructure. Key issues for process industries include high availability, security, performance, and maintainability.

Reference Architectures

Rockwell Automation and Cisco have mapped out reference architectures that meet the specialized needs of the process industry to deliver process automation excellence. These architectures describe the strategy for a structured arrangement of servers, software, network switches, and control level devices that meet the needs for performance and reliability from software and device levels. However, the area not fully addressed – an area that is critical for the success of these architectures - is the physical layer. This refers to the infrastructure required to connect, manage, secure, and optimize the connectivity and installation of the devices in the physical plant. A structured, engineered approach is required for this physical layer to ensure that the investments in control software, controllers, servers, switches, and fieldbus devices actually startup and perform at peak output.

Physical Layout Considerations

To properly engineer the physical layer for a process plant involves understanding the physical environment requirements which includes size of the operation, plant and control room layout, environmental considerations, and network topologies. At the top of the manufacturing zone architecture is the control room which requires server and switch enclosures. The performance and security of the critical control applications housed in this room can be optimized by leveraging best practices from data center rooms concerning enclosures, wire management, grounding/bonding, physical security, power and thermal considerations.

The next physical area to analyze is the cell/area zone area of the architecture which involves distributing network cabling to motor control centers, distributed valves and sensors on fieldbus networks, instrumentation and control cabinets. Wireless use is growing, especially for sensors or actuators for which wired connectivity is too costly or failure-prone due to harsh environment considerations. The physical layer design should leverage zone cabling consolidation cabinet designs that reduce installation cost and time while promoting improved manageability and flexibility. The media and connectivity selected should have performance that exceeds TIA standard margin to ensure performance long term. For connecting field devices in harsh MICE environments, sealed IP-67 rated cord sets provide robust connectivity. Wire management and abrasion protection are key for reliability and maintainability for networks deployed 'on-machine' to connect to sensors or actuators in the process. A well-engineered grounding/bonding system that mitigates noise considerations for communications is critical both for the control room as well as distributed cabinets and I/O networks.

Network Schematic Analysis

As the network and computing resource requirements become more important to the process control systems, there is a need to leverage best practices from the IT world in conjunction with process control system knowledge. This requires partnering between IT and controls groups, developing 'hybrid' engineering skills to be able to make key decisions on network architectures and physical infrastructure component selection. It is recommended that IT and controls review a schematic layout of the process system's switches and control devices to make decisions on physical infrastructure components to ensure security, performance and testability for each layer of the design.

This Guide provides a reference schematic layout showing a typical topology with callouts that show where physical security for ports can be applied, where performance decisions on media and connectivity need to be made, and where it's recommended to install patching for testability of critical fiber or copper links. For process industries where redundant networks are common and also have possibilities for sub-networks from several vendors, it is crucial to identify and secure these physical links to avoid configuration mistakes and to prevent problems during startups and maintenance. Selection of appropriate fiber and copper media that can perform over the distances and environmental factors is key for robust operation. Diverse pathway planning for redundancy across the plant as well as in control plans should be considered. Selecting fiber and copper connectivity solutions engineered for high performance exceeding standard margins reduces risks associated with installation and long term performance. A careful plan for deploying test points will insure that the network distribution meets performance targets before critical startups of equipment where delays can be costly as well as on a periodic basis during preventative maintenance to avoid loss of control during operation.

End-to-End Solution

In summary, a careful analysis and plan developed for the physical infrastructure for process plants for the entire network from the control room out to field devices will meet the critical needs for process plants for high availability, security and performance. Use of reference architectures that leverage best practice physical infrastructure approaches for control room hardware, network distribution, network connectivity, control panels and on-machine wiring will result in process control systems that enable the full benefit of the investments made in advanced process control systems. This guide provides information on selecting, installing, testing, and documenting this critical physical infrastructure for all levels of this architecture.

Process Plant Physical Infrastructure

This section defines the sequence of actions involved with deploying a physical infrastructure to support Process Plant applications.

1. Logical Design

Define the logical architecture governing the layout of Process Plant industrial systems and active devices. The logical architecture should be based on logical layer reference architectures developed by Rockwell Automation and Cisco, as well as on applicable topology diagrams.

2. Physical Design

Map out the physical locations of control panels, MCC, control room, and production offices to identify Ethernet network structured cabling reach requirements, noise considerations, and bonding/grounding requirements. The following diagram shows recommended best practices for ‘in plant’ distribution.

This step provides the opportunity to identify distributed zone cabling topologies and plan out required patching, test point, and security considerations.

3. Detail Design

Develop a network-level schematic diagram (or use a reference diagram) to identify the exact physical layer components required to deploy Ethernet network. These components include number of patch cords and horizontal links, patching fields, bonding and grounding elements, labeling and identification schemes, cable management tools, and safety and security tools.

This diagram also should identify IP and NEMA ratings for physical layer components based on MICE level analysis of Process Plant areas, in order for the network and industrial systems to withstand the identified range of environments throughout the industrial facility.

NOTE: Steps 2 and 3 are often done concurrently.

4. Review the levels of the architecture in the diagram and identify solutions to address your system needs.

5. Review the recommended solution component List of Materials and specify your infrastructure.

1. Logical Design

Define the Logical Architecture

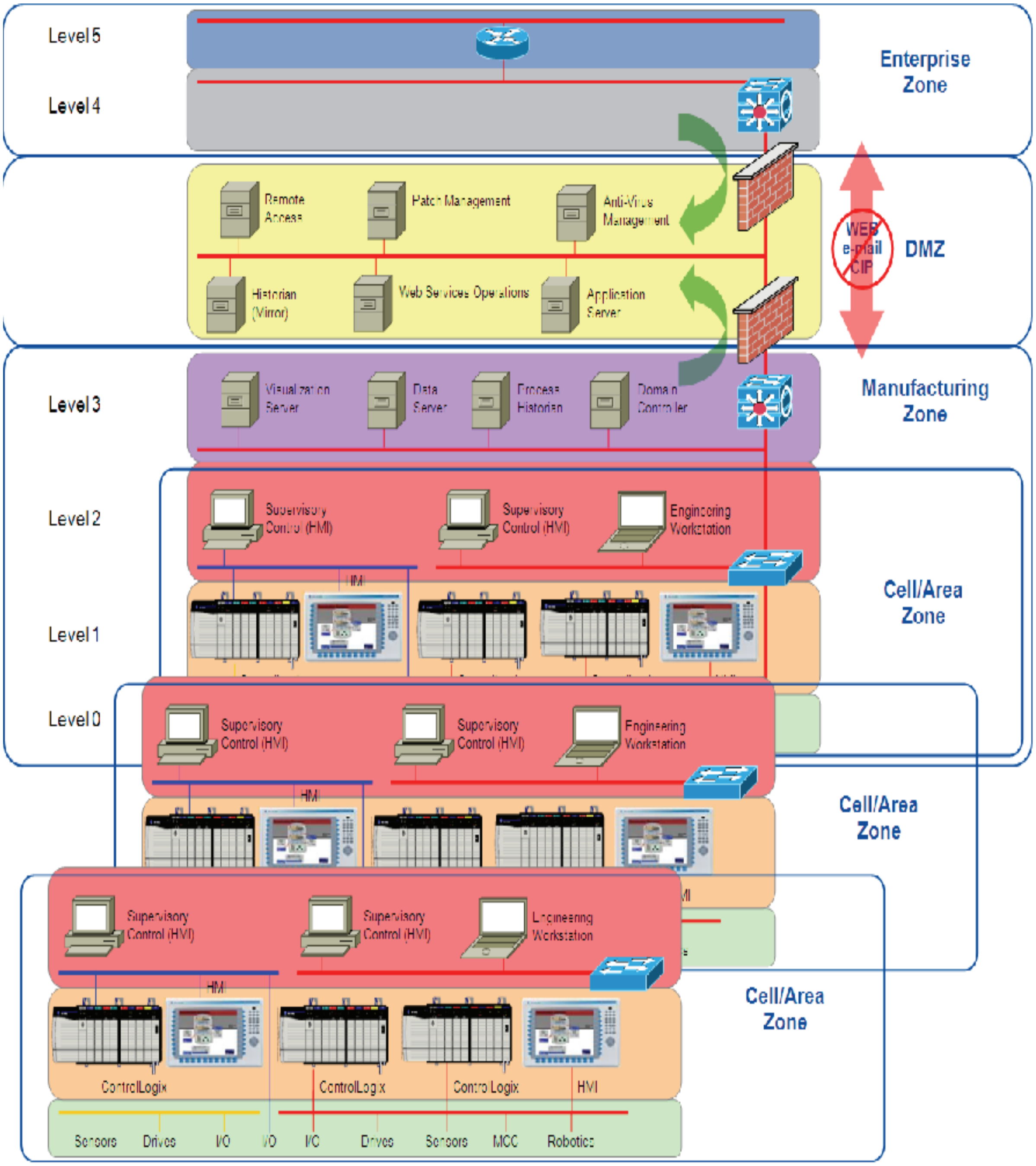
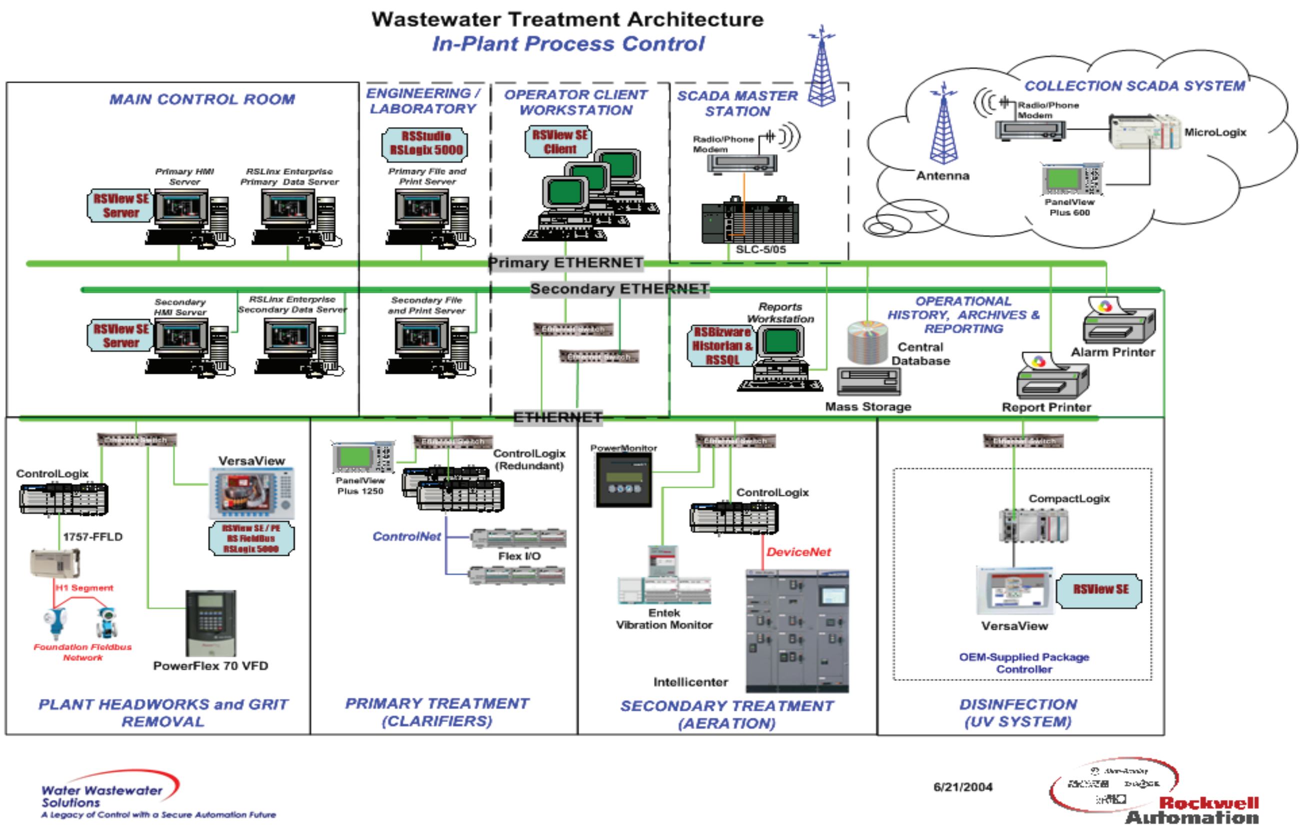


Fig 2.10-1. Logical Diagram for Process plant network


Wastewater Treatment Architecture
In-Plant Process Control
MAIN CONTROL ROOM
ENGINEERING / LABORATORY
OPERATOR CLIENT WORKSTATION
SCADA MASTER STATION
COLLECTION SCADA SYSTEM
Primary HMI Server
RSLinx Enterprise Primary Data Server
RSView SE Server
RSStudio RSLogix 5000
Primary File and Print Server
RSView SE Client
Radio/Phone Modem
SLC-5/05
Antenna
MicroLogix
PanelView Plus 600
Primary ETHERNET
Secondary ETHERNET
Secondary HMI Server
RSLinx Enterprise Secondary Data Server
Secondary File and Print Server
Reports Workstation
RSBizware Historian & RSSQL
OPERATIONAL HISTORY, ARCHIVES & REPORTING
Central Database
Mass Storage
Alarm Printer
Report Printer
ETHERNET
ControlLogix
VersaView
1757-FFLD
RSView SE / PE RS FieldBus RSLogix 5000
H1 Segment
Foundation Fieldbus Network
PowerFlex 70 VFD
PanelView Plus 1250
ControlLogix (Redundant)
ControlNet
Flex I/O
PowerMonitor
DeviceNet
Entek Vibration Monitor
Intellicenter
CompactLogix
RSView SE
OEM-Supplied Package Controller
PLANT HEADWORKS and GRIT REMOVAL
PRIMARY TREATMENT (CLARIFIERS)
SECONDARY TREATMENT (AERATION)
DISINFECTION (UV SYSTEM)
Water Wastewater Solutions
A Legacy of Control with a Secure Automation Future
6/21/2004
Rockwell Automation

1. Physical Design

Map Device Locations to Identify Physical Infrastructure Reach, Noise, Bonding/Grounding Requirements

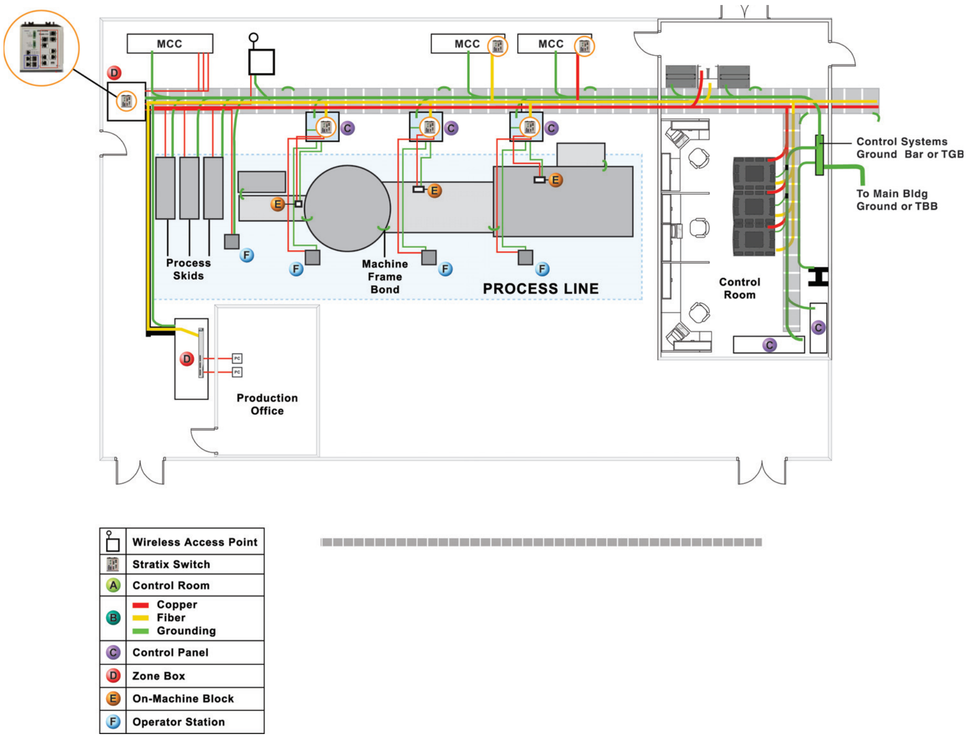


Fig 2.10-2. Physical Diagram for Process plant network infrastructure

Process Plant Physical Infrastructure Reference Architecture for Process Plants

- Zone architecture leveraging Fiber runs to zone enclosures with Stratix 8000 Switches to distribute copper and fiber to MCCs, control panels, process instrumentation
- Control panels with Stratix 8000 switches for PACs, drives, instrumentation both internal to panel and ‘on machine’
- MCC enclosures with Stratix 8000 switches for internal networking Wireless access point(s) driven from zone enclosures with POE for wireless networks
- Coordinated grounding and bonding to mitigate risks to communication disruptions
- Control room featuring best practices for FactoryTalk servers, Stratix switches, Cisco Level 3 switches, firewalls.
- Enhanced security with keyed jacks, lock in and block out connectivity

3. Detail Design

Develop Network-Level Schematic Diagram Identify Exact Physical Infrastructure Components

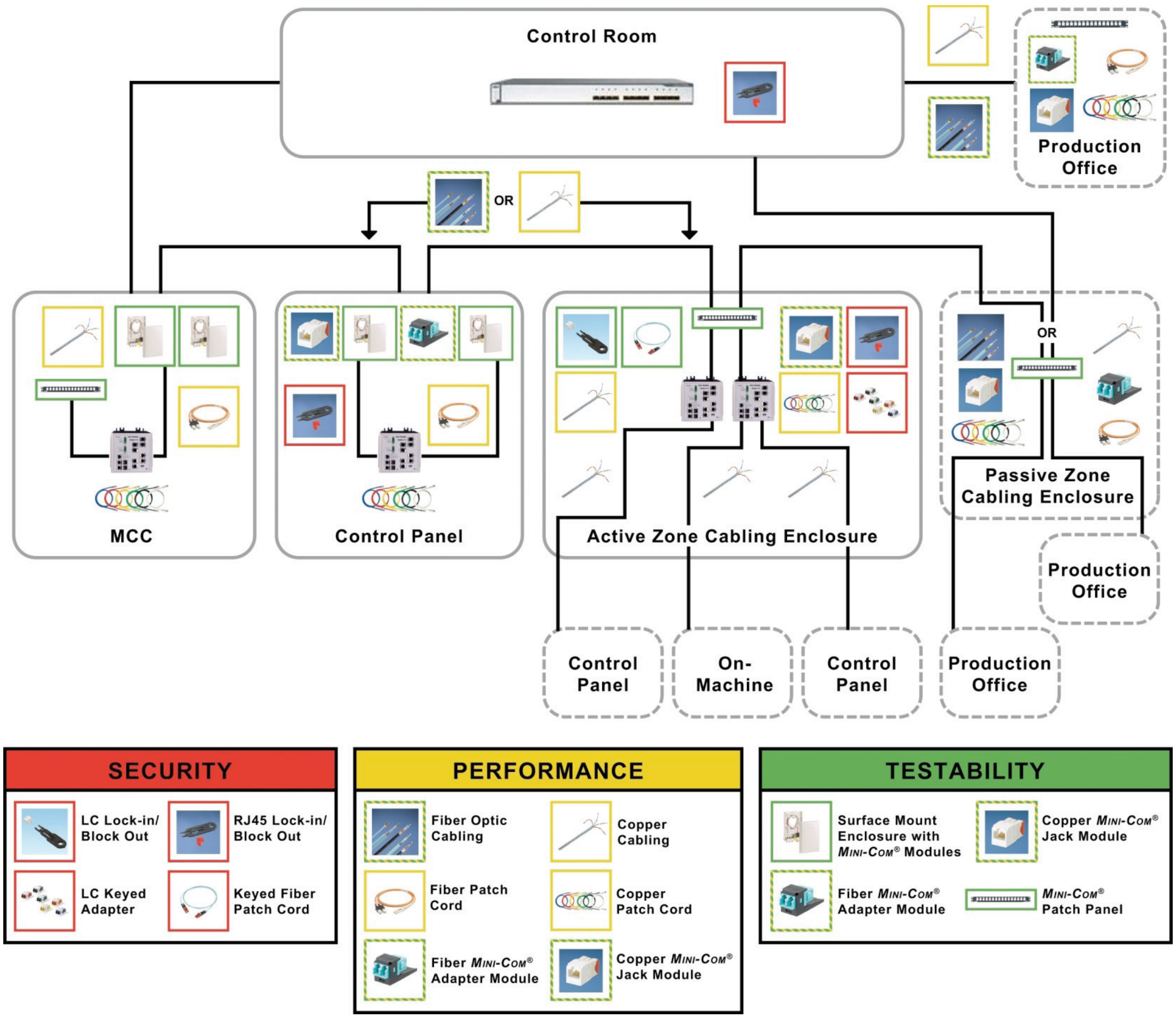


Fig 2.10-3 Detail of Process Plant network

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4. Discuss the Levels of the Architecture in the Diagram and Identify Solutions to Address Your System Needs.

Zone Area Physical Infrastructure	Zone Issues	Panduit Solution
Enterprise Zone (Level 1,2)		
Enterprise Data Center connectivity	Futureproof, High Availability, high performance connectivity	Fiber and 10GB copper connectivity solutions
DMZ		
Shared enclosure, rack areas	Security: Control and Management of connections, patching	Color coded, keyed jacks can prevent crossing channels inadvertently. Lock-in connectors can secure connections in switches or patching to control who can make changes
		Lockable enclosure systems, cross connect patch panels
		PanView infrastructure management
Manufacturing Zone (Level 3)		
Control room	Performance: Noise issues	Grounding/Bonding solutions for under raised floor, cabinet systems
	Performance: Cable/Connector performance	Copper and Fiber solutions, installation tools, and testing guidance for end-to-end connectivity performance that exceeds standards
	Performance: Thermal management	Enclosure systems and wire management solutions that efficiently direct cooling to critical servers and switches improving robustness
	High Availability: Redundant networks	Color coded, keyed jacks can prevent crossing channels inadvertently. Lock-in connectors can secure connections in switches or patching to control who can make changes
	Maintainability: Cable management	Fiber runner, enclosure and rack systems, wire management and identification products
		PanView infrastructure management
Cell/Area Zone (Level 0,1,2)		
Network Distribution	Large system deployments require robust communications over long distances	Fiber solutions with pre-terminated connections easing use of fiber
Network Consolidation Points	Cost effective consolidation with security and manageability	Zone enclosure solutions to cost effectively distribute cabling with consolidation points
Wireless implementation	Deploying wireless access points securely without expensive power runs	Utilize lockable, environmentally rated enclosures designed for Cisco Wireless Access Points and antenna systems and Power Over Ethernet (POE) to distribute power
Control panels	Security: Control of ports	Color coded fiber and copper jacks or keyed connectivity solutions can provide means to segregate critical systems
	Performance: Noise issues	Comprehensive control panel solution utilizing grounding/ bonding, cable segregation and separation to reduce risks
	Performance: Throughput, Latency	Connectivity solutions that exceed standards for copper and fiber connectivity. Pre-tested patch cords deliver long term performance reducing risk

Cell Area Zone (Continued)

Zone Area Physical Infrastructure	Zone Issues	Panduit Solution
	Testability: Verify during startup, preventative maintenance	Patching for testing fiber, copper uplinks and critical external connections. Pre-tested copper and fiber patch cords to mitigate risks
	Maintainability	Identification and wire management products that improve ability to change, modify, debug
On-Machine	Performance; ESD, Noise	Comprehensive Grounding/Bonding solutions
	Maintainability	
Safety Zone		
Control Panel, On-Machine	Safe access to networks without exposing to shock, arc flash	Panduit Data Access Port featuring secure modular connectivity
	Arc Flash, Voltage hazards identified	Warning labels, lock out solutions
	Security: Network connectivity	Color coded, keyed jacks

5. Review the Recommended Solution Component List of Materials and Specify your Infrastructure:

Solution Area	Products	Detailed Parts List
Control Room	Racks Enclosures Security Connectivity Grounding/Bonding Pathways	Section 2.5 Pages 2-19 to 2-32
Network Distribution	Fiber Cable Copper Cable Pathways Grounding/Bonding	Section 2.6 Pages 2-33 to 2-43
Zone Cabling	Enclosures Connectivity Cable Management Security Grounding/Bonding	Section 2.7 Pages 2-44 to 2-55
Control Panel	Connectivity Cable Management Safety Abrasion protection Grounding/Bonding	Section 2.8 Pages 2-56 to 2-73
On-Machine	Connectivity Abrasion protection Cable management Safety Pathways Grounding/Bonding	Section 2.9 Pages 2-74 to 2-85

2.11 SCADA Application

SCADA (Supervisory Control and Data Acquisition) applications are critical to many process applications including oil/gas, water treatment, wind farms, solar, and many others. SCADA applications are characterized by control panels distributed across a wide area linked by fiber optic cables or increasingly through wireless networks. Ethernet/IP communications as well as embedded web servers provide access to the data, configuration, and control enabled by these remote systems. SCADA control panel data is then consolidated and converged with other on-site or off-site process data in a control room where servers and higher level switches are housed. These control rooms are sometimes also deployed in harsh environments as a prefabricated e-building wired off-site and then deployed in the field. The outdoor environments that the control panels, control rooms, and networking components are fielded present challenges for the physical infrastructure in regards to environmental ratings, cabling distances, wireless coverage as well as requirements for high security, high availability, and manageability.

Reference Architectures

Rockwell Automation and Cisco have mapped out reference architectures that address the form factors, cost considerations, security, and network topologies required for today's SCADA systems. These architectures describe the strategy for a structured arrangement of servers, software, network switches, and SCADA RTU systems. However, the area not fully addressed that is critical for the success of these architectures is the physical layer. This refers to the infrastructure required to connect, manage, secure, and optimize the connectivity and installation of the networks, panels and control rooms required for these data collection and control systems. A structured, engineered approach is required for this physical layer to ensure that the investments in control software, controllers, servers, switches, and RTU devices actually startup and perform at peak output.

Physical Layout Considerations

To properly engineer the physical layer for a SCADA installation involves understanding the physical environment requirements including scale of the operation, control room layout, environmental considerations, and RTU network topologies. At the top of the manufacturing zone architecture for a SCADA operation is the control room which requires server and switch enclosures. The performance and security of the critical control applications housed in this room can be optimized by leveraging best practices from data center rooms concerning enclosures, wire management, grounding/bonding, physical security, power and thermal considerations.

The next physical area to analyze is the cell/area zone area of the architecture which involves distributing network cabling and wireless connectivity to the typically widely distributed RTU systems. For high availability, redundant fiber rings are often employed which require consideration for media selection for the distances and environments involved as well as physical security concerns. Distributed enclosures for fiber distribution and consolidation may also be employed in certain architectures for cost-effective cabling to clusters of RTU panels. The media and connectivity selected should have performance that exceeds TIA standard margin to ensure performance long term. For connecting field devices in harsh MICE environments, sealed IP-67 rated cord sets provide robust connectivity. Wire management and abrasion protection are key for reliability and maintainability for networks deployed 'on-machine' to connect to sensors or actuators in these harsh environment areas. A well-engineered grounding/bonding system that mitigates noise considerations for communications is critical, both for the control room and distributed cabinets and I/O networks.

Network Schematic Analysis

As the network and computing resource requirements become more important to the SCADA systems, there is a need to leverage best practices from the IT world in conjunction with process control system knowledge. This requires partnering between IT and controls groups, developing 'hybrid' engineering skills to be able to make key decisions on network architectures and physical infrastructure component selection. It is recommended that IT and controls review a schematic layout of the SCADA system's switches and control devices to make decisions on physical infrastructure components to ensure security, performance and testability for each layer of the design. With the growing use of wireless for SCADA systems, it important to engineer a robust wireless access system by performing site surveys and leveraging vendor guidance.

This Guide provides a reference schematic layout showing a typical topology with callouts that show where physical security for ports can be applied, where performance decisions on media and connectivity need to be made, and where it's recommended to install patching for testability of critical fiber or copper links. For SCADA where redundant networks are common and also have need for wireless access, it's crucial to identify and secure these physical links to avoid configuration mistakes and to prevent problems during startups and maintenance. Selection of appropriate fiber and copper media that can perform over the distances and environmental factors is key for robust operation. Diverse pathway planning for redundancy across the plant as well as in control plans should be considered. Selecting fiber and copper connectivity solutions engineered for high performance exceeding standard margins reduces risks associated with installation and long term performance. A careful plan for deploying test points will insure that the network distribution meets performance targets before critical startups of equipment where delays can be costly as well as on a periodic basis during preventative maintenance to avoid loss of control during operation. Power over Ethernet approaches for wireless access points should be considered to minimize deployment costs and to provide robust coverage.

End-to-End Solution

In summary, a careful analysis and plan developed for the physical infrastructure for SCADA operations for the entire network from the control room out to RTU and field devices will meet the critical needs for high availability, security and performance. Use of reference architectures that leverage best practice physical infrastructure approaches for control room hardware, network distribution, network connectivity, wireless distribution, RTU control panels and field device wiring will result in SCADA operations that are more intelligent and robust. This guide provides information on selecting, installing, testing, and documenting this critical physical infrastructure for all levels of this architecture.

SCADA Plant Physical Infrastructure

This section defines the sequence of actions involved with deploying a physical infrastructure to support SCADA plant applications.

1. Logical Design
Define the logical architecture governing the layout of the SCADA system. The logical architecture should be based on logical layer reference architectures developed by Rockwell Automation and Cisco, as well as on applicable topology diagrams.

2. Network Design
Map out the physical locations of control panels, MCC, control room, and production offices to identify Ethernet network structured cabling reach requirements, noise considerations, and bonding/grounding requirements. The following diagram shows recommended best practices for 'in plant' distribution.

This step provides the opportunity to identify distributed zone cabling topologies and plan out required patching, test point, and security considerations.

3. Detail Design
Develop a network-level schematic diagram (or use a reference diagram) to identify the exact physical layer components required to deploy Ethernet network. These components include number of patch cords and horizontal links, patching fields, bonding and grounding elements, labeling and identification schemes, cable management tools, and safety and security tools.

This diagram also should identify IP and NEMA ratings for physical layer components based on MICE level analysis of Process Plant areas, in order for the network and industrial systems to withstand the identified range of environments throughout the industrial facility.

NOTE: Steps 2 and 3 are often done concurrently.

4. Review the levels of the architecture in the diagram and identify solutions to address your system needs.

5. Review the recommended solution component List of Materials and specify your infrastructure.

1. Logical Design

Define the Logical Architecture

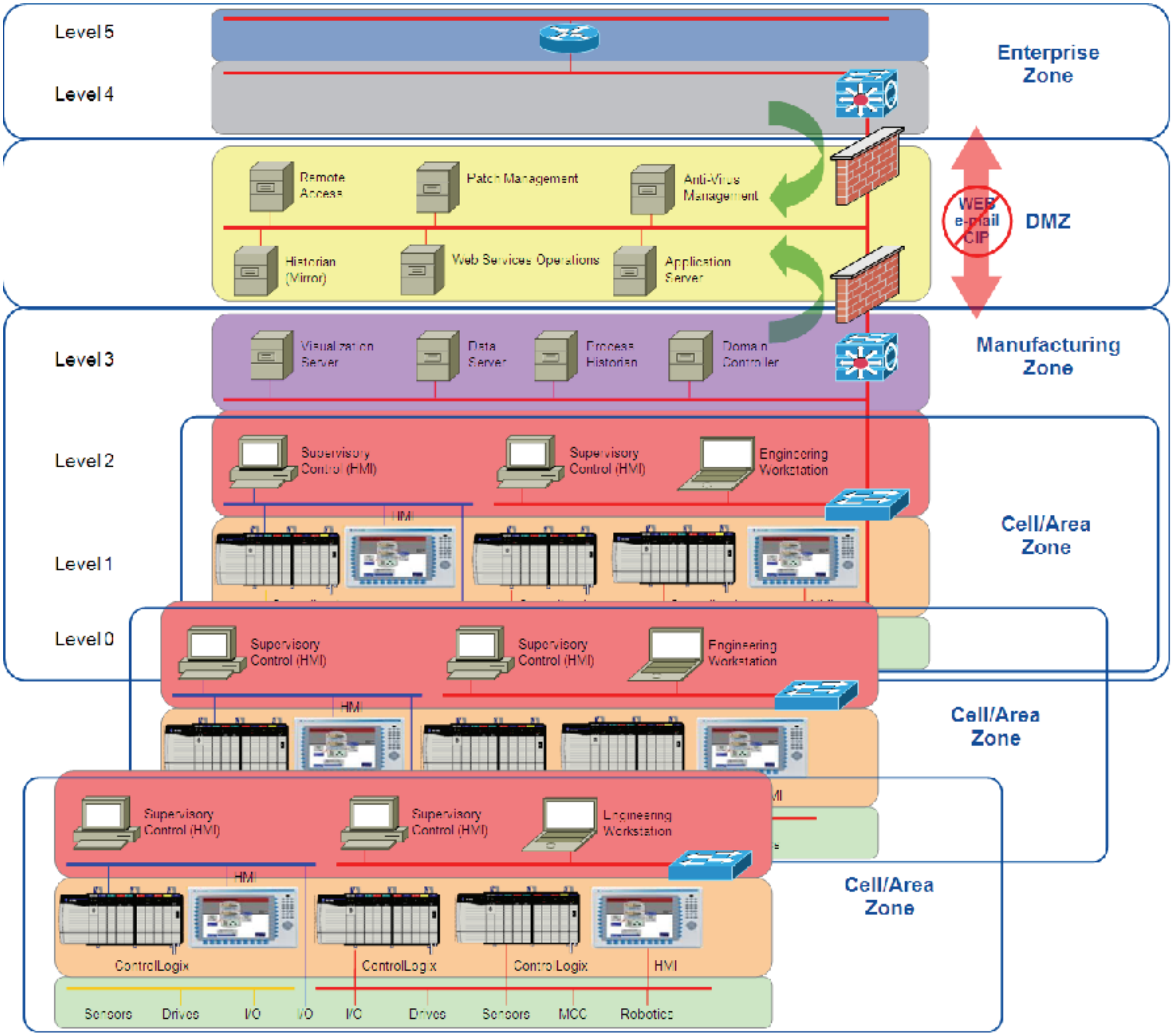
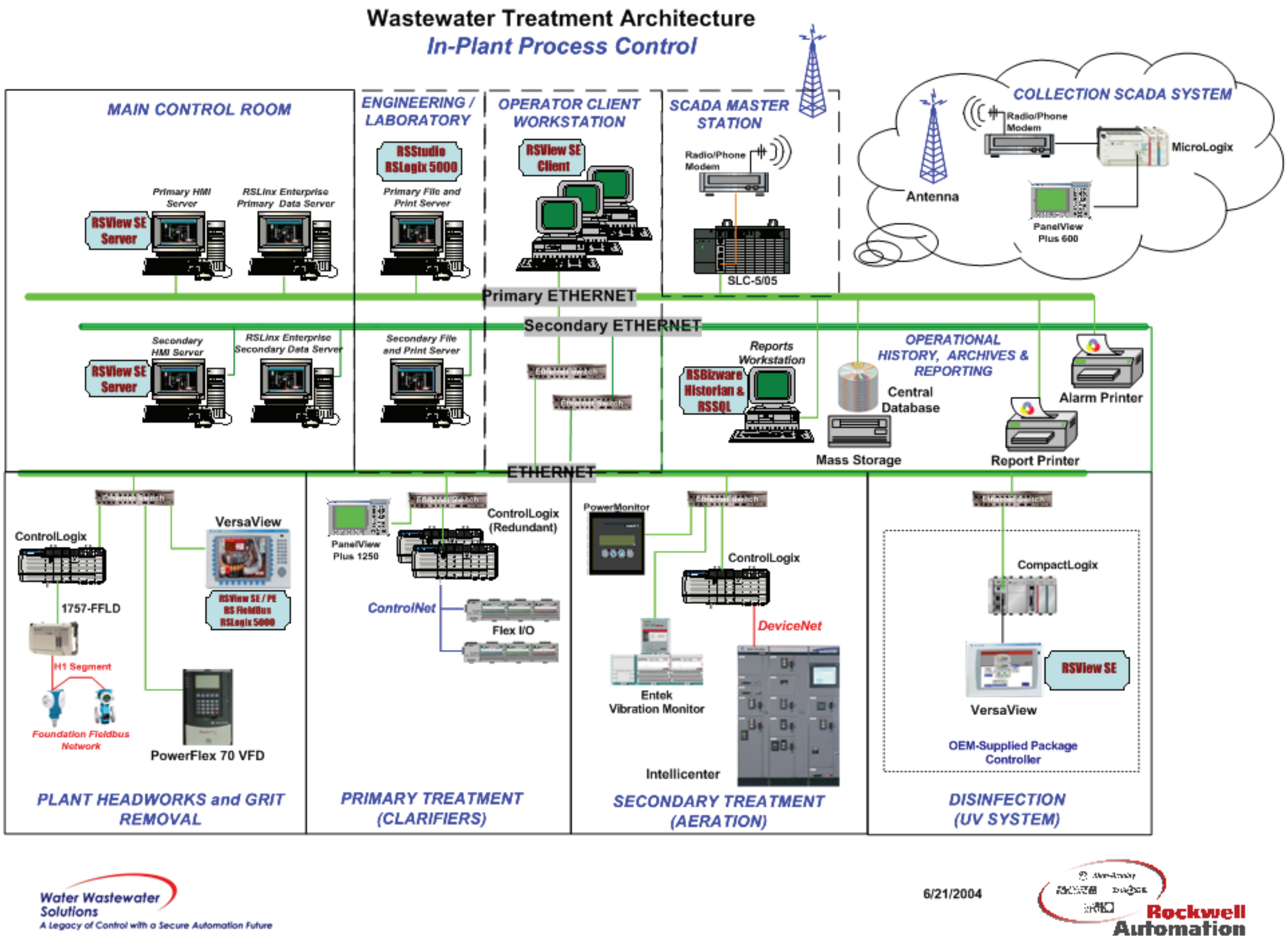


Fig 2.11-1. Logical Diagram for SCADA network


Wastewater Treatment Architecture
In-Plant Process Control
MAIN CONTROL ROOM
ENGINEERING / LABORATORY
OPERATOR CLIENT WORKSTATION
SCADA MASTER STATION
COLLECTION SCADA SYSTEM
Primary HMI Server
RSLinx Enterprise Primary Data Server
RSView SE Server
RSStudio RSLogix 5000
Primary File and Print Server
RSView SE Client
Radio/Phone Modem
SLC-5/05
Antenna
MicroLogix
PanelView Plus 600
Primary ETHERNET
Secondary ETHERNET
Secondary HMI Server
RSLinx Enterprise Secondary Data Server
Secondary File and Print Server
Reports Workstation
RSBizware Historian & RSSQL
OPERATIONAL HISTORY, ARCHIVES & REPORTING
Central Database
Mass Storage
Alarm Printer
Report Printer
ETHERNET
ControlLogix
VersaView
1757-FFLD
RSView SE / PE RS FieldBus RSLogix 5000
H1 Segment
Foundation Fieldbus Network
PowerFlex 70 VFD
PLANT HEADWORKS and GRIT REMOVAL
PanelView Plus 1250
ControlLogix (Redundant)
ControlNet
Flex I/O
PRIMARY TREATMENT (CLARIFIERS)
PowerMonitor
ControlLogix
DeviceNet
Entek Vibration Monitor
Intellicenter
SECONDARY TREATMENT (AERATION)
CompactLogix
RSView SE
VersaView
OEM-Supplied Package Controller
DISINFECTION (UV SYSTEM)
Water Wastewater Solutions
A Legacy of Control with a Secure Automation Future
6/21/2004
Rockwell Automation

2. Physical Design

Map Device Locations to Identify Physical Infrastructure
Reach, Noise, Bonding/Grounding Requirements

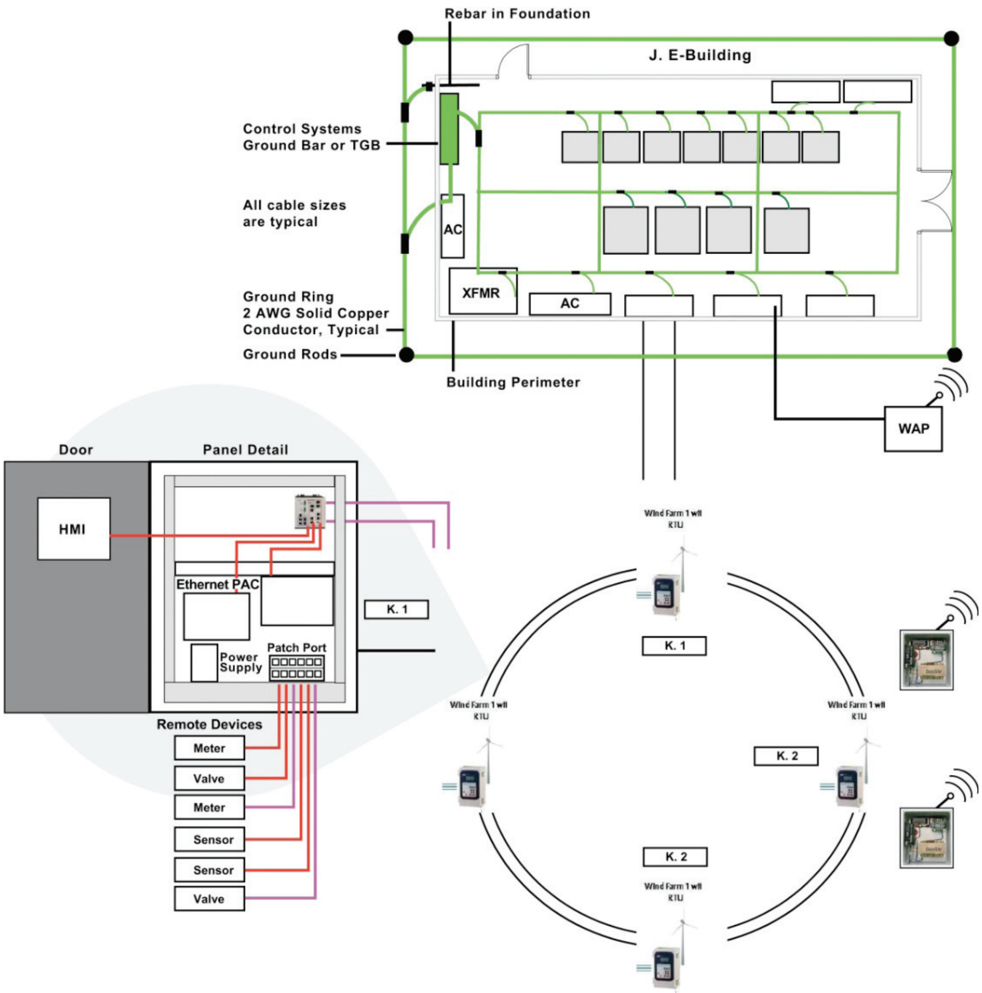


Fig 2.11-2. Physical Diagram for SCADA network

- E-building remote control rooms leverage best practice grounding/ bonding and wire management for FactoryTalk servers, Stratix switches, Cisco Level 3 switches, firewalls.
- Fiber ring connectivity from E-building to remote RTU. Use single mode for long distance runs and multimode fiber for shorter runs (see table in section IV_
- SCADA RTU Control panels with Stratix switches for PACs, drives, instrumentation leverage fiber connectivity
- Wireless access point(s) driven from E-building with POE for wireless networks
- Coordinated grounding and bonding to mitigate risks to communication disruptions
- Control room featuring best practices for FactoryTalk servers, Stratix switches, Cisco Level 3 switches, firewalls.
- Enhanced security with keyed jacks, lock in and block out connectivity

3. Develop Network

Level Schematic Diagram Identify Exact Physical Infrastructure Components

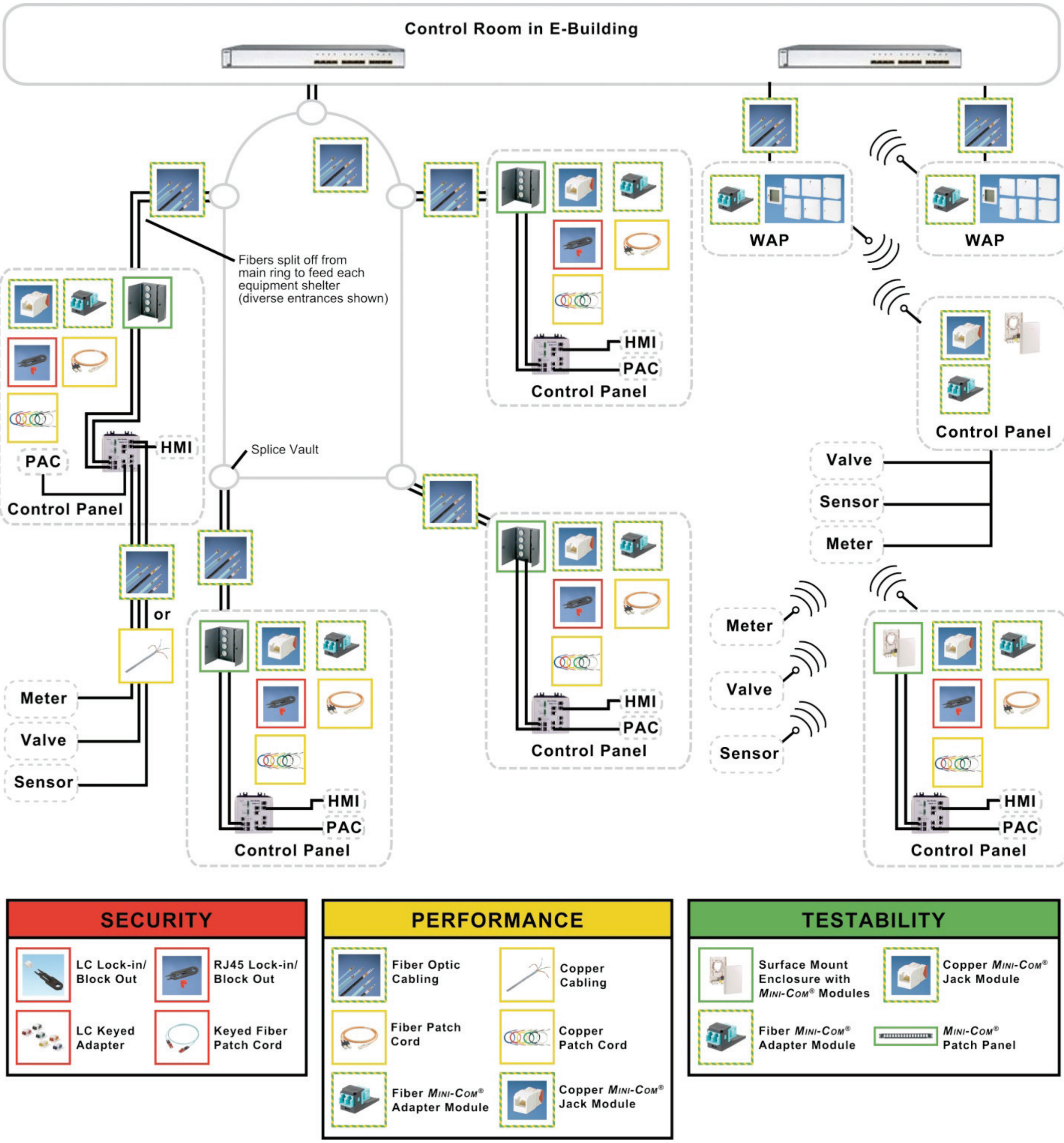


Fig 2.11-3. Detail Diagram for SCADA network physical infrastructure

4. Review the Levels of the Architecture in the Diagram and Identify Solutions to Address Your System Needs.

Zone Area Physical Infrastructure	SCADA Issues	Panduit Solution
Enterprise Zone (Level 1,2)		
Enterprise Data Center connectivity	Future-proof, High Availability, high performance connectivity	Fiber and 10GB copper connectivity solutions
DMZ		
Shared enclosure, rack areas	Security: Control and Management of connections, patching	Color coded, keyed jacks can prevent crossing channels inadvertently. Lock-in connectors can secure connections in switches or patching to control who can make changes
		Lockable enclosure systems, cross connect patch panels
		PanView infrastructure management
Manufacturing Zone (Level 3)		
Control Room	Performance: Noise issues	Grounding/Bonding solutions for under raised floor, cabinet systems
	Performance: Cable/Connector performance	Copper and Fiber solutions, installation tools, and testing guidance for end-to-end connectivity performance that exceeds standards
	Performance: Thermal management	Enclosure systems and wire management solutions that efficiently direct cooling to critical servers and switches improving robustness
	High Availability: Redundant networks	Color coded, keyed jacks can prevent crossing channels inadvertently. Lock-in connectors can secure connections in switches or patching to control who can make changes
	Maintainability: Cable management	Fiber runner, enclosure and rack systems, wire management and identification products. PanView infrastructure management
	Mixture of Office and IE network	Color coded, keyed jacks can prevent crossing networks inadvertently. Lock-in connectors can secure connections in switches or patching to control who can make changes
	Reliability: Power	Superior termination with Panduit terminals.
Wireless implementation	Deploying wireless access points securely without expensive power runs	Utilize lockable, environmentally rated enclosures designed for Cisco Wireless Access Points and antenna systems and Power Over Ethernet (POE) to distribute power

Cell/Area Zone (Level 0,1,2)		
Network Distribution	Large system deployments require robust communications over long distances	Fiber solutions with pre-terminated connections easing use of fiber
	Reliability: Impact of extreme weather conditions or harsh environment	Stainless and weather resistant wire management products. Non-metallic raceways, heat shrink, insulation/abrasion products. Bulk Head connectors (IP67 or M12)
	Troubleshoot: Loss of network	PanView infrastructure management
Wireless implementation	Deploying wireless access points securely without expensive power runs	Utilize lockable, environmentally rated enclosures designed for Cisco Wireless Access Points and antenna systems and Power over Ethernet (PoE) to distribute power
Network Consolidation Points	Cost effective consolidation with security and manageability	Zone enclosure solutions to cost effectively distribute cabling with consolidation points
Control panels	Security: Control of ports	Color coded fiber and copper jacks or keyed connectivity solutions can provide means to segregate critical systems
	Performance: Noise issues	Comprehensive control panel solution utilizing grounding/bonding, cable segregation and separation to reduce risks
	Performance: Throughput, Latency	Connectivity solutions that exceed standards for copper and fiber connectivity. Pre-tested patch cords deliver long term performance reducing risk
	Testability: Verify during startup, preventative maintenance	Patching for testing fiber, copper uplinks and critical external connections. Pre-tested copper and fiber patch cords to mitigate risks
	Troubleshoot: Loss of network	PanView infrastructure management
	Reliability: Power	Superior termination with Panduit terminals.
	Reliability: Impact of extreme weather conditions or harsh environment	Stainless and weather resistant wire management products. Non-metallic raceways, heat shrink, insulation/abrasion products. Bulk Head connectors (IP67 or M12)
On Machine	Performance: ESD, Noise	Comprehensive Grounding/Bonding solutions
	Reliability: Mitigate failures due to vibration and motion	Abrasion and insulation protection to prevent severed wires.
	Reliability: Impact of extreme weather conditions or harsh environment	Stainless and weather resistant wire management products. Non-metallic raceways, heat shrink, insulation/abrasion products. Bulk Head connectors (IP67 or M12)
Safety Zone		
Control Panel, On Machine	Safe access to networks without exposing to shock, arc flash	Panduit Data Access Port featuring secure modular connectivity
	Arc Flash, Voltage hazards identified	Warning labels, lock out solutions
	Security: Network connectivity	Color coded, keyed jacks

5. Review the Recommended Solution Component List of Materials and Specify your Infrastructure:

Solution Area	Products	Detailed Parts List
Control Room	Racks Enclosures Security Connectivity Grounding/Bonding Pathways	Section 2.5 Pages 2-19 to 2-32
Network Distribution	Fiber Cable Copper Cable Pathways Grounding/Bonding	Section 2.6 Pages 2-33 to 2-43
Zone Cabling	Enclosures Connectivity Cable Management Security Grounding/Bonding	Section 2.7 Pages 2-44 to 2-55
Control Panel	Connectivity Cable Management Safety Abrasion protection Grounding/Bonding	Section 2.8 Pages 2-56 to 2-73
On-Machine	Connectivity Abrasion protection Cable management Safety Pathways Grounding/Bonding	Section 2.9 Pages 2-74 to 2-85

2.12 Discrete Manufacturing Application

Discrete Manufacturing refers to manufacturing operations that create products from a bill of materials from a sequence of automated and manual steps rather than in a raw material flow as in a process plant. The automation required for typical discrete manufacturing operations involves motion control using servo and VFD drives, PAC controllers, pneumatics, robotics, vision systems, sensors, and other processing elements.

Today's manufacturers are under pressure as never before to be globally competitive, which means configuring lean operations that have world-class efficiency, quality and agility. These needs are driving use of MES applications to link the ERP to the factory floor to provide visibility and automatic setup of equipment. Global manufacturing operations and increased regulatory and security requirements also are factors driving changes in automation deployments. The rapid growth of Ethernet connectivity is making all this connected manufacturing automation possible but is fraught with problems if unsophisticated users attempt to 'plug 'n play' into existing networks with low cost, unmanaged switches and cheap patch cords. Performance problems, startup delays, and production outages can occur from networking infrastructure not specified or installed to meet the application requirements, environmental and security challenges of the manufacturing space.

The discrete manufacturing automation system now requires multiple levels of physical infrastructure for networked connectivity that spans different environments and cuts across knowledge domains of control engineers and IT support staff. This infrastructure includes control rooms that resemble IT data centers with racks or enclosures housing multiple servers, switches, patching and other devices. Networking needs to be distributed to cell/area zones in an efficient manner that promotes high availability, maintainability, security, and flexibility. Control panels and on-machine cabling systems need to be engineered to promote testability, performance and security of the critical Ethernet communications that enable automation systems to function.

Reference Architectures

Rockwell Automation and Cisco have mapped out reference architectures that address the form factors, cost considerations, security, and network topologies required for today's discrete manufacturing operations. These architectures describe the strategy for a structured arrangement of servers, software, network switches, and control systems. However, the area not fully addressed that is critical for the success of these architectures is the physical layer. This refers to the infrastructure required to connect, manage, secure, and optimize the connectivity and installation of the networks, panels and control rooms required for control systems and MES integration. A structured, engineered approach is required for this physical layer to ensure that the investments in control software, controllers, servers, switches, and on machine devices actually startup and perform at peak output.

Physical Layout Considerations

To properly engineer the physical layer for a discrete manufacturing plant involves understanding the physical environment requirements which includes scale of the operation, control room layout, environmental considerations, and cell/area topologies. At the top of the manufacturing zone architecture for a discrete plant operation is the control room which requires server and switch enclosures. The performance and security of the critical control applications housed in this room can be optimized by leveraging best practices from data center rooms concerning enclosures, wire management, grounding/bonding, physical security, power and thermal considerations.

The next physical area to analyze is the cell/area zone area of the architecture, which involves distributing network cabling and wireless connectivity to each grouping of machines. Business/office networks may be co-located with the critical automation networks so means to identify, secure and mistake proof can provide important benefits. Distributed (i.e., zone cabling) enclosures for fiber or copper distribution and consolidation should also be employed for cost-effective cabling to cell/areas where control panels housing Stratix switches may be located.

The media and connectivity selected should have performance that exceeds TIA standard margin to ensure performance long term. For connecting field devices in harsh MICE environments, sealed IP-67 rated cord sets provide robust connectivity. Wire management and abrasion protection are key for reliability and maintainability for networks deployed 'on-machine' to connect to sensors or actuators in harsh environment areas or when subjected to repetitive motion. A well-engineered grounding/bonding system that mitigates noise considerations for communications is critical, both for the control room as well as distributed cabinets and I/O networks.

Network Schematic Analysis

As the network and computing resource requirements become more important to discrete automation systems, there is a need to leverage best practices from the IT world in conjunction with automation system knowledge. This requires partnering between IT and controls groups, developing 'hybrid' engineering skills to be able to make key decisions on network architectures and physical infrastructure component selection. It is recommended that IT and controls review a schematic layout of the discrete manufacturing system's switches and control devices to make decisions on physical infrastructure components to ensure security, performance and testability for each layer of the design.

This Guide provides a reference schematic layout showing a typical topology with callouts that show where physical security for ports can be applied, where performance decisions on media and connectivity need to be made, and where it's recommended to install patching for testability of critical fiber or copper links. For discrete manufacturing where office/business networks are commonly deployed in the same general area as manufacturing networks, it is crucial to identify and secure the critical control system physical links to avoid configuration mistakes and to prevent problems during startups and maintenance. Selection of appropriate fiber and copper media that can perform over the distances and environmental factors is key for robust operation.

Diverse pathway planning for redundancy across the plant as well as in control plans should be considered. Selecting fiber and copper connectivity solutions engineered for high performance exceeding standard margins reduces risks associated with installation and long term performance. A careful plan for deploying test points will insure that the network distribution meets performance targets before critical startups of equipment where delays can be costly as well as on a periodic basis during preventative maintenance to avoid loss of control during operation. Power Over Ethernet approaches for wireless access points should be considered to minimize deployment costs and to provide robust coverage.

End- to-End Solution

In summary, a careful analysis and plan developed for the physical infrastructure for discrete manufacturing operations for the entire network from the control room out to control panels and on-machine devices will meet the critical needs for high availability, security and performance. Use of reference architectures that leverage best practice physical infrastructure approaches for control room hardware, network distribution, network connectivity, wireless distribution, control panels and field device wiring will result in discrete manufacturing operations that are more intelligent and robust. This guide provides information on selecting, installing, testing, and documenting this critical physical infrastructure for all levels of this architecture.

Discrete Manufacturing Physical Infrastructure

This section defines the sequence of actions involved with deploying a physical infrastructure to support Discrete Manufacturing Plant layouts.

1. Logical Design

Define the logical architecture governing the layout of Discrete Manufacturing industrial systems and active devices. The logical architecture should be based on logical layer reference architectures developed by Rockwell Automation and Cisco, as well as on applicable topology diagrams.

2. Physical Design

Map out the physical locations of control panels, MCC, control room, and production offices to identify Ethernet network structured cabling reach requirements, noise considerations, and bonding/grounding requirements. The following diagram shows recommended best practices for 'in plant' distribution.

This step provides the opportunity to identify distributed zone cabling topologies and plan out required patching, test point, and security considerations.

3. Detail Design

Develop a network-level schematic diagram (or use a reference diagram) to identify the exact physical layer components required to deploy Ethernet network. These components include number of patch cords and horizontal links, patching fields, bonding and grounding elements, labeling and identification schemes, cable management tools, and safety and security tools.

This diagram also should identify IP and NEMA ratings for physical layer components based on MICE level analysis of Discrete Manufacturing areas, in order for the network and industrial systems to withstand the identified range of environments throughout the industrial facility.

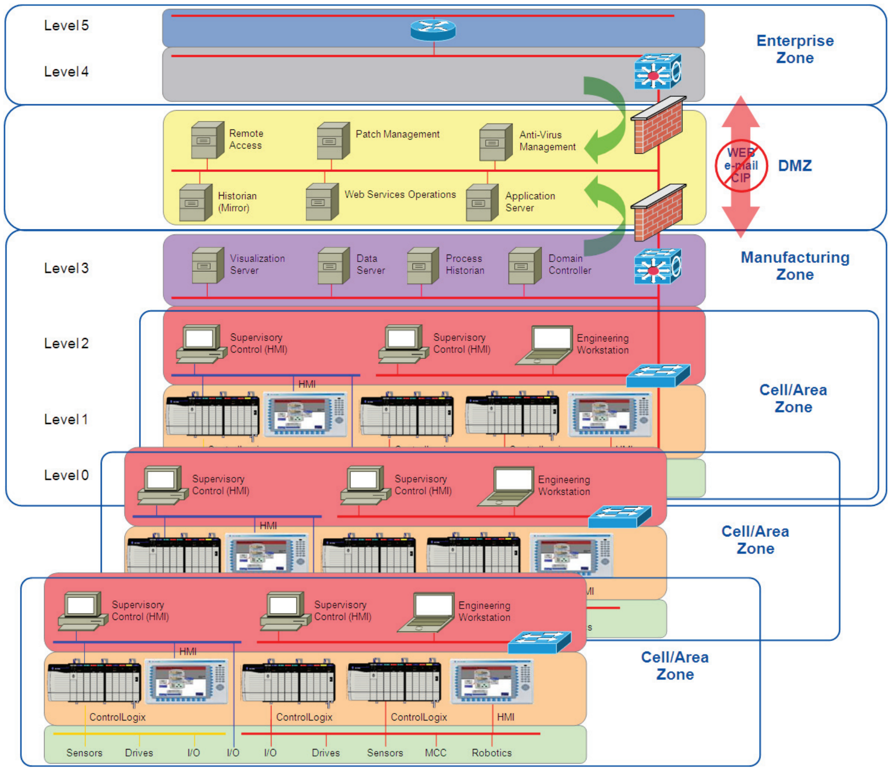
NOTE: Steps 2 and 3 are often done concurrently.

4. Review the levels of the architecture in the diagram and identify solutions to address your system needs.

5. Review the recommended solution component List of Materials and specify your infrastructure.

1. Logical Design

Define the Logical Architecture



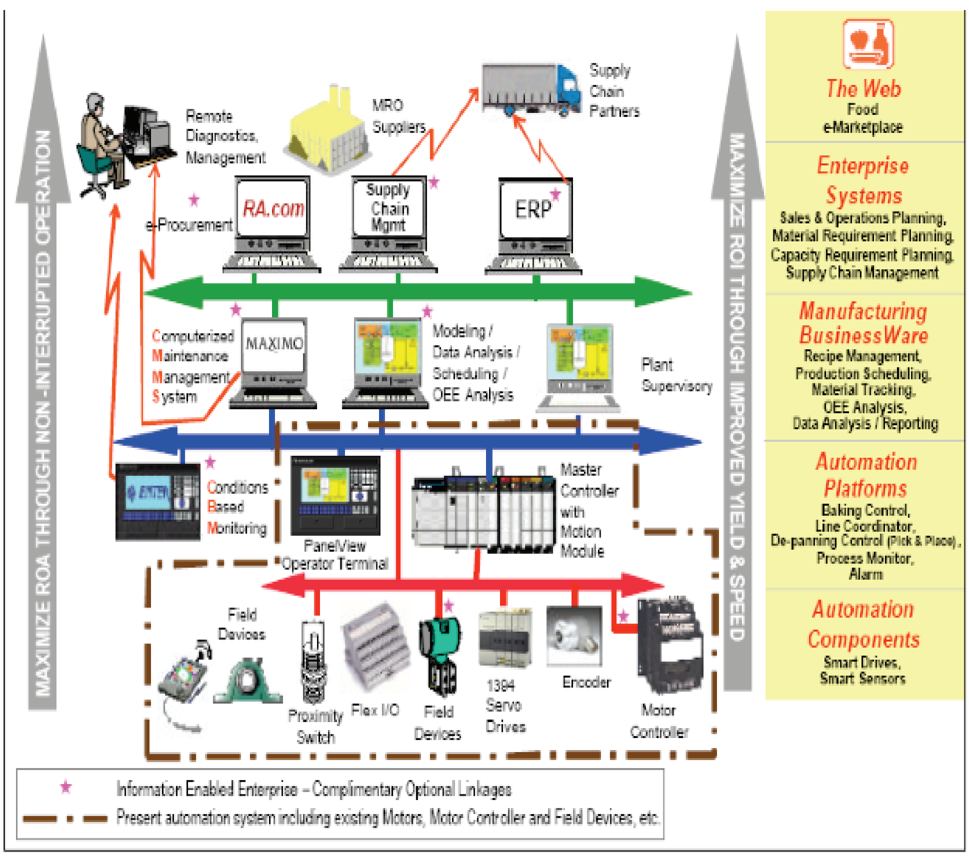


Fig 2.12-1 Logical Diagram for discrete manufacturing

2. Physical Design

Map Device Locations to Identify Physical Infrastructure
Reach, Noise, Bonding/Grounding Requirements

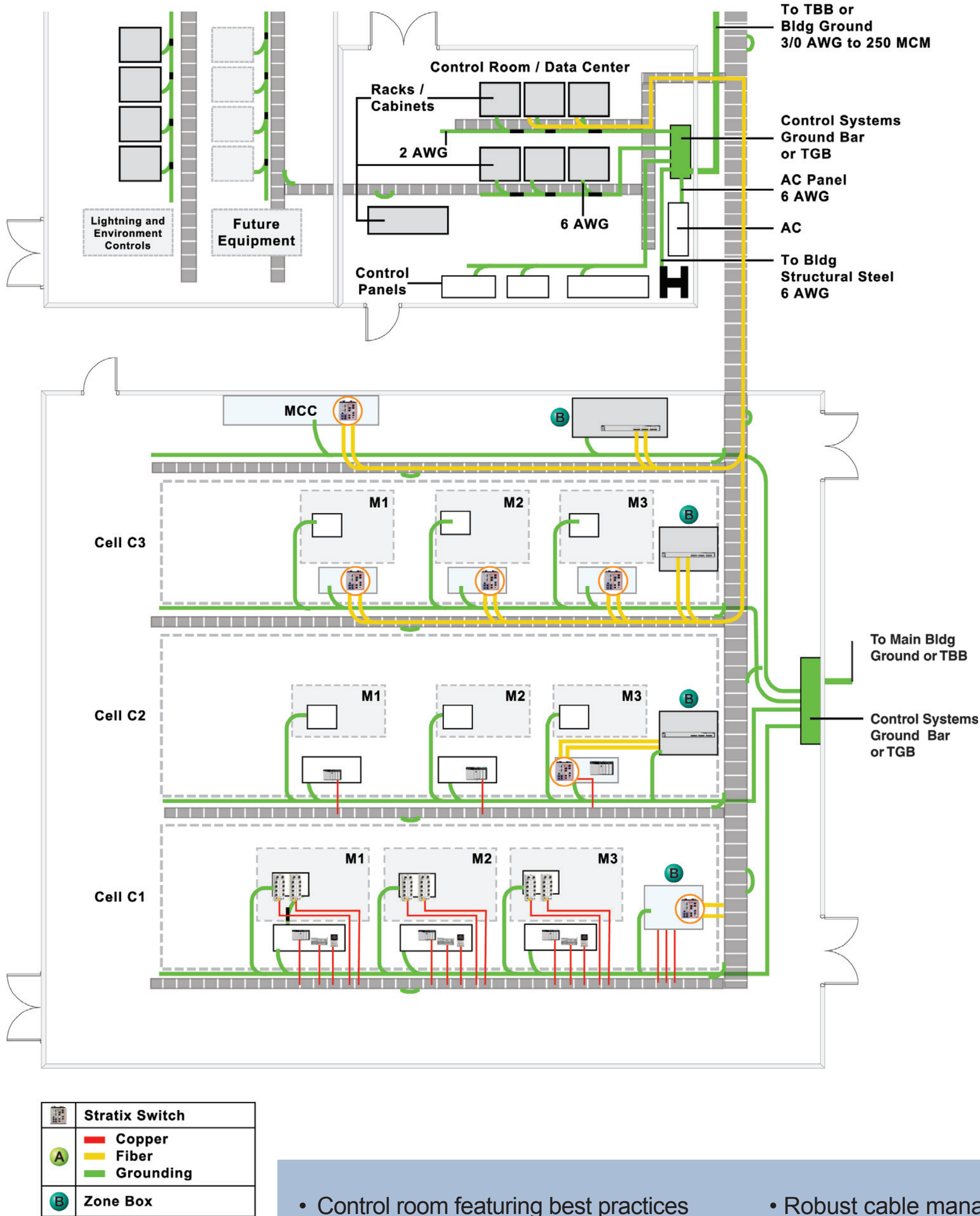


Fig 2.12-2 Physical Diagram for discrete manufacturing

- Control room featuring best practices for FactoryTalk servers, Stratix switches, Cisco Level 3 switches, firewalls.
- Control rooms housing enclosures/ racks with well engineered ground/ bonding, power and thermal mgt.
- Zone cabling approach to distribute cabling efficiently to the machine/area/zone.
- Robust cable management to secure and isolate Ethernet and control cabling mounted on machine.
- Grounding and bonding to equipment to mitigate risks to communication disruptions
- Enhanced security with keyed jacks, lock-in and blockout connectivity

3. Detail Design

Develop Network-Level Schematic Diagram Identify Exact Physical Infrastructure Components

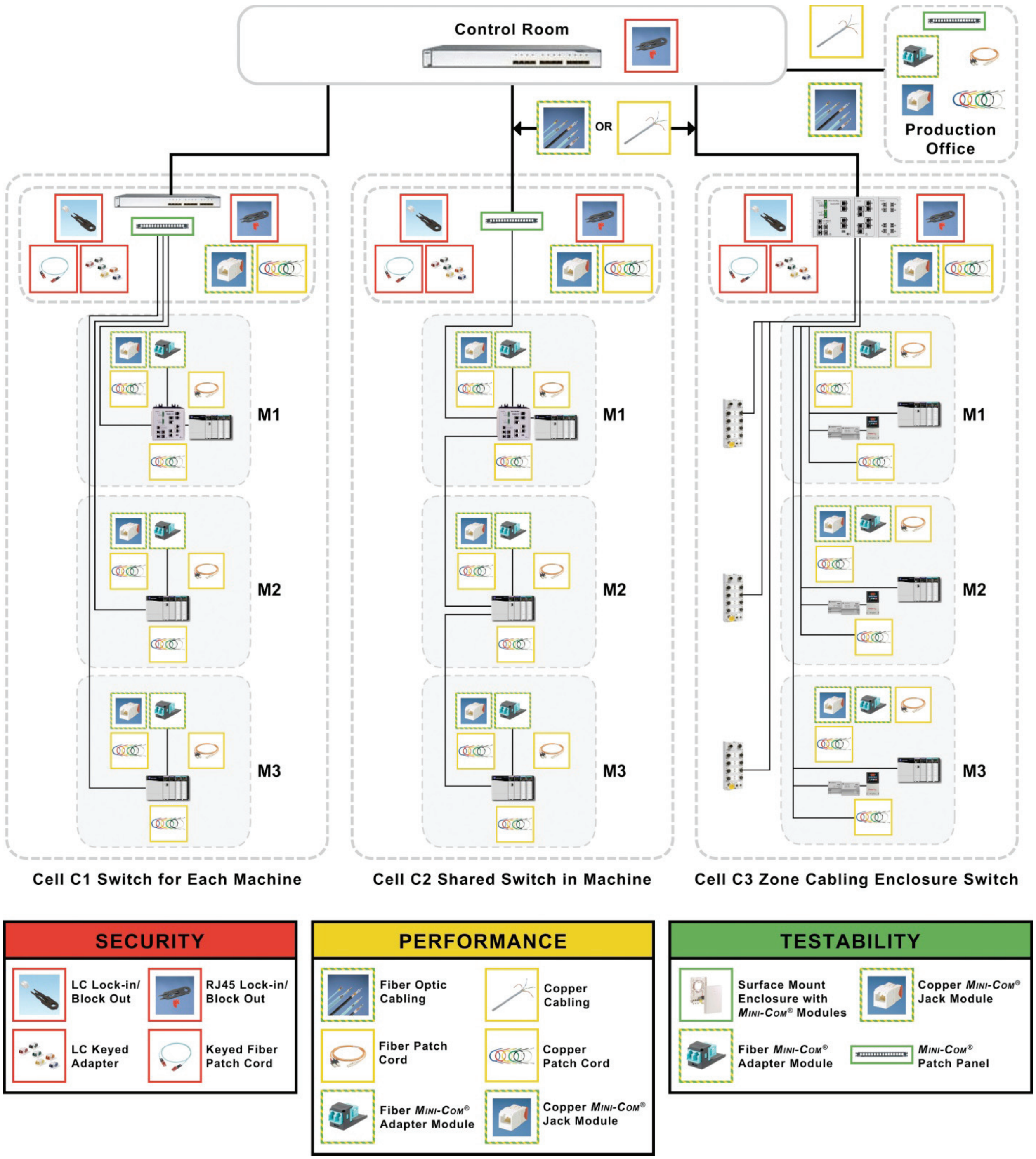


Fig. 2.12-3 Detail diagram for discrete manufacturing network physical infrastructure

4. Review the Levels of the Architecture in the Diagram and Identify Solutions to Address Your System Needs.

Zone Area Physical Infrastructure	SCADA Issues	Panduit Solution
Enterprise Zone (Level 1,2)		
Enterprise Data Center connectivity	Future-proof, High Availability, high performance connectivity	Fiber and 10GB copper connectivity solutions
DMZ		
Shared enclosure, rack areas	Security: Control and Management of connections, patching	Color coded, keyed jacks can prevent crossing channels inadvertently. Lock-in connectors can secure connections in switches or patching to control who can make changes
		Lockable enclosure systems, cross connect patch panels
		PanView infrastructure management
Manufacturing Zone (Level 3)		
Control Room	Performance: Noise issues	Grounding/Bonding solutions for under raised floor, cabinet systems
	Performance: Cable/Connector performance	Copper and Fiber solutions, installation tools, and testing guidance for end-to-end connectivity performance that exceeds standards
	Performance: Thermal management	Enclosure systems and wire management solutions that efficiently direct cooling to critical servers and switches improving robustness
	High Availability: Redundant networks	Color coded, keyed jacks can prevent crossing channels inadvertently. Lock-in connectors can secure connections in switches or patching to control who can make changes
	Maintainability: Cable management	Fiber runner, enclosure and rack systems, wire management and identification products. PanView infrastructure management
	Mixture of Office and IE network	Color coded, keyed jacks can prevent crossing networks inadvertently. Lock-in connectors can secure connections in switches or patching to control who can make changes
	Reliability: Power	Superior termination with Panduit terminals.

Cell/Area Zone (Level 0,1,2)		
Network Distribution	Large system deployments require robust communications over long distances	Fiber solutions with pre-terminated connections easing use of fiber
	Troubleshoot: Loss of network	PanView infrastructure management
	Numerous network drops to controllers, HMIs, testers, printers, scanners, etc.	Fiber runner, enclosure and rack systems, wire management and identification products. PanView infrastructure management
Network Consolidation Points	Cost effective consolidation with security and manageability	Zone enclosure solutions to cost effectively distribute cabling with consolidation points
Wireless implementation	Deploying wireless access points securely without expensive power runs	Utilize lockable, environmentally rated enclosures designed for Cisco Wireless Access Points and antenna systems and Power over Ethernet (PoE) to distribute power
	Safety: Tripping hazard to wire movable equipment	Utilize lockable, environmentally rated enclosures designed for Cisco Wireless Access Points and antenna systems and Power over Ethernet (PoE) to distribute power
Control panels	Security: Control of ports	Color coded fiber and copper jacks or keyed connectivity solutions can provide means to segregate critical systems
	Performance: Noise issues	Comprehensive control panel solution utilizing grounding/bonding, cable segregation and separation to reduce risks
	Performance: Throughput, Latency	Connectivity solutions that exceed standards for copper and fiber connectivity. Pre-tested patch cords deliver long term performance reducing risk
	Testability: Verify during startup, preventative maintenance	Patching for testing fiber, copper uplinks and critical external connections. Pre-tested copper and fiber patch cords to mitigate risks
	Troubleshoot: Loss of network	PanView infrastructure management
	Reliability: Power	Superior termination with Panduit terminals.
	Mixture of Office and IE network	Color coded, keyed jacks can prevent crossing networks inadvertently. Lock-in connectors can secure connections in switches or patching to control who can make changes
	Maintainability: Dynamic production floor - equipment relocation, additions, expansions, removal	Zone enclosure solutions to cost effectively distribute cabling with consolidation points. Wire management and identification products. Expandable, high density patch panels
On Machine	Performance; ESD, Noise	Comprehensive Grounding/Bonding solutions
	Reliability: Mitigate failures due to vibration and motion	Abrasion protection to prevent severed wires
	Maintainability: additional and enhanced devices, HMI, printers, etc.	Identification and wire management products that improve ability to change, modify, debug

Cell/Area Zone (Level 0,1,2)		
Control Panel, On Machine	Safe access to networks without exposing to shock, arc flash	Panduit Data Access Port featuring secure modular connectivity
	Arc Flash, Voltage hazards identified	Warning labels, lock out solutions
	Security: Network connectivity	Color coded, keyed jacks

5. Review the Recommended Solution Component List of Materials and Specify your Infrastructure.

Solution Area	Products	Detailed Parts List
Control Room	Racks Enclosures Security Connectivity Grounding/Bonding Pathways	Section 2.5 Pages 2-19 to 2-32
Network Distribution	Fiber Cable Copper Cable Pathways Grounding/Bonding	Section 2.6 Pages 2-33 to 2-43
Zone Cabling	Enclosures Connectivity Cable Management Security Grounding/Bonding	Section 2.7 Pages 2-44 to 2-55
Control Panel	Connectivity Cable Management Safety Abrasion protection Grounding/Bonding	Section 2.8 Pages 2-56 to 2-73
On-Machine	Connectivity Abrasion protection Cable management Safety Pathways Grounding/Bonding	Section 2.9 Pages 2-74 to 2-85

2.13 Packaging / Conveying Applications

Packaging and conveying areas of a typical manufacturing enterprise feature a unique set of physical infrastructure requirements that bring together aspect of discrete manufacturing, process, and business system integration. Packaging is a dynamic industry due to the market impact and rapid advancements in materials and strategies for ensuring packaging that is secure, green, and that earns consumer preference.

Conveying systems are comprised of conveying sections, bar code printers, readers, weigh scales, vision systems, palletizers and other logistics components that allow shipping final products efficiently. The automation required for typical packaging operations involve motion control using servo and VFD drives, PAC controllers, pneumatics, robotics, vision systems, sensors, and other processing elements. Conveying systems rely on MCC (Motor Control Centers) and distributed I/O systems for conveying sections controlled by PAC systems for coordinated motion. The logistical needs to coordinate these steps are driving use of MES applications to link the ERP layer to the factory floor to provide visibility and automatic setup of equipment.

The rapid growth of Ethernet connectivity is making all this connected manufacturing automation possible but is fraught with problems if unsophisticated users attempt to 'plug 'n play' into existing networks with low-cost, unmanaged switches and cheap patch cords. Performance problems, startup delays, and production outages can occur from networking infrastructure not specified or installed to meet the application requirements, environmental and security challenges of the manufacturing space.

The packaging automation systems and conveying operations now require multiple levels of physical infrastructure for networked connectivity that spans different environments and cuts across knowledge domains of control engineers and IT support staff. This infrastructure includes control rooms that resemble IT data centers with racks or enclosures housing multiple servers, switches, patching and other devices. IT closets are replaced with industrial enclosures on the plant floor. Networking needs to be distributed to cell/area zones in an efficient manner that promotes high availability, maintainability, security, and flexibility. Control panels and on-machine cabling systems need to be engineered to promote testability, performance and security of the critical Ethernet communications that enable automation systems to function.

Reference Architectures

Rockwell Automation and Cisco have mapped out reference architectures that address the form factors, cost considerations, security, and network topologies required for today's discrete manufacturing operations. These architectures describe the strategy for a structured arrangement of servers, software, network switches, and control systems. However, the area not fully addressed that is critical for the success of these architectures is the physical infrastructure. This refers to the infrastructure required to connect, manage, secure, and optimize the connectivity and installation of the networks, panels and control rooms required for control systems and MES integration. A structured, engineered approach is required for this physical infrastructure to ensure that the investments in control software, controllers, servers, switches, and on machine devices actually startup and perform at peak output.

Physical Layout Considerations

To properly engineer the physical infrastructure for a packaging/conveying operation involves understanding the physical environment requirements including scale of the operation, control room layout, environmental considerations, and cell/area topologies. At the top of the manufacturing zone architecture for a discrete plant operation is the control room which requires server and switch enclosures. The performance and security of the critical control applications housed in this room can be optimized by leveraging best practices from data center rooms concerning enclosures, wire management, grounding/bonding, physical security, power and thermal considerations.

The next physical area to analyze is the cell/area zone area of the architecture which involves distributing network cabling and wireless connectivity to each grouping of machines. Business/office networks may be co-located with the critical automation networks so means to identify, secure and mistake proof can provide important benefits Distributed enclosures for fiber or copper distribution and consolidation should also be employed for cost-effective cabling to cell/areas where control panels housing Stratix switches may be located. The media and connectivity selected should have performance that meets or exceeds TIA and ODVA standards to ensure performance long term. For connecting field devices in harsh MICE environments, sealed IP-67 rated cord sets provide robust connectivity. Wire management and abrasion protection are key for reliability and maintainability for networks deployed on-machine to connect to sensors or actuators in harsh environment areas or when subjected to repetitive motion. A well- engineered grounding/bonding system that mitigates noise considerations for communications is critical both for the control room as well as distributed cabinets and I/O networks.

Network Schematic Analysis

As the network and computing resource requirements become more important to packaging systems, there is a need to leverage best practices from the IT world in conjunction with automation system knowledge. This requires partnering between IT and controls groups, developing 'hybrid' engineering skills to be able to make key decisions on network architectures and physical infrastructure component selection. It is recommended that IT and controls review a schematic layout of the manufacturing system's switches and control devices to make decisions on physical infrastructure components to ensure security, performance and testability for each layer of the design.

This guide provides a reference schematic layout showing a typical topology with callouts that show where physical security for ports can be applied, where performance decisions on media and connectivity need to be made, and where it's recommended to install patching for testability of critical fiber or copper links. For packaging/conveying operations where office/business networks are commonly deployed in the same general area as manufacturing networks, it is crucial to identify and secure the critical control system physical links to avoid configuration mistakes and to prevent problems during startups and maintenance. Selection of appropriate fiber and copper media that can perform over the distances and environmental factors is key for robust operation. Diverse pathway planning for redundancy across the plant as well as in control plans should be considered. Selecting fiber and copper connectivity solutions engineered for high performance exceeding standard margins reduces risks associated with installation and long term performance. A careful plan for deploying test points will ensure that the network distribution meets performance targets before critical startups of equipment where delays can be costly as well as on a periodic basis during preventative maintenance to avoid loss of control during operation. Power over Ethernet (PoE) approaches for wireless access points should be considered to minimize deployment costs and to provide robust coverage.

End-to-End Solution

In summary, a careful analysis and plan developed for the physical infrastructure for packaging/conveying operations for the entire network from the control room out to control panels and 'on-machine' devices will meet the critical needs for high availability, security and performance. Use of reference architectures that leverage best practice physical infrastructure approaches for control room hardware, network distribution, network connectivity, wireless distribution, control panels and field device wiring will result in discrete manufacturing operations that are more intelligent and robust. This Guide provides information on selecting, installing, testing, and documenting this critical physical infrastructure for all levels of this architecture.

Packaging / Conveying Physical Infrastructure

This section defines the sequence of actions involved with deploying a physical infrastructure to support Packaging/Conveying Plant layouts.

1. Logical Design

Define the logical architecture governing the layout of Packaging and Conveying industrial systems and active devices. The logical architecture should be based on logical layer reference architectures developed by Rockwell Automation and Cisco, as well as on applicable topology diagrams.

2. Physical Design

Map out the physical locations of control panels, MCC, control room, and production offices to identify Ethernet network structured cabling reach requirements, noise considerations, and bonding/grounding requirements. The following diagram shows recommended best practices for 'in plant' distribution.

This step provides the opportunity to identify distributed zone cabling topologies and plan out required patching, test point, and security considerations.

3. Detail Design

Develop a network-level schematic diagram (or use a reference diagram) to identify the exact physical layer components required to deploy Ethernet network. These components include number of patch cords and horizontal links, patching fields, bonding and grounding elements, labeling and identification schemes, cable management tools, and safety and security tools.

This diagram also should identify IP and NEMA ratings for physical layer components based on MICE level analysis of Discrete Manufacturing areas, in order for the network and industrial systems to withstand the identified range of environments throughout the industrial facility.

NOTE: Steps 2 and 3 are often done concurrently.

4. Review the levels of the architecture in the diagram and identify solutions to address your system needs.

5. Review the recommended solution component List of Materials and specify your infrastructure.

1. Logical Design

Define the Logical Architecture

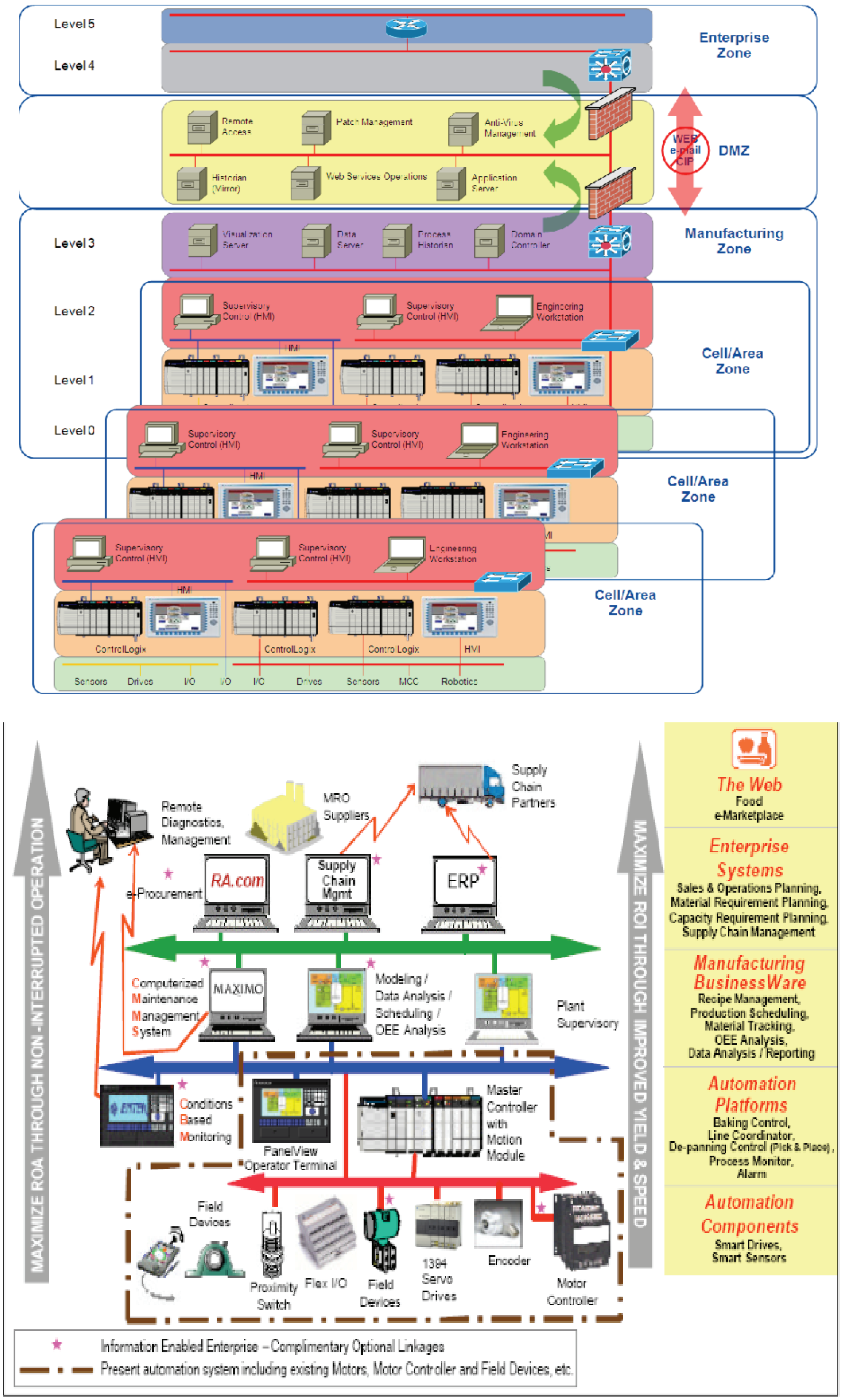
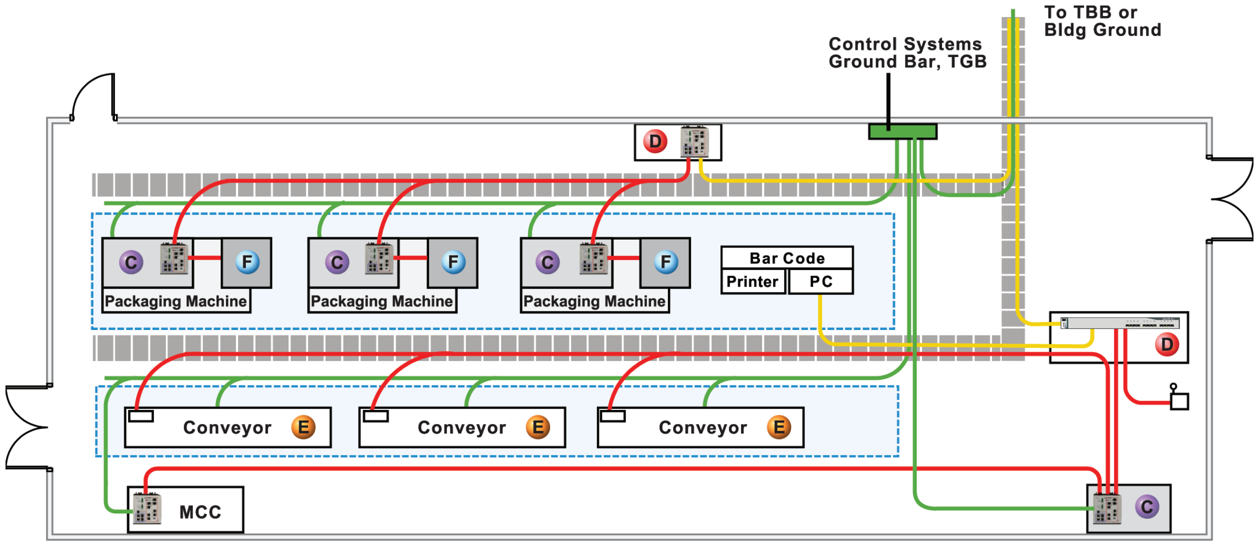


Fig 2.13-1: Logical Diagram for Packaging/ Conveying Network

2. Physical Design

Map Device Locations to Identify Physical Infrastructure

Reach, Noise, Bonding/Grounding Requirements



(icon)	Wireless Access Point
(icon)	Stratix Switch
A	Control Room
B	Copper Fiber Grounding
C	Control Panel
D	Zone Box
E	On-Machine Block
F	Operator Station

Fig. 2.13-2: Physical diagram for packaging/conveying network.

- Zone cabling approach to distribute cabling efficiently to the machine/area/zone
- Robust cable management to secure and isolate Ethernet and control cabling mounted on machine on conveyor sections.
- Grounding and bonding to equipment to mitigate risks to communication disruptions
- Enhanced security with keyed jacks, lock in and block out connectivity

3. Detail Design

Develop Network-Level Schematic Diagram Identify Exact Physical Infrastructure Components

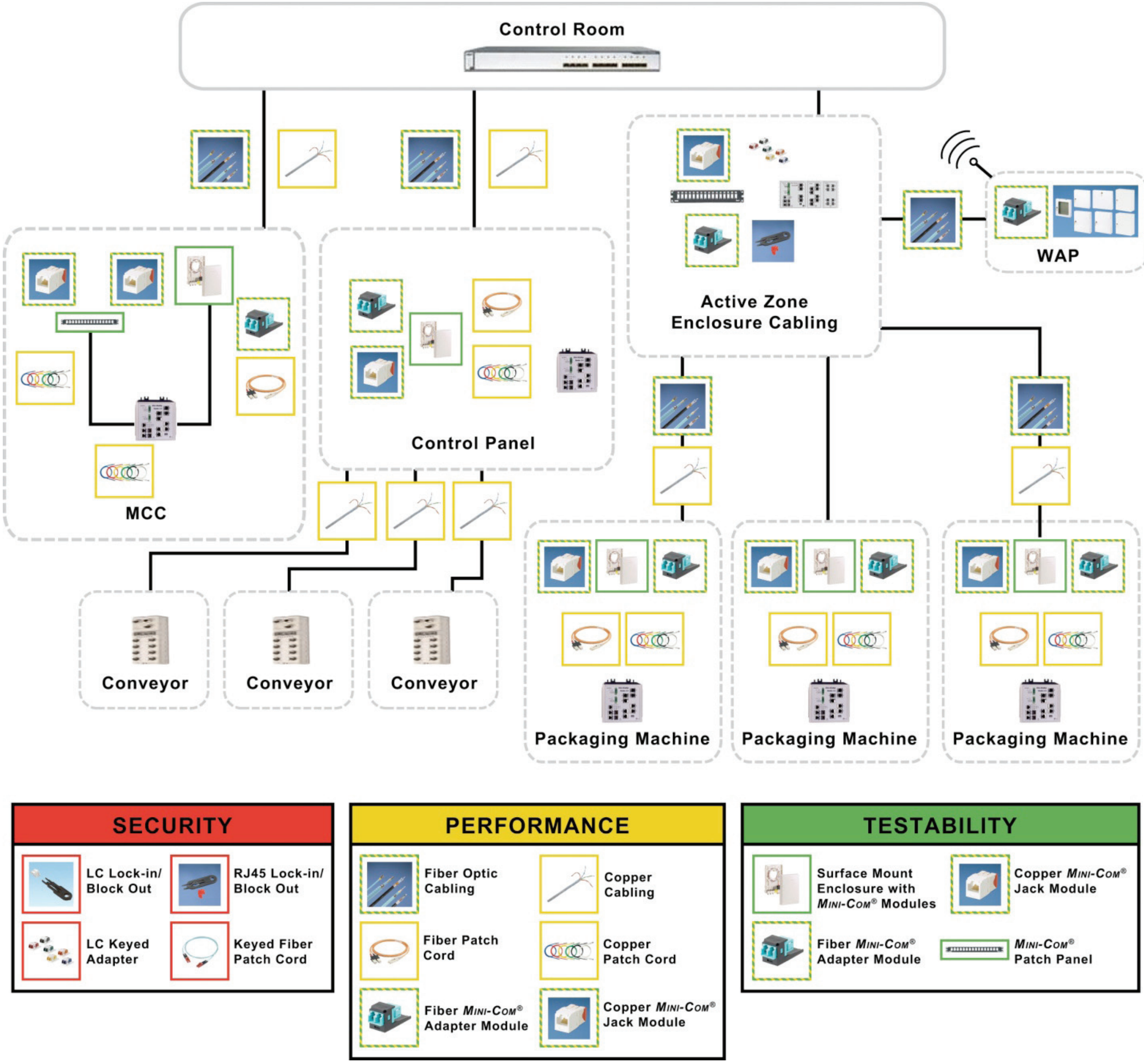


Fig. 2.13-3: Detail diagram for Packaging/Conveying physical network infrastructure

4. Review the Levels of the Architecture in the Diagram and Identify Solutions to Address Your System Needs.

Zone Area Physical Infrastructure	SCADA Issues	Panduit Solution
Enterprise Zone (Level 1,2)		
Enterprise Data Center connectivity	Future-proof, High Availability, high performance connectivity	Fiber and 10GB copper connectivity solutions
DMZ		
Shared enclosure, rack areas	Security: Control and Management of connections, patching	Color coded, keyed jacks can prevent crossing channels inadvertently. Lock-in connectors can secure connections in switches or patching to control who can make changes
		Lockable enclosure systems, cross connect patch panels
		PanView infrastructure management
Manufacturing Zone (Level 3)		
Control Room	Performance: Noise issues	Grounding/Bonding solutions for under raised floor, cabinet systems
	Performance: Cable/Connector performance	Copper and Fiber solutions, installation tools, and testing guidance for end-to-end connectivity performance that exceeds standards
	Performance: Thermal management	Enclosure systems and wire management solutions that efficiently direct cooling to critical servers and switches improving robustness
	High Availability: Redundant networks	Color coded, keyed jacks can prevent crossing channels inadvertently. Lock-in connectors can secure connections in switches or patching to control who can make changes
	Maintainability: Cable management	Fiber runner, enclosure and rack systems, wire management and identification products. PanView infrastructure management
	Mixture of Office and IE network	Color coded, keyed jacks can prevent crossing networks inadvertently. Lock-in connectors can secure connections in switches or patching to control who can make changes
	Reliability: Power	Superior termination with Panduit terminals.

Cell/Area Zone (Level 0,1,2)		
Network Distribution	Large system deployments require robust communications over long distances	Fiber solutions with pre-terminated connections easing use of fiber
	Troubleshoot: Loss of network	PanView infrastructure management
	Numerous network drops to controllers, HMIs, testers, printers, scanners, etc.	Fiber runner, enclosure and rack systems, wire management and identification products. PanView infrastructure management
Network Consolidation Points	Cost effective consolidation with security and manageability	Zone enclosure solutions to cost effectively distribute cabling with consolidation points
Wireless implementation	Deploying wireless access points securely without expensive power runs	Utilize lockable, environmentally rated enclosures designed for Cisco Wireless Access Points and antenna systems and Power over Ethernet (PoE) to distribute power
	Safety: Tripping hazard to wire movable equipment	Utilize lockable, environmentally rated enclosures designed for Cisco Wireless Access Points and antenna systems and Power over Ethernet (PoE) to distribute power
Control panels	Security: Control of ports	Color coded fiber and copper jacks or keyed connectivity solutions can provide means to segregate critical systems
	Performance: Noise issues	Comprehensive control panel solution utilizing grounding/bonding, cable segregation and separation to reduce risks
	Performance: Throughput, Latency	Connectivity solutions that exceed standards for copper and fiber connectivity. Pre-tested patch cords deliver long term performance reducing risk
	Testability: Verify during startup, preventative maintenance	Patching for testing fiber, copper uplinks and critical external connections. Pre-tested copper and fiber patch cords to mitigate risks
	Troubleshoot: Loss of network	PanView infrastructure management
	Reliability: Power	Superior termination with Panduit terminals.
	Mixture of Office and IE network	Color coded, keyed jacks can prevent crossing networks inadvertently. Lock-in connectors can secure connections in switches or patching to control who can make changes
	Maintainability: Dynamic production floor - equipment relocation, additions, expansions, removal	Zone enclosure solutions to cost effectively distribute cabling with consolidation points. Wire management and identification products. Expandable, high density patch panels
On Machine	Performance; ESD, Noise	Comprehensive Grounding/Bonding solutions
	Reliability: Mitigate failures due to vibration and motion	Abrasion protection to prevent severed wires
	Maintainability: additional and enhanced devices, HMI, printers, etc.	Identification and wire management products that improve ability to change, modify, debug

Cell/Area Zone (Level 0,1,2)		
Control Panel, On Machine	Safe access to networks without exposing to shock, arc flash	Panduit Data Access Port featuring secure modular connectivity
	Arc Flash, Voltage hazards identified	Warning labels, lock out solutions
	Security: Network connectivity	Color coded, keyed jacks

5. Review the Recommended Solution Component List of Materials and Specify your Infrastructure.

Solution Area	Products	Detailed Parts List
Control Room	Racks Enclosures Security Connectivity Grounding/Bonding Pathways	Section 2.5 Pages 2-19 to 2-32
Network Distribution	Fiber Cable Copper Cable Pathways Grounding/Bonding	Section 2.6 Pages 2-33 to 2-43
Zone Cabling	Enclosures Connectivity Cable Management Security Grounding/Bonding	Section 2.7 Pages 2-44 to 2-55
Control Panel	Connectivity Cable Management Safety Abrasion protection Grounding/Bonding	Section 2.8 Pages 2-56 to 2-73
On-Machine	Connectivity Abrasion protection Cable management Safety Pathways Grounding/Bonding	Section 2.9 Pages 2-74 to 2-85

ISO defined an Open System Interconnect 7 Layer reference model for networks (see Figure 3.1). The Physical Layer which forms the foundation layer for the entire network specifies the network media (copper, fiber wireless). The Network Physical Infrastructure includes the entire Physical Layer and adds the entire mechanical infrastructure necessary to support the Physical Layer and other layers that collectively form the network.

The entire Network Physical Infrastructure is often relegated to a contractor's discretion based on outdated specifications or past practices. To implement a Network Physical Infrastructure that supports a Rockwell Automation and Cisco's Reference Architectures for Manufacturing, more careful consideration must be given to the physical architecture, component specification, installation practice, testing, and documentation.

To properly execute a robust industrial Network Physical Infrastructure based on Ethernet technology that addresses these considerations requires solid project planning to ensure that the decisions and actions are made at the right time and by the right people. If properly planned and executed, the result is a robust, high performance Network Physical Infrastructure that has enables fast startup of an automation system that performs reliably long term in spite of environmental issues and that can handle new devices or system reconfiguration over time.

This section of this guide makes recommendations on how to turn a potentially chaotic process into a predictable controlled process that can be replicated globally.

The following subsections will introduce:

1. Basic considerations for project phases
2. Best practices and pitfalls to avoid for each phase.
3. Detailed checklist of steps to consider for each phase and layer of a typical physical infrastructure project.
4. Design tools for those responsible for the major phases of an industrial Ethernet physical infrastructure project.

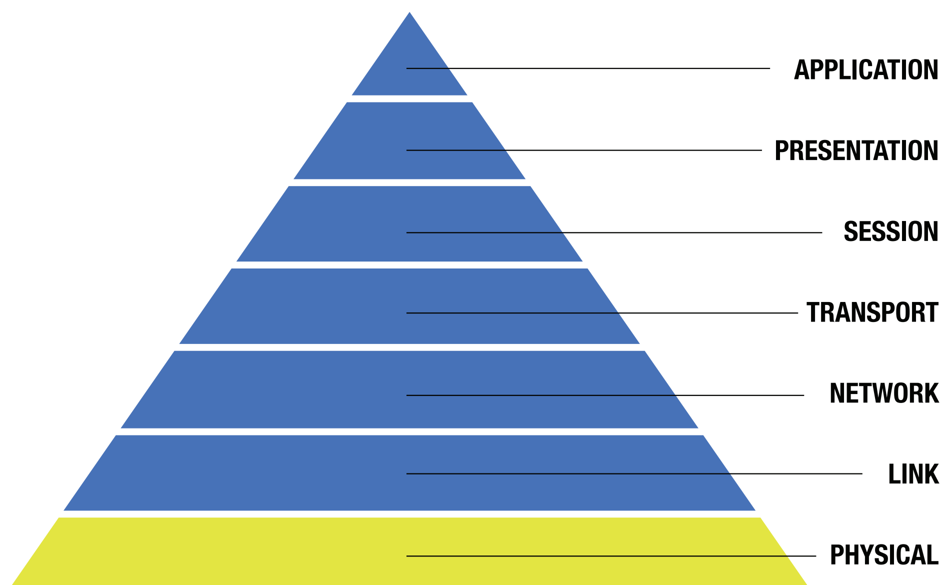


Figure 3.1-1 OSI 7-Layer Model

3.1 Basic Consideration for Project Phases

Planning

The planning phase is the most critical phase of the physical infrastructure installation process– changes after this stage will normally incur additional costs and delays to the project. A thorough project plan should be composed that identifies tasks, responsibilities, and due dates for the design, installation, testing and documentation steps.

First step is to fully understand the existing system including field verification of equipment and available ports. Every effort should be made to understand types of traffic and limitations of the existing physical infrastructure. The reliability of existing system should also be investigated and quantified.

The scope of the networking required for an automation system needs to be fully described to formulate an effective plan. The scope should include how the network will be used, in what type of physical atmosphere, code issues related to wiring, quantified amount and types of equipment on the network including POE, and potential future growth. Every effort should be made to reduce disparate systems operating on separate networks.

Designing

The design stage should include generating a Bill of Materials, CAD drawings, and firm scope of work for permit and bid use. When laying out the pathways for network installation, factor in production/maintenance department preference, ease of installation, and avoidance of harmful atmospheres where possible. As with the planning, field verification of routes should be performed to ensure no interferences which can change design and add to cost. Follow TIA, EIA, ANSI, Panduit Certified installers, tray fill %, etc… for best design practices. Bills of material should take into account specialty tools needed for installation and amount of slack needed at both ends of pulls. Every effort should be made to utilize pre-terminated products to reduce installation time and reduce errors in the field.

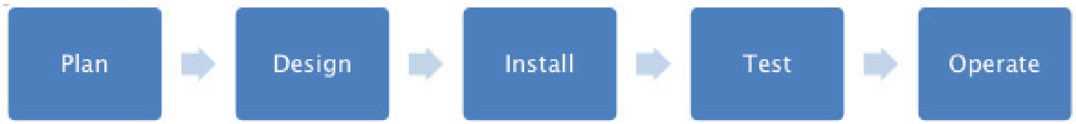
Implementing/Testing/Documentation/Operations

The installation by certified installer should also include 100% testing of all connections following Panduit warranty procedures. All testing is to be documented with copy to customer and Panduit for warranty records. All cabling must be properly labeled with products suitable for long-life in the environment.

Every effort should be made to not deviate from design without careful consideration of original intent and limitations. Any changes to the design plan must be updated on CAD drawings for customer retention. All change orders to original design should be carefully reviewed so as to avoid in future work. As-built drawings and network documentation should be generated to provide important information for support and maintenance over the lifetime of the system.

NOTE:

It can not be stressed enough that proper documentation occurs during each phase. Keeping up to date documentation for the entire network, including prints, mechanical hardware, devices, IP Addresses and switch configuration is essential to a successful network installation and operation.



Phase	Best Practices	Pitfalls To Avoid
Planning/Designing	Understanding the environment	Not planning the Infrastructure
	Follow MICE	Not taking environment into consideration, using business network specifications on the plant floor
	Understanding the extent of the network, how it will be used and by whom, who owns it, how changes will be made, future growth	Not planning for future growth Not understanding types of data traffic, how traffic interacts, and how to separate when and where necessary
	Written specification for networking components, establishing consistency (cable, cable type, connectors, enclosures, connection methods, etc.)	Incompatible components or partial compliance to standards (i.e., using Category 6 cable with standard connectors)
	Understanding the networking layout, the different types of traffic, limitations of the network	
	Fully document the network design showing device location, cable runs, pathways, label designations, color codes, keying and segmenting for security	Neglecting to fully document the design and to specify cable labels results in mistakes during subsequent phases.
Implementing	Network installation that will outlast the system, planned for future growth and future enhancements, ability to be used for future, faster network speeds when necessary, keeping costs reasonable, balancing future necessities with realistic costs	
	Certified installers with cable certification documentation	
	Installers, OEMs, system integrators having a standard to follow, no room for error	No structure or standard for OEMs / integrators to follow, mix of hardware makes for difficult maintenance
	Using correct tool	
	Using pretested, modular solutions	
	Configuration for optimization	Out of the box configuration
	Create 'As Built' documentation showing cable routing, identification, port assignments, and IP addresses assigned.	No 'as built' corrections to document results in confusion, wasted time
	Planned additions to the network	Adding in piecemeal
Testing	Operational testing without unnecessary shutdown	
	Test each horizontal link and store test results for future reference.	Neglecting to test links can result in extended startup troubleshooting
Operations	Regularly monitor network, assess before or after changes made	
	Monitor physical degradation due to environmental factors	
	Keep documentation up to date as equipment moves, adds, changes	

Table 3-1. Project Phases Best Practices, Pitfalls to Avoid

3.2 Detailed List of Project Steps

The following section details considerations for each step of the project phases.

PLANNING

1. Review applicable codes and standards for application area and each level of the architecture
2. Review Application requirements, reference architecture logical diagrams
3. Review/Create block diagram for system following applicable Rockwell Automation/Cisco reference architecture
4. Review site plan and building(s) floor plan to understand the physical layout of equipment on a plant floor or grounds
    a. Identify cell/area zones
    b. Identify existing control rooms and suitable locations for expansion or new rooms as required.
5. Perform walk through area to identify and verify:
    a. Existing cabling: location, category, media type
    b. Suitable pathway location for fiber or copper media runs
    c. Cell/area zones and suitable locations for consolidation points
    d. Existing control room or networking rooms and suitable location for new room if necessary
    e. Identify MICE level of environments for each level of the architecture:
    f. Identify physical cable run distances between:
        I. Control Room(s)
        II. Control Panel (s)
        III. On Machine
6. Review and document grounding/bonding scheme for building, control room, machine, cell or process

DESIGN

General Layout

1. Layout plant floor locations for:
    a. Control room racks/enclosures
    b. Zone cabling consolidation points
    c. Network drops
        I. Single mode fiber for runs over 550m
        II. Multimode fiber for runs under 550m
        III. Copper for runs under 100m
2. Specify amount of cable for BOM including slack for each end of run

Control Room Design

1. Determine number of servers and form factor. Determine rack or enclosure space
2. Layout rack with higher level switches and associated patching
3. Layout demilitarized zone firewalls and associated cabling
    a. Consider use of lockable enclosures, keyed fiber or copper jacks, lock in/block out connection technology to provide security
4. Select appropriate fiber and copper patching solutions
5. Specify blanking panels for mounting switches in 19 inch rack
6. Specify control room grounding bonding (See Section 2B, pages 2-37 and 2-38, Section 4C)
    a. Underfloor or overhead solutions
7. Specify fiber and copper pathway solutions for cabling within room (see Section 2B, Section 4E)
    a. Fiber runner for overhead system (Section 2B, page 2-35; Section 4E, pages 4-76 and 4-77)
    b. Grid runner for under-floor system (Section 2B, page 2-35 Section 4E, pages 4-78 and 4-79)
    c. Transition points: Wire basket, Ladder Rack (Section 4E, pages 4-81 and 4-82)
8. Review thermal management for enclosure systems (Section 4D page 4-73)
    a. Consider wire management, ‘Cool Boot’ and other products to maximize cooling efficiency
9. Review power conditioning and backup systems
10. Consider infrastructure management system to monitor patching
11. Specify pretested patch cable solutions
12. Consider modular high density patching solutions between enclosures, racks
13. Use standards based identification schemes to mark enclosures, ports, cables. Consider color codes for different network levels.
14. Determine Physical Security products to be used for segregating VLANs, network segments and DMZ:
    a. Keyed jacks, patch cords,
    b. Lock-in, blockout for desired ports
15. If shielded cable is used, design bonding scheme to avoid ground loops - use insulated patching approach, evaluate hybrid bonding

Network Distribution Design

1. Review channel length and decide on appropriate media for each level
2. Review performance and environmental needs and select category of copper horizontal runs
    a. Choose media and connectors with performance margins over standard for improved noise mitigation (see section 4A)
3. Review performance and environmental needs of fiber horizontal runs
    a. Select appropriate rated cable and number of fibers required
4. Specify pathway products for each area: ladder rack, j-hook, corrugated loom tubing, conduit, (see section 4E)
5. Use standards based identification schemes to mark enclosures, ports, cables (see section 4G)

Zone Cabling Enclosure Design

1. Determine environmental requirements and specify suitable enclosure rating
2. If zone enclosure is designed to be active or passive:
    a. Determine switch to be housed: 19 rack or Stratix panel mount switch
    b. Determine fiber/copper patching needs
    c. Determine Power over Ethernet (PoE) needs: mount midspan injectors in enclosure.
3. Determine number of RackUnits (RU's) required to specify size of rack or enclosure
4. Layout enclosure RU's with switches, patching, and Power over Ethernet (PoE)
5. Use standards based identification schemes to mark enclosures, ports, cables. Consider color codes for different network levels.
6. Determine physical security products (keyed jacks, patch cords, lock-in, blockout):

Control Panel Design

1. Address safety considerations for control panel
    a. Voltage and Arc Flash labels
    b. Provision for lockout/tagout
    c. Data Access Port for safe access to network without opening panel
2. Ensure panel uses appropriate grounding/bonding scheme and panel layout for noise mitigation (see section 4C pages 4-60 and 4-61)
    a. Galvanized back panel for any drives panel
    b. Bond sub panels
    c. Segregate clean and dirty signals in color-coded duct
3. Specify location for Stratix switch and design installation details
    a. Route Protective Earth (PE) wire to switch
    b. Location for patching and/or surface mount box for fiber slack management
    c. Segregate network cabling, and leave space for proper bend radius
4. Provide for ability to test links with appropriate test points
    a. Surface mount boxes, patch panels
5. Copper solutions (see section 4A)
    a. Choose quality copper jacks and media with performance margins over standard for improved noise mitigation
    b. Specify pretested patch cords
6. Fiber connectivity (see section 4B)
    a. Choose OptiCam pre-polished solution to speed installation and reduce risks since no field polish or adhesive required.
    b. Specify pre-tested patch cords
7. Wire management (see section 4F)
    a. Specify abrasion protection and clips, clamps, and ties engineered to protect cable and avoid over-cinching cables risking performance degradation.
8. Identification (See section 4G)
    a. Use standards based identification schemes to mark devices, ports, cables. Consider color codes for different network levels

On-Machine Design (See section 2F)

1. Review scope of system and layout of machines and process
2. Specify locations for zone enclosures to feed 'on-machine' drops
3. Use M12 connectors or sealed RJ45 network connectivity for 'on machine' devices for devices exposed to high MICE level hazards (mechanical, ingress, chemical exposures).
4. Review grounding/bonding for equipment and control panels to mitigate EMI noise and ESD risks
5. Design 'on machine' pedestals or panels with wire management and identification features
    a. Hinged duct for slack management
    b. Clips and clamps for cable bundles
    c. Identification products for devices and cabling
    d. Metal detectable wire management products for food industry
6. Safety design: lockout/tagout, warning signage

INSTALLATION

Control Room, Network Distribution, Zone Cabling Enclosures

1. Certified installer using correct tools for fiber termination
2. Certified installer using correct tools for copper termination
3. Install bonding, grounding with specified conductor sizes and ensuring all paint piercing washers are used on painted surfaces, etc. to ensure adequate bonding.
4. Ensure adequate bend radius
5. Identify cabling and devices per drawing
6. Avoid over-cinching or deforming cabling

Control Panels

1. Segregate wiring into color coded clean/dirty duct for noise mitigation
2. Install bonding for all subpanels.
    a. Use wide bonding straps rather than narrow gauge wire for bonding
3. Install surface mount boxes, patch fields to aid in testing
4. Install security devices to lock-in, block out ports per drawing
5. Install Data Access Port where convenient for troubleshooting in side of panel or on door
6. Use abrasion protection and dynamic cable mounts for wiring on door of panel to manage and secure cabling
7. Identify IP addresses of critical devices (e.g. PAC system, HMI, drives to allow connectivity for configuration or troubleshooting)

On-Machine

1. Use abrasion protection products to manage and protect cables
2. Consider use of duct for slack management
3. Separate different classes of wiring for noise mitigation
4. Identify devices, ports, cables, and address information

TESTING

1. Test each copper link to ensure that it meets or exceeds Category ratings
2. Test each fiber link to ensure it has desired performance
3. Record baseline information on new system for later reference
4. Verify grounding and bonding resistance, record for later reference, audit

OPERATION

1. Periodically audit network performance
2. Periodically check grounding/bonding integrity and resistance

NOTE: REMEMBER TO DOCUMENT

1. Document Rack, port layout for switches in control room, zone enclosure or control panels
2. Make as built network diagrams and plant layout schematics showing fiber and cable drops

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3.3 Project Phase Design Tools

Phase	Typically Responsible	Tools
Plan	Control Engineer, IT Network Analyst/ Engineer, Plant Engineer or Supervisor	- Reference Architectures - Design Guides - Project Management Software
Design	Control Engineer, IT Network Analyst/ Engineer	- Reference Architectures - Rockwell Automation Integrated Architecture Builder - Panduit Design tool for Visio - Bentley promisE Electrical CAD tools for panel layout, network layout, documentation
Implement	Contractor, Electricians, Network analyst	- Panduit installation tooling and kits - Panduit training - Panduit Label Printing Systems - Bentley promisE Electrical CAD tools for panel layout, network documentation
Test	Contractor, Electricians, Network analyst	- Panduit training - Fluke testing tools
Operate	Regularly monitor network, assess before or after changes made	- FactoryTalk Asset Center - Panduit Panview patching infrastructure Monitoring

A network physical infrastructure implementation requires the selection of connectors, media, pathways, enclosures, identification and security components along with associated installation methodologies (e.g. wire management, grounding & bounding). The following section provides guidance on specifying, installing, testing, and documenting these critical components.

The physical infrastructure forms the foundation to support the communication channels that connect a distributed system tasked with real-time control, process data collection and device configuration. Industrial networks require deterministic performance. Therefore, the physical infrastructure of the network channel must be specified with sufficient performance margin, proper environmental rating, and dependable security features to ensure that the network performs consistently and reliably.

Besides EMI noise coupling risks, the other factors that are the most problematic for selecting, planning, and installing the fiber and copper media are the environmental factors that can prevail in certain points of a communication channel. These factors can range from extreme cold or hot temperatures outdoors or in a process line to humidity or chemical exposure that can degrade insulation to vibration or shock that can cause mechanical failures of connections. The MICE rating system allows these factors to be categorized and analyzed for mitigation. Products that can assist in mitigation include armored fiber cable, IP67 rated connectors, and special grades of insulation.

A further refinement in best practices related to managing environmental concerns is described in TIA-1005 which allows more than 4 connectors per channel to enable setting up MICE boundary points (see Figure 4-1) along the channel length as the media passes through different areas. This approach can be very cost effective since only those limited areas needing elevated protection require the more expensive hardened infrastructure components. The areas that are more protected can use standard solutions which are more cost effective.

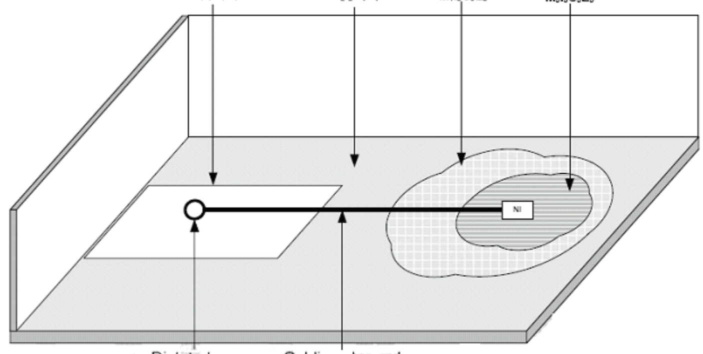


Figure 4.1-1. MICE boundaries can change at various points across channel length as cabling channels pass through multiple areas, as defined in TIA-1005 (Source: ISA).

To design an effective end-to-end solution that mitigates environmental and EMI requires carefully analyzing the control system communication requirements, device characteristics, environmental conditions and transition points, as well as availability and security considerations. Designers and specifiers are left to answer many questions regarding these critical connectivity issues. What type of media? How much hardening do I need? What is cost effective? What is overkill? What will meet today's and tomorrow's needs in the face of the new technologies …wireless, POE, VOIP? The answer requires careful consideration of many factors. Reference architectures and environmental analysis tools like the MICE rating system can provide these answers. The following selection guide information will reveal products that will allow implementing end to end connectivity that can meet these needs.

STANDARDS and CODES

ANSI/TIA-1005 / ANSI/TIA-1005-1

Publication of the Telecommunications Infrastructure Standard for Industrial Premises and its first addendum, covering Industrial Pathways and Spaces, is forthcoming is 2009. The documents are based on the ANSI/TIA/EIA-568-B and TIA-569-B series of standards, and include appropriate allowances and exceptions to those standards for industrial premises. They also include techniques to mitigate mechanical, ingress, climate/chemical, and electromechanical (M.I.C.E.) effects across multiple areas.

TIA/EIA-568-B

TIA/EIA-568-B (Commercial Building Telecommunications Cabling Standard) covers structured cabling systems (both balanced copper cabling and fiber optic cabling) for commercial buildings, and between buildings in campus environments. The bulk of the standards define cabling types, distances, connectors, cable system architectures, cable termination standards and performance characteristics, cable installation requirements, and methods of testing installed cable. Two common network architectures are described by this standard: hierarchal star and centralized fiber (FTTx).

TIA/EIA-569-B

TIA/EIA-569-B (Commercial Building Standards for Telecommunications Pathways and Spaces) provides requirements for spaces (rooms or areas) and pathways into and through which telecommunications equipment and media are installed. This standard, along with Addendum 5 to TIA/EIA-568-B, specifically addresses fiber to the enclosure (FTTE), a method for network deployment under which active equipment is typically centralized in a single location (such as a control room), and fiber backbones are run to distributed enclosures located close to machinery and work stations. This is the lowest cost and most flexible infrastructure.

TIA/EIA-942

TIA/EIA-942 (Telecommunications Infrastructure Standard for Data Centers) specifies the minimum requirements for the telecommunications infrastructure of data centers and computer rooms. This standard differs from 568-B/569-B in that it specifically recommends a particular fiber grade, laser-optimized OM3, as the most reliable fiber media solution at 10Gbit/sec. The data center is a fiber-rich environment where fiber runs typically are less than 50 meters. Storage Area Network (SAN) components are nearly 100% cabled with fiber media, and fiber cabling is an increasingly popular option as a high-speed server/switch interconnect.

ISO/IEC 11801

International standard ISO/IEC 11801 (Generic Customer Premises Cabling) specifies general-purpose telecommunication cabling systems that are suitable for a wide range of applications (analog and ISDN telephony, various data communication standards, building control systems, factory automation). It covers both balanced copper cabling and fiber optic cabling. The standard was designed for use within commercial premises that may consist of either a single building or of multiple buildings on a campus.

4.1 Copper Media

4.1.1 Selection

When choosing Ethernet copper-based cabling solutions, the following criteria should be taken into consideration prior to installation to ensure system performance, reliability, and scalability.

4.1.1.1 Media Type

Several different kinds of twisted-pair copper cables are available for deployment in Industrial Ethernet applications, depending on reach and bandwidth requirements (see Table 4.1-1). The following types of copper twisted-pair cable are most often deployed in industrial settings:

Category 6A

- Allows 10 Gb/s performance over 100m channel
- Designed for the most bandwidth intensive applications:
- Converged networks – Data, VoIP, Stream Video, Medical Imagery
- Backbones serving increase network traffic Data Centers – Shared network storage, clusters/server farms
- Future proofing for the certain growth and demand on the network
- Can deploy PoE without sacrificing high network throughput

Category 6
- Ideal for critical applications where network up-time is extremely important
- Provides guaranteed performance headroom
- Compensates for:
- Variations in installation practices
- Affects of future disturbance to the structured cabling system
- Allows limited 10 Gb/s applications (37 meters)

Category 5e
- Expansion of existing Category 5e networks
- Expansion of short/limited life networks
- Cost critical installations where future proofing/longevity is not an issue

Parameter	Category 5e	Category 6	Category 6A
Standard	• TIA/EIA-568-B.2 Category 5e • ISO/IEC 11801 Edition 2, Class D	• TIA/EIA-568-B.2-1 Category 6 • ISO/IEC 11801 Edition 2, Class E • TSB-155 supports 10GBASE-T applications up to 37m channels	• TIA/EIA-568-B.2-10 Augmented Category 6 • ISO/IEC 11801 Edition 2, Amendment 1 Class EA
Specified Bandwidth	100 MHz	250 MHz	500 MHz
Insertion Loss @ 100MHz	24 dB	21.3 dB	20.9 dB
Cable Diameter	0.19 – 0.21 inch	0.23 – 0.25 inch	0.295 inch
POE Support	Yes	Yes	Yes

Ethernet Reach:

10G/1000BASE-T	Category 5e	Category 6	Category 6A
Gigabit Ethernet	100 m	100 m	100 m
10Gigabit Ethernet	Not supported	37 m	100 m
10GBT low power mode	Not supported	Not supported	30 m

Fiber Channel Reach over Copper:

FC-BASE-T	Category 5e	Category 6	Category 6A
1G FC-BASE-T	100 m	100 m	100 m
2G FC-BASE-T	60 m	70 m	100 m
4G FC-BASE-T	Not supported	40 m	100 m

Fig. 4.1-2. Balanced Copper Media Types and Reach / Bandwidth Characteristics

Ensuring 10Gb/s Performance.

The control room physical infrastructure can be leveraged to support multiple generations of factory systems and equipment as machine cells are upgraded, reconfigured, or extended. Also, links in the control room may need to carry 10 Gb/s in order to support convergence of disparate batch, continuous process, discrete, safety, motion, and drive control industrial network technologies. For these reasons, a 10-Gigabit ready cabling infrastructure is recommended, with Industrial Ethernet bandwidth and reach requirements favoring the deployment of Category 6A copper links.

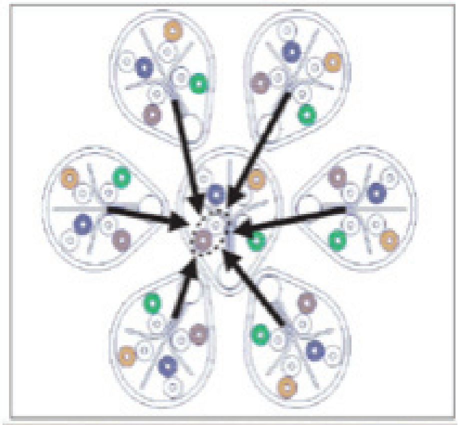
For 10GBASE-T performance the IEEE requires Category 6 electrical channel parameters to be extended from the current 250 MHz to 500 MHz, and introduces Power Sum Alien Crosstalk requirements up to 500 MHz. While the standard recognizes that Category 6 cabling systems may support 10 Gigabit Ethernet over limited distances, only Category 6A copper cabling systems will be able to support 10 Gb/s data rates for distances up to 100 meters.

The IEEE also has determined that alien crosstalk is the main electrical parameter limiting the performance of the structured cabling system when applied to 10 Gigabit transmission lines. Alien crosstalk is a coupled signal in a disturbed pair arising from a signal in a neighboring cable. Today's digital signal processing (DSP) electronics are not as effective in canceling alien crosstalk as they are for suppressing internal channel noise. Only through the use of innovative complementary design technologies that are developed to work together as a system can true 10 Gigabit warranted performance be achieved. In order to support 10 Gb/s data rates, new twisted-pair cable constructions improve cable separation in bundles and new connectors are available to ensure that gains achieved by the cable improvements are not lost in the channel. Jack modules, copper cable, patch panels and patch cords also must be precisely tuned to achieve 10 Gigabit speeds.

4.1.1.2 Unshielded vs. Shielded Solutions

With the exception of some countries in Western Europe, the cable of choice throughout the world for structured copper cabling installations has been UTP. The IEEE 10GBASE-T specification, which defines 10 Gigabit Ethernet transmission over copper twisted pair, permits both UTP and STP copper cabling systems. There are advantages and disadvantages to using either type (see Table 4.1-2).

The main advantage of using a STP cabling system is the dramatic suppression of alien crosstalk. The containment of this noise helps ensure better signal integrity than can be achieved with a UTP cabling system. The main advantages of UTP cabling are that it is simpler to install, quicker to terminate, and less expensive than STP cabling based on product and installation costs. Also, within most regions, installers and contractors are more familiar with UTP cabling, including its proper installation. For many markets, a learning curve for STP cabling installations still remains.



Power Sum Alien Crosstalk (PSANEXT) is the aggregation of unwanted signal coupling of crosstalk noise at the near-end from external cabling pairs into an affected pair of a cable.

While proper bonding and grounding methods should always be followed, in practice there is often more confusion on how to do this with STP cabling and how much additional cost will be incurred to meet these requirements. Also, attention to proper grounding beyond the cabling itself to the electrical systems must be implemented to eliminate the possibility of ground loops. If the power cabling system is not properly designed and/or installed, an electrical potential difference could result between the two ends of an STP cabling link. This electrical potential difference could result in a ground loop, which would likely cause data rate errors. Thus, the overall integrity of the power and grounding system is very important to ensure 10GBASE-T date rate performance. This becomes less of an issue with UTP because UTP cabling systems are not closed ground loops.

Advantages of STP	Advantages of UTP
Excellent alien crosstalk suppression (> 20 dB ANEXT headroom over the standard)	Installers and contractors are more comfortable installing UTP over STP systems which may lead to lower installation quotes
Field testing for alien crosstalk not necessary due to superior headroom margin over the 10GBASE-T standard (estimated time savings of 20-40 minutes per individual link)	Additional step of bonding cable to connectivity components is not required, no potential ground loop concerns
Excellent immunity from devices that emanate EMI and FRI noise such as WLAN's, cellular phones, TV broadcasting or radios	No cable preparation required when terminating jacks, less installation time (Shielded jack termination takes 50% longer than UTP)
Increased patch cord cable manageability due to smaller cable (0.23 in. STP vs. 0.29 in. UTP)	Lower product and installation cost
	UTP and STP patch cables have channel de-rating of 20% and 50% respectively, which allows for longer channel length in UTP installation when using more than 8 meters of patch cords

Figure 4.1-3. Comparison of STP and UTP 10GBASE-T Compliant Cabling

4.1.1.3 Media and Connector Selection for Noise Mitigation

Installation of copper Ethernet cabling near control panel noise sources increases the potential for common mode noise coupling that can result in bit errors and delays. Common-mode noise is the voltage that can develop on the entire LAN channel with respect to ground. Since Ethernet cabling system uses differential mode signaling, the voltage difference within the two wires in a twisted pair defines the signal so common mode noise should be subtracted out and not cause a problem.

Figure 4.1-2 illustrates the allowed coupled common mode noise signal in a 1000BASE-T and 100BASE-T system for a 100 meter channel. Note that 100Base-T cable cannot tolerate more than 0.5 volt of noise coupling near 100 MHz with the 1000BaseT tolerating much less only 0.1 V. A VFD, servo, or inductive load with spikes in hundreds of volts could easily couple in noise at these low levels leading to disrupted communications.

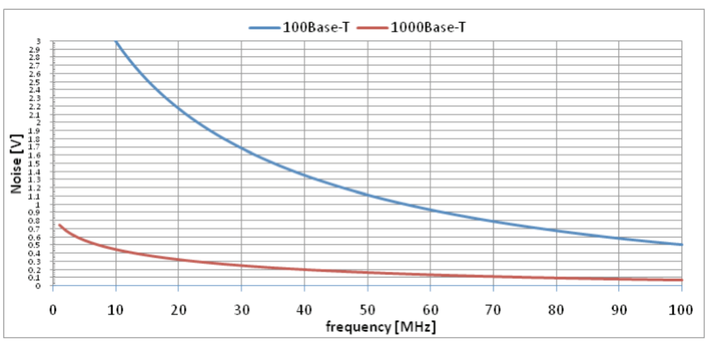


Figure 4.1-4. Coupled Common Mode Noise Signal

The balance of twisted pair cables and RJ45 connectors is key to preventing common mode noise from being converted to differential mode noise that corrupts communication (see Figure 4.1-3). If the balance is perfect, then the differential mode measurements will be equal on both conductors of the twisted pair and thereby cancel out imposed noise. Not all manufacturers design their connectors for optimized balance so it is important to review this critical specification when choosing a connector as well as patch cable vendor.

In practice, a completely balanced system is unachievable and a level of imposed noise is observed on one of the two conductors. The CMRR (Common-Mode Rejection Ratio) of a cabling system is a ratio, articulated in dB, of common-mode noise rejected and prevented from converting to a differential mode voltage. IEEE and EIA/TIA defies the minimum requirements for CMRR in term of TCL and TCTL which are power ratio measurements characterizing unbalance from transmit and receive ends.

Infrastructure design techniques that can improve noise rejection include maintaining proper bend radius and separation distance between conductors, avoiding over-tightened cable ties, using shielded cables where possible, observing good bonding practices for shielded and motor cables, and ensuring cable and connector balance using best-in-class vendor connectivity solutions that exceed standards specifications.

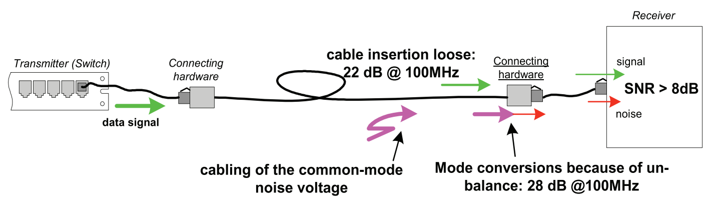


Figure 4.1-5. Signal and Noise Routing Diagram

4.1.1.4 Pre-Terminated Solutions

Pre-terminated cabling solutions are ideally suited for quick deployment in dense control room areas. The pre-tested modular construction of these cable assemblies offer several key advantages over using multi-connector cables that require time-consuming punchdown and testing:

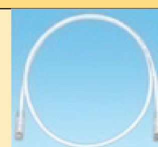
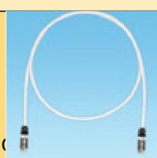
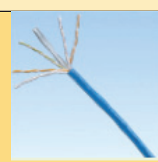
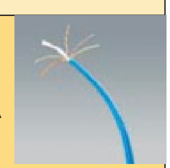
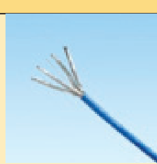
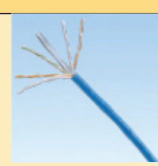
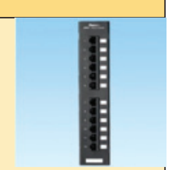
- The **primary benefit** of using pre-terminated solutions is that they offer **consistently high** and precisely known levels of **performance for improved network integrity.** This level of reliability is crucial in all environments, where channel insertion loss budgets are very tight and channel performance issues have an immediate and negative impact on the bottom line. The PANDUIT® QuickNet™ copper pre-terminated solution exceeds standards for 10 GB/s performance, which leaves designers extra headroom in the channel for channel upgrades and modifications.

- Pre-terminated components also are **100% factory terminated and tested to deliver assured quality and consistent, reliable performance.** Highly controlled, precision termination processes for copper take place in a clean factory environment to offer a strong advantage over the variability that can result from terminating many control room links under adverse field conditions.

- Quick-snap connections **reduce copper link install times by 75%** for a very high speed of deployment. Cassette-based copper assemblies that plug in quickly throughout the data center drastically reduce installation time and cost. When you consider the hundreds or thousands of permanent links in today's control rooms, the time and money saved using pre-terminated solutions adds up quickly and helps designers and installers to keep on schedule (and even more importantly, on budget).

- Finally, pre-terminated solutions are **engineered for high design flexibility and scalability.** These modular solutions help achieve high densities per unit of rack space and promote efficient use of floor space. The modularity of pre-terminated solutions also allows the control room to quickly and easily scale up as needed, which is especially valuable in high-growth storage areas. And the speed and ease of deployment translates into a similar ease to upgrade and maintain the system, as it takes very little time to make necessary moves, ads and changes.

Building the Copper Channel

Category 6 Mini-Com® TX6™ PLUS Shielded Jack Module  **Specifications:** 8-position jack module shall terminate 4-pair 22 – 26 AWG 100 ohm shielded twisted pair cable and shall not require the use of a punch-down tool.	**Mini-Com® TX6™ PLUS UTP Jack Module**  **Specifications:** Category 6/Class E eight-position jack module shall terminate unshielded twisted 4 pair, 22 – 26 AWG, 100 ohm cable and shall not require the use of a punchdown tool.	**Mini-Com® TX6A™ 10Gig™ UTP Jack Module**  **Specifications**: Category 6A, 8-position jack module shall terminate unshielded twisted 4-pair, 22 – 26 AWG, 100 ohm cable and shall not require the use of a punchdown tool.
TX6™ 10Gig™ Shielded Jack Module  **Specifications:** Augmented Category 6 eight-position jack module shall terminate shielded twisted 4-pair 22-26 AWG 100 ohm cable and shall not require the use of a punchdown tool.	**TX6™ PLUS UTP Patch Cords**  **Specifications**: Category 6/Class E UTP patch cords shall be constructed of 24 AWG unshielded twisted pair stranded copper cable and an enhanced performance modular plug at each end	**TX6™ 10Gig™ UTP Patch Cords**  **Specifications:** Category 6A UTP patch cords shall be constructed of 24 AWG solid copper cable with an enhanced performance modular plug at each end.
TX6™ 10Gig™ Shielded Patch Cords  **Specifications:** Category 6A shielded patch cords shall be c of shielded 26 AWG stranded copper cable and an enhanced performance shielded modular plug at each end.	**TX6000™ UTP Copper Cable**  **Specifications**: Category 6 cable shall exceed ANSI/TIA /EIA-568-B.2-1 and IEC 61156-5 Category 6 component standards.	**TX6A™ 10Gig™ UTP Copper Cable**  **Specifications**: Category 6A cable shall meet the ANSI/EIA /TIA-568-B.2-10 and IEC 61156-5 component standards.
TX6™ 10Gig™ Shielded Cable – U/FTP  **Specifications:** Augmented Category 6 Shielded Copper Cable shall be constructed of 4-pair twisted insulated 23 AWG conductors.	**TX6500™ UTP Copper Cable**  **Specifications:** Category 6 cable shall far exceed ANSI/ TIA/EIA-568-B.2-1 and ISO/IEC 11801 Class E standards. The conductors shall be 23 AWG construction with FEP (CMP) or polyolefin (CMR) insulation.	**DP6™ PLUS Patch Panel**  **Specifications:** Category 6 Class E punchdown patch panels shall terminate unshielded twisted 4 pair, 22 – 26 AWG, 100 ohm pair cable and shall mount to standard EIA 19" or 23"racks. Industry standard single wire 110 punchdown tool shall be used for terminations

Building the Copper Channel (cont.)

Mini-Com® TX5e Shielded Jack Module

Specifications: Eight-position jack module shall terminate 4 pair 22-26 AWG 100 ohm shielded twisted pair cable and shall not require the use of a punchdown tool.

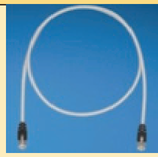
Mini-Com® TX5e™ UTP Jack Module

Specifications: Category 5e/Class D eight-position jack module shall terminate unshielded twisted 4-pair, 22 – 26 AWG, 100 ohm cable and shall not require the use of a punchdown tool.

Data-Patch™ 10/100BASE-T Patch Panel

Specifications: 10/100BASE-T patch panels shall feature RJ45 ports on the front of the panel. Panel PC board is wired for 10BASE-Tand 100BASE-T Ethernet utilizing pins 1, 2 and 3, 6. The back of the patch consists of female telco 50-pin/25-pair connectors wired per RJ21 industry standards for backward compatibility.

TX5e™ Shielded Patch Cord



Specifications: Category 5e patch cords shall be constructed of 26 AWG shielded stranded copper cable and shielded high performance modular plugs at each end.

TX5e™ UTP Patch Cords

Specifications: Category 5e/Class D UTP patch cords shall be constructed of unshielded twisted pair stranded copper cable and a high performance modular plug at each end.

QuickNet™ Copper Cabling System

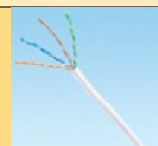
The PANDUIT Quick Net™ Copper Cabling System provides a custom, pre-terminated cabling solution which meets unique requirements. QuickNet™ Angled and Flat Patch Panels accept QuickNet™ Pre-Terminated Cassettes, Patch Panel Adapters, and Blacks, which snap in and out, with one hand, for quick installation.

S/FTP TX5500™ Shielded Cable – S/FTP

Specifications

The S/FTP Shielded cable shall be constructed of 4-pair insulated AWG conductors. The twisted pairs shall be wrapped in an overall metallic foil with an overall braid within a LSZH or PVC jacket.

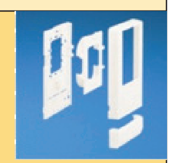
TX5500™ UTP Copper Cable



Specifications

Category 5e cable shall far exceed ANSI/TIA/EIA-568-B.2 and IEC 61156-5 Category 5e component standards.

Mini-Com® Ultimate ID® Hybrid Box



Specifications: The hybrid box shall be a merging point for fiber and copper installations and shall accept all modules. The hybrid box shall offer independent access to each type of media providing easy installation and maintenance. A retention block shall include a built-in spool that holds a total of 12 meters of fiber buffered cable and shall accept a single gang faceplate for up to 6 modules. A cover extension shall provide additional security and bend radius protection to the connections. The hybrid box shall comply with labeling standards by including a station ID pocket and a 6 port ID pocket for all base mounted modules.

DP5e™ Patch Panel

Specifications: Category 5e/Class D punchdown patch panels shall terminate unshielded twisted 4 pair, 22 – 26 AWG, 100 ohm cable and shall mount to standard EIA 19” or 23” racks.

Rockwell Automation Ethernet Media

As Ethernet becomes increasingly utilized in industrial control, survival of physical media in rugged or harsh environments is becoming a necessity. Rockwell Automation's Cat5e Ethernet cable was designed to supply a reliable network connection in harsh surroundings. By optimizing the balance of twisted pair conductors inside a robust Thermoplastic Elastomer (TPE) jacket, data is protected from noise, chemicals and mechanical issues. The cable is available in RJ45 patchcords for IP20 applications or in four-pin D-coded M12 patchcords for IP67 applications where high vibration, fluids and other contaminants can threaten the reliability of a network. M12 D-code field attachable insulation displacement connectors (IDC) are available in both shielded and unshielded housings with male or female connectors. Male eight-pin RJ45 connectors are available in both a crimp termination and a toolless IDC connector for custom cabling.

Rockwell Automation's M12 to RJ45 bulkhead connector provides an elegant transition for network architecture from an IP20 setting to an IP67 environment. The adaptor can be used to connect remote junction boxes or implement an On-Machine™ solution with Armor™ I/O products. Rockwell Automation's Ethernet media portfolio provides reliable connectivity to maintain network integrity and prevent costly downtime.

See Rockwell Automation's Network Media catalog information at the following link:

http://literature.rockwellautomation.com/idc/groups/literature/documents/ca/1585-ca500_-en-p.pdf

Sample Rockwell Automation Ethernet Media Part Numbers

Part Number	Description
1585D-M4DC-H	Field Installable M12 Polyamide Small Body unshielded, Insulation Displacement Connector (IDC)
1585-F4TBDF-2	M12 Patchcord 4-conductor, Teal TPE, Flex-rated, 2 Meter (Female to Female)
1585D-M4TBDF-1A	M12 Patchcord 4-conductor, Teal TPE, Flex-rated, 1 Meter (Female to Male)
1585A-DD4JD	Female M12 Receptacle to RJ45 Female Adapter Right Angle; Polyamide and Brass with Nickel Plating
1585J-M8TBJM-1	RJ45 Patchcord 8-conductor, teal flex-rated robotic TPE , 1 meter
1585J-M8CC-H	Field Installable Cat6 RJ45 Insulation Displacement Connector (IDC)

4.1.2 Installation

Copper cabling systems must be installed in accordance to the cable management requirements set forth in ANSI/TIA/EIA-568-B (Commercial Building Telecommunications Cabling Standard) and in ANSI/TIA/EIA-569-B (Commercial Building Standard for Telecommunications Pathways and Spaces). To aid compliant installation, guidelines for installing copper cabling systems are provided below.

4.1.2.1 Pathways and Spacing Management

- Pathways should be located to allow easy access to cabling for non-disruptive maintenance and upgrades.
- For initial installation, the maximum fill capacity for pathways (i.e. conduit, raceways, trays, baskets) is 40 percent (see Table 4A-3).

$$\text{Number cables} = \frac{\text{Pathway Internal Area X 40\%}}{\text{Cable Area}}$$

Table 4A-3. Copper Cable Areas for Pathway Fill Calculations

Panduit Cable Type	Part Number	Cable Area
Category 6A / 7		
TX6A™ 10Gig™ Plenum	P/N PUP6A04**	0.0683 inches2 (44 mm2)
TX6A™ 10Gig™ Riser	P/N PUR6A04**	0.0683 inches2 (44mm2)
TX6A™ 10Gig™ Low Smoke Zero Halogen	P/N PUL6A04**	0.0683 inches2 (44 mm2)
TX6A™ 10Gig™ CM/PVC	P/N PUC6A04**	0.0683 inches2 (44 mm2)
TX6™ 10Gig™ Plenum Shielded	P/N PSP6004**	0.0683 inches2 (44 mm2)
TX6™ 10Gig™ Riser Shielded	P/N PSR6004**	0.0744 inches2 (48 mm2)
TX6™ 10Gig™ Low Smoke Zero Halogen Shielded	P/N PUFL6X04**	0.0610 inches2 (40 mm2)
TX7000™ Category 7 Low Smoke Zero Halogen Shielded	P/N PSL7004**	0.0707 inches2 (46 mm2)
Category 6		
TX6000™ Category 6 Plenum	P/N PUP6004**	0.0426 inches2 (27.5 mm2)
TX6000™ Category 6 Riser	P/N PUR6004**	0.0452 inches2 (29.2 mm2)
TX6000™ Category 6 Low Smoke Zero Halogen	P/N PUL6004**	0.0397 inches2 (25.6 mm2)
TX6000™ Category 6 CM	P/N PUC6004**	0.0397 inches2 (25.6 mm2)
TX6000™ Category 6 Low-Smoke Zero-Halogen Shielded	P/N PFL6004**	0.0688 inches2 (45 mm2)
TX6000™ Category 6 CM Shielded	P/N PFC6004**	0.0688 inches2 (45 mm2)
Category 5e		
TX5500™ Category 5e Plenum	P/N PUP5504**	0.0292 inches2 (18.8 mm2)
TX5500™ Category 5e Riser	P/N PUR5504**	0.0397 inches2 (25.6 mm2)
TX5500™ Category 5e Low Smoke Zero Halogen	P/N PUL5504**	0.0294 inches2 (18.9 mm2)
TX5500™ Category 5e CM	P/N PUC5504**	0.0277 inches2 (17.9 mm2)
TX5500™ Category 5e Plenum Shielded	P/N PSP5504**	0.0433 inches2 (27.9 mm2)
TX5500™ Category 5e Riser Shielded	P/N PSR5504**	0.0494 inches2 (31.9 mm2)
TX5500™ Category 5e Low Smoke Zero Halogen Shielded	PFL5504**	0.0468 inches2 (30.2 mm2)
TX5500™ Category 5e CM Shielded	P/N PFC5504**	0.0468 inches2 (30.2 mm2)

(NOTE: Refer to the TX6A™ 10Gig™ UTP Copper Cabling conduit fill capacity guideline table in Appendix A-1 of this document to determine the maximum number of cables per conduit trade size.)

- The maximum fill capacity of 60 percent is allowed to accommodate future additions after initial installation.

- Proper cable bend radius control must be maintained throughout the pathways. The bend radius needs to be four (4) times the cable diameter (see Table 4.1-4).

Table 4.1-4. Copper Cable Bend Radius Requirements

Panduit Cable Type	Part Number	Minimum Bend Radius
Category 6A / 7		
TX6A™ 10Gig™ Plenum	P/N PUP6A04**	1.18 inches (30 mm)
TX6A™ 10Gig™ Riser	P/N PUR6A04**	1.18 inches (30 mm)
TX6A™ 10Gig™ Low Smoke Zero Halogen	P/N PUL6A04**	1.18 inches (30 mm)
TX6A™ 10Gig™ CM/PVC	P/N PUC6A04**	1.18 inches (30 mm)
TX6™ 10Gig™ Plenum Shielded	P/N PSP6004**	1.18 inches (30 mm)
TX6™ 10Gig™ Riser Shielded	P/N PSR6004**	1.23 inches (31 mm)
TX6™ 10Gig™ Low Smoke Zero Halogen Shielded	P/N PUFL6X04**	1.11 inches (28 mm)
TX7000™ Category 7 Low Smoke Zero Halogen Shielded	P/N PSL7004**	1.18 inches (30 mm)
Category 6		
TX6000™ Category 6 Plenum	P/N PUP6004**	0.772 inches (19.6 mm)
TX6000™ Category 6 Riser	P/N PUR6004**	0.9 inches (22.8 mm)
TX6000™ Category 6 Low Smoke Zero Halogen	P/N PUL6004**	0.9 inches (22.86 mm)
TX6000™ Category 6 CM	P/N PUC6004**	0.9 inches (22.86 mm)
TX6000™ Category 6 Low-Smoke Zero-Halogen Shielded	P/N PFL6004**	1.18 inches (30 mm)
TX6000™ Category 6 CM Shielded	P/N PFC6004**	1.18 inches (30 mm)
Category 5e		
TX5500™ Category 5e Plenum	P/N PUP5504**	0.772 inches (19.6 mm)
TX5500™ Category 5e Riser	P/N PUR5504**	0.9 inches (22.8 mm)
TX5500™ Category 5e Low Smoke Zero Halogen	P/N PUL5504**	0.774 inches (19.6 mm)
TX5500™ Category 5e CM	P/N PUC5504**	0.752 inches (19.1 mm)
TX5500™ Category 5e Plenum Shielded	P/N PSP5504**	1.18 inches (29.5 mm)
TX5500™ Category 5e Riser Shielded	P/N PSR5504**	1.23 inches (31.25 mm)
TX5500™ Category 5e Low Smoke Zero Halogen Shielded	PFL5504**	0.975 inches (24.8 mm)
TX5500™ Category 5e CM Shielded	P/N PFC5504**	0.975 inches (24.8 mm)

• For control room applications, it is recommended to use PANDUIT® FIBERRUNNER™ or GridRunner™ Underfloor Cable Routing Systems for cable raceway management. The fittings provide minimum 1.5-inch bend radius to protect against signal loss due to excessive cable bends.

• Pathways should be designed to allow for future expansion (minimum two cables per work area, with pathways supporting three cables per work area). Therefore when designing a pathway, the pathway needs to accommodate 150% of the initial cable installation. For example, if the initial design requires 2 cables each for ten work areas, the pathway shall be designed to accommodate 30 cables.

• Conduit should be run in the most direct route possible with no more than two 90 degree bends between pull boxes and serve no more than three outlet boxes. Conduit bends should be at least six times the conduit diameter.
Cable trays are to be installed per manufacturing guidelines and loading capacities must be considered during cabling installation.

• Cable trays used in the ceiling should allow for at least 12 inches (305 mm) of clearance above the tray. Cable trays used in the floor should allow for at least 2 inches (51 mm) of clearance between the top part of the tray and the bottom of the floor tile.

• J-mod® or J-PRO® Cable Support System should be located at 5 foot intervals maximum and have at least 3 inches (76 mm) of clearance above suspended ceilings.

• Please reference Panduit website for J-mod® or J-PRO® Cabling Support System fill capacity information for various sizes available.

4.1.2.2 Cable Separation Management

• There are no specific limitations with sharing pathways with other category copper cables throughout the whole cable run.

• Separation and physical barriers between copper and power cables must be maintained within raceways. If copper and power cables need to cross, install perpendicular to each other. Please reference the National Electric Code for local installation guidelines.

• The maximum channel distance for copper cabling in the backbone and/or horizontal is 328 feet (100 meters). The total length of equipment cords, patch cords and work area cords shall not exceed 33 feet (10 meters)

• The maximum permanent link distance for copper cabling in the backbone and/or horizontal is 295 feet (90 meters)

4.1.2.3 Cable Pulling & Installation Management

• The maximum pulling tension is not to exceed 25 lbf. Cable installation should not in any way deform the cable jacket.

• The cable should not come in contact with any water or chemicals (ex. paint, lubricants), or be exposed to any high humidity during or after installation.

• Avoid any cable kinks and maintain proper bend radius control during cabling pulling. If any kinks should occur, kinked cable should be removed and replaced.

• Tak-Ty® Hook & Loop Cable Ties, Contour-Ty® Cable Ties, Belt-Ty™ In-Line Cable Ties or Pan-Ty® Cable Ties should be applied loosely and at random intervals to cable bundles to avoid any pinching or crushing of the cable jackets.

• For aesthetics and ease of bundling, the Cable Bundling and Organizing Tool (ie: P/N CBOT24K) is recommended

4.1.2.4 Cable Management in the Telecommunications Room

- Organize and manage cables for quick and easy moves, adds and changes

- Use the rack vertical manager fill cable capacity table in Appendix A-2 of this document to determine the maximum number of cables per telecommunication rack.

- Termination procedures at the patch panel include:
  - Feed cables from both sides of the panel
  - Maintain acceptable bend radius levels
  - Do not kink cables
  - Do not cinch cable ties so tightly as to deform the cable in any way
  - To enhance wire management in the back of the panel, it is recommended that a strain relief bar (ie: P/N SRBM19BLY) be mounted to the rack. The strain relief bar includes Tak-Ty® Hook & Loop Cable Ties for additional cable management.

- Termination procedures for patch panels include:
  - Follow PANDUIT installation instruction sheet PN379.
  - Outer cable jacket should be as close as possible to point of termination
  - Last twist should be no further than 0.5 inches from the point of termination.

4.1.2.5 Cable Management in the Production Office Area

- For surface raceway applications, the PanWay® TG Surface Raceway system is the optimal solution in the work area for routing copper cables. The TG Raceway system provides adequate space to maintain proper cable bend radius control.

- Allow for at least one outlet per work area with a minimum of two cable terminations.

- Pathways should be designed to allow for future expansion. For example, work areas with two cables must be served by pathways that can accommodate a minimum of three cables.

- Allow for at least 12 inches (305 mm) of slack at the work area. Pull slack up into the ceiling or back into the raceway and store it there, where it can later be pulled into the box if re-termination is necessary.
- Terminate PANDUIT Mini-Com® Jack Modules per the appropriate installation instruction sheet referenced below.

- To improve bend radius control copper cable in junction boxes, it is recommended that PANDUIT sloped faceplates (i.e. P/N UICFPSE2**) be used in the work area.

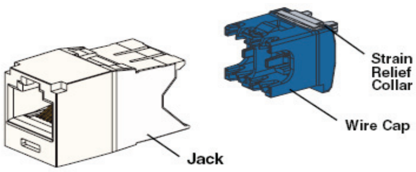
- With PANDUIT sloped faceplates, the following junction boxes can be used with copper cable (ie: P/N JBX3510**-A, JB1**-A, JBP1**-A, JBP1I**-A, JB1FS**-A, JBP2**-A, JB1D**-A, JBP1D**-A, JBP2D**-A).

- With PANDUIT flush faceplates, the following junction boxes can be used copper cable (ie: P/N JB1D**-A, JBP1D**-A, JBP2D**-A).

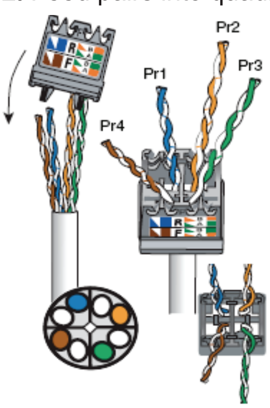
4.1.2.6 Copper Jack Installation

- Enhanced GIGA-TX TM Technology
- Enhanced wire-cap that places all four pairs into quadrants
- Forward motion termination, no punch-down tool required
- Fast, easy, consistent performance
  UTP and STP same process, only difference in cable prep.

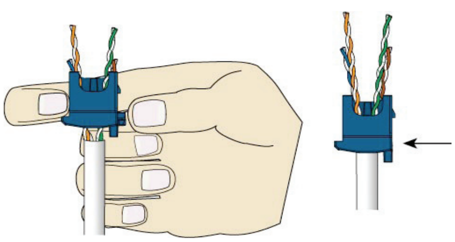
1. Verify parts: Jack and WireCap



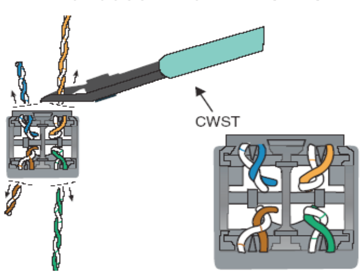
2. Feed pairs into quadrants of wire cap



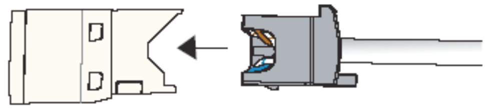
3. Pull pairs through to seat wire cap on insulation



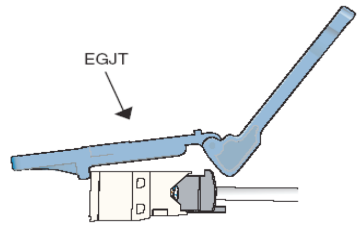
4. Trim excess wire with CWST tool



5. Push wire cap into jack



6. Snap jack onto wirecap with EGJT tool.



4.1.2.7 Installation Reference Documents

- DP6TM 10GigTM, DP6™ PLUS, and DP5eTM Patch Panel installation instruction sheet PN379.
- Mini-Com® TX6ATM 10GigTM UTP Jack Modules installation instruction sheet PN511.
- Mini-Com® TX6™ 10Gig™ Shielded Jack Modules installation instruction sheet PN366.
- Mini-Com® TX6™ PLUS and TX5e™ UTP Jack Modules installation instruction sheet PN403.
- Mini-Com® TX6™ PLUS and TX5e™ Shielded Jack Modules installation instruction sheet PN399.

4.1.3 Testing

Copper cabling transmission performance depends on cable characteristics, connecting hardware, patch cords and cross-connect wiring, the total number of connections, and the care with which they are installed and maintained.

The following channel test configuration should be used by system designers and users of data communications systems to verify the performance of the overall copper channel (see Figure 4.1-4). Channel performance is the most critical to the end user, as this is how their network will perform. The channel includes up to 90 m (295 ft) of horizontal cable, a work area equipment cord, a telecommunications outlet/connector, an optional transition/consolidation connector, and two connections in the telecommunications room.

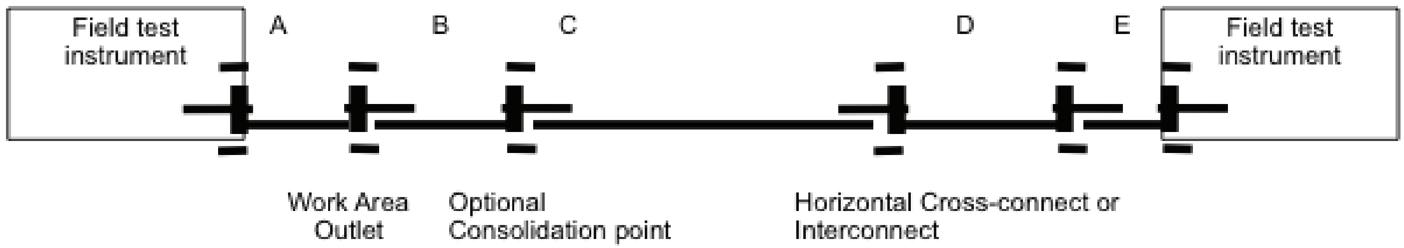


Figure 4.1-4.
Schematic representation of copper cabling channel
(in accordance with TIA/EIA-568B.2-1).

Maximum length
B + C = 90 m (295 ft)
A + D + E = 10 m (32.8 ft)

TIA/EIA-568B.2-1 recommends and ISO 11801 requires that the consolidation point be located at least 5 m (16.4 ft) from the telecommunications room to reduce the effect of multiple connections in close proximity on NEXT loss and return loss. Per the TIA standard, the total length of equipment cords, patch cords or jumpers and work area cords shall not be more than 10 m (32.8 ft). If total patch cords are longer than 10 meters, the entire channel length must be de-rated by the length exceeding 10 meters depending either by 20% or 50% depending on the patch cord cable type used. The connections to the equipment at each end of the channel are not included in the channel definition. The channel definition does not apply to those cases where the horizontal cabling is cross-connected to the backbone cabling.

Panduit has evaluated the Fluke DTX-1800 Series Digital Cable Analyzer and approves the use of this tester for the certification of installed 10 Gb/s cabling channels. In order to verify that the installed cabling will meet or exceed the performance requirements of the designated classification defined in the IEEE 802.3an Standard, it is important that the following steps are followed.

4.1.3.1 Channel Testing

1. Verify that your DTX-1800 Series tester has the most up-to-date software (software version 2.12 or better is required). The latest software updates can be found on the Fluke website at:
http://www.flukenetworks.com/fnet/en-us/supportAndDownloads/downloadsAndUpdates/?pid=50004

2. Perform a Set Reference procedure in the special functions prior to testing. Fluke Networks recommends that a Set Reference procedure be performed every 30 days to ensure the maximum accuracy of the test results.

For detailed instructions on Set Reference procedure, refer to Fluke Network's DTX-1800 Series Users Manual page 20, on "Setting the Reference for Twisted Pair Cabling". The link for the User's Manual is:
http://www.flukenetworks.com/fnet/en-us/techdocs/Manuals.htm?pid=50004

Note: *Fluke Networks also recommends factory calibration once a year to ensure that the test tool meets or exceeds the published accuracy specifications.*

3. Select the Fluke Channel Adapter (# DTX-CHA001A (AxTalk)) and attach them to the DTX-1800 Series Main and Remote unit.

4. Select from the following Fluke Autotests:
- 10GBASE-T
- TIA Category 6A Ch
- TIA Category 6A PL
- ISO ClassEA Ch AMD1
- ISO ClassEA PL 25N1513
- TIA Category 6 Channel
- ISO Channel Class E
- TIA Category 5e Channel
- ISO Class D Channel

5. For channel testing, install all patch cords prior to testing.

Note: *Panduit recommends for installers to install and test a few channels before completing the entire system.*

6. Begin testing your installed channels with the Fluke DTX-1800 Series Digital Cable Analyzer and save all test results.

7. Troubleshoot and repair any failing channels. Channels resulting in a PASS* are considered a PASS and will be acceptable for warranty.

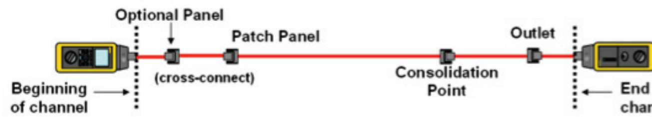
Note: *The Fluke HDTDX analyzer and HDTDR test are very helpful when troubleshooting failing channels. Both can be found on the SINGLE TEST menu and will also run automatically when a failure occurs.*

8. Submit electronic channel test reports to the Panduit Warranty Department with all required warranty paperwork. A channel warranty will then be given based on passing test results.

Note: *Panduit recommends for installers to install and test a few channels before completing the entire system.*

4.1.3.2 Alien Crosstalk Testing (Optional)

For testing Alien crosstalk the Alien crosstalk “DTX-10GKIT” for the Fluke DTX1800 is required.



The alien test kit contains the following items:

- DTX-PLA002 Permanent Link adapters
- AxTALK Analyzer Software- (software version 3.0 or newer is required). The latest software updates can be found on the Fluke website at:

http://www.flukenetworks.com/fnet/en-us/supportAndDownloads/downloadsAndUpdates/?pid=50004

- DTX-ATERM Link Terminators (2)
- RJ45 to RJ45 Couplers (2) for channel testing
- DTX- CHA001A channel test heads
- DTX-AXTK1 (2) Alien Crosstalk Modules

Items needed in addition to the kit:
- Patch cords (2)
- Laptop computer

Process description:

1. Determine bundles and cables to test:

For 10GBASE-T (Category 6 TSB-155):
- To certify a complete installation, choose 1% or 5 links whichever is greater. Start with the victim links as the longest since the highest insertion loss links are of the highest risk of failing
- Include links that are terminated in neighboring positions in the patch panel if not in the bundle
- Typically a 10 meter shorter link will achieve 1.5 or 2 dB improved margin
- Include all of the links in the bundle as disturber links

If links are in the same bundle and are the same length:

- For victims, choose 10% of the links in each bundle and round partial links down to the nearest link. For example, for a bundle of 12, test 1 link.
- Next move down to the next longest bundle. As the lengths get shorter the results improve. Once 3 bundles of worst case margin 5 dB or better is achieved testing is finished.

For Category 6A:

- Select the longest and shortest links
- Apply rules for 10GBASE-T

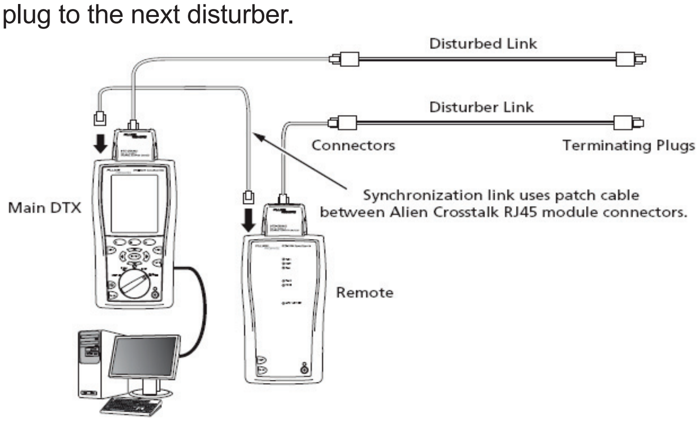
2. For alien testing, Fluke recommends performing a Set Reference at least once a day.

3. Perform permanent link internal testing to the appropriate standard and save all internals of the bundle under test to a separate folder. All links must pass internals.

4. Open the AxTalk Analyzer application and click on the new icon to start a new victim file. Browse for the folder containing the bundle internal tests. Select the file to be used as the victim link. By saving, the application will automatically title as the victim file as titled from the internal file selected.

5. Select the appropriate standard from the test limit menu.

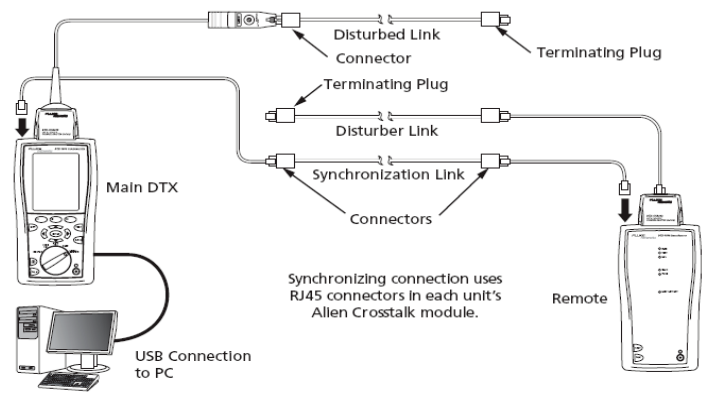
6. Select end 1 and PSANEXT from the radio buttons. Run test and follow the directions. Connect the main and remote as shown below. The Main will always be the victim and the Remote the disturber. For PSANEXT both units are on the same end and the opposite end will have terminated plugs. Run a separate disturber test for each non-victim link of the bundle for end 1, while making the appropriate connection changes. This involves moving the remote and termination plug to the next disturber.



7. When finished select end 2 and repeat.

8. When finished, select PSAACR-F. Repeat as for PSANEXT but now the main and remote units will be on opposite ends as shown below. If the patch cord is not long enough, use 2 patch cords and a separate link as the synchronization link.

9. When finished, select end 2 and repeat.



Pass/fail determination:

- For 10GBASE-T (Category 6 TSB-155) the overall pass or fail is determined from Alien Cross talk Margin Computation (ACMC) in the results detail. As long as the ACMC average is positive, the overall status is a pass.

- For Category 6A, ACMC does not exist, and any single failure of any pair will result in an overall fail.

For additional information, see Alien Crosstalk User Manual located under the help tab in the AxTalk Analyzer application.

4.1.3.3 Standards Limits

TIA Category 6A Channel

Freq. (MHz)	Insertion Loss (db)	NEXT (dB)	PSNEXT (dB)	Return Loss (dB)	ACR-F (dB)	PS ACR-F (dB)	ACR-N (dB)	PSACR-N (dB)
1	3	65.0	62.0	19.0	63.3	60.3		
4	4.2	63.0	60.5	19.0	51.2	48.2		
8	5.8	58.2	55.6	19.0	45.2	42.2		
10	6.5	56.6	54.0	19.0	43.3	40.3		
16	8.2	53.2	50.6	18.0	39.2	36.2		
20	9.2	51.6	49.0	17.5	37.2	34.2		
25	10.2	50.0	47.3	17.0	35.3	32.3		
31.25	11.5	48.4	45.7	16.5	33.4	30.4		
62.5	16.4	43.4	40.6	14.0	27.3	24.3		
100	20.9	39.9	37.1	12.0	23.3	20.3		
200	30.1	34.8	31.9	9.0	17.2	14.2		
250	33.9	33.1	30.2	8.0	15.3	12.3		
350	40.6	30.3	27.3	6.6	12.4	9.4		
500	49.3	26.1	23.2	6.0	9.3	6.3		

ISO Class EA Ch AMD1

Freq. (MHz)	Insertion Loss (db)	NEXT (dB)	PSNEXT (dB)	Return Loss (dB)	ACR-F (dB)	PS ACR-F (dB)	ACR-N (dB)	PSACR-N (dB)
1	4	65.0	62.0	19.0	63.3	60.3	61.0	58.0
4	4.2	63.0	60.5	19.0	51.2	48.2	58.9	56.4
8	5.8	58.2	55.6	19.0	45.2	42.2	52.4	49.8
10	6.5	56.6	54.0	19.0	43.3	40.3	50.1	47.5
16	8.2	53.2	50.6	18.0	39.2	36.2	45.0	42.4
20	9.2	51.6	49.0	17.5	37.2	34.2	42.5	39.8
25	10.2	50.0	47.3	17.0	35.3	32.3	39.8	37.1
31.25	11.5	48.4	45.7	16.5	33.4	30.4	36.9	34.2
62.5	16.4	43.4	40.6	14.0	27.3	24.3	28.0	24.2
100	20.9	39.9	37.1	12.0	23.3	20.3	19.0	16.2
200	30.1	34.8	31.9	9.0	17.2	14.2	4.7	1.8
250	33.9	33.1	30.2	8.0	15.3	12.3	-0.8	-3.7
350	40.6	30.6	27.6	6.6	12.4	9.4	-10.0	-13.0
500	49.3	27.9	24.8	6.0	9.3	6.3	-21.4	-24.5

TIA Category 6 Channel

Freq. (MHz)	Insertion Loss (db)	NEXT (dB)	PSNEXT (dB)	Return Loss (dB)	ACR-F (dB)	PS ACR-F (dB)	ACR-N (dB)	PSACR-N (dB)
1	3	65.0	62.0	19.0	63.3	60.3	62.0	59.0
4	4.0	63.0	60.5	19.0	51.2	48.2	59.0	56.5
8	5.7	58.2	55.6	19.0	45.2	42.2	52.5	49.9
10	6.3	56.6	54.0	19.0	43.3	40.3	50.2	47.7
16	8.0	53.2	50.6	18.0	39.2	36.2	45.2	42.6
20	9.0	51.6	49.0	17.5	37.2	34.2	42.6	39.9
25	10.1	50.0	47.3	17.0	35.3	32.3	39.9	37.2
31.25	11.4	48.4	45.7	16.5	33.4	30.4	37.0	34.3
62.5	16.5	43.4	40.6	14.0	27.3	24.3	26.9	24.1
100	21.3	39.9	37.1	12.0	23.3	20.3	18.6	15.8
200	31.5	34.8	31.9	9.0	17.2	14.2	3.3	0.3
250	35.9	33.1	30.2	8.0	15.3	12.3	-2.8	-5.8

ISO 11801 Channel Class E

Freq. (MHz)	Insertion Loss (db)	NEXT (dB)	PSNEXT (dB)	Return Loss (dB)	ACR-F (dB)	PS ACR-F (dB)	ACR-N (dB)	PSACR-N (dB)
1	4	65.5	62.0	19.0	63.3	60.3	61.0	58.0
4	4.2	63.0	60.5	19.0	51.2	48.2	58.9	56.4
8	5.9	58.2	55.6	19.0	45.2	42.2	52.3	49.7
10	6.6	56.6	54.0	19.0	43.3	40.3	50.0	47.4
16	8.3	53.2	50.6	18.0	39.2	36.2	44.9	42.3
20	9.3	51.6	49.0	17.5	37.2	34.2	42.3	39.7
25	10.5	50.0	47.3	17.0	35.3	32.3	39.6	36.9
31.25	11.7	48.4	45.7	16.5	33.4	30.4	36.7	34.0
62.5	16.9	43.4	40.6	14.0	27.3	24.3	26.5	23.7
100	21.7	39.9	37.1	12.0	23.3	20.3	18.2	15.4
200	31.7	34.8	31.9	9.0	17.2	14.2	3.1	0.1
250	35.9	33.1	30.2	8.0	15.3	12.3	-2.8	-5.8

TIA Category 5e Channel

Freq. (MHz)	Insertion Loss (db)	NEXT (dB)	PSNEXT (dB)	Return Loss (dB)	ACR-F (dB)	PS ACR-F (dB)	ACR-N (dB)	PSACR-N (dB)
1	3	60.0	57.0	17.0	57.4	54.4	57.0	54.0
4	4.5	53.5	50.5	17.0	45.5	42.4	49.1	46.1
8	6.3	48.6	45.6	17.0	39.3	36.3	42.3	39.3
10	7.1	47.0	44.0	17.0	37.4	34.4	39.9	36.9
16	9.1	43.6	40.6	17.0	33.3	30.3	34.5	31.5
20	10.2	42.0	39.0	17.0	31.4	28.4	31.8	28.8
25	11.4	40.3	37.3	16.0	29.4	26.4	28.9	25.9
31.25	12.9	38.7	35.7	15.1	27.5	24.5	25.9	22.9
62.5	18.6	33.6	30.6	12.1	21.5	18.5	15.0	12.0
100	24.0	30.1	27.1	10.0	17.4	14.4	6.1	3.1

ISO 11801 Channel Class D

Freq. (MHz)	Insertion Loss (db)	NEXT (dB)	PSNEXT (dB)	Return Loss (dB)	ACR-F (dB)	PS ACR-F (dB)	ACR-N (dB)	PSACR-N (dB)
1	4	60.0	57.0	17.0	57.4	54.4	56.0	53.0
4	4.5	53.5	50.0	17.0	45.4	42.4	49.0	46.0
8	6.4	48.6	45.6	17.0	39.3	36.3	42.2	39.2
10	7.2	47.0	44.0	17.0	37.4	34.4	39.8	36.8
16	9.1	43.6	40.6	17.0	33.3	30.3	34.5	31.5
20	10.2	42.0	39.0	17.0	31.4	28.4	31.8	28.8
25	11.5	40.3	37.3	16.0	29.4	26.4	28.9	25.9
31.25	12.9	38.7	35.7	15.1	27.5	24.5	25.8	22.8
62.5	18.6	33.6	30.6	12.0	21.5	18.5	15.0	12.0
100	24.0	30.1	27.1	10.0	17.4	14.4	6.1	3.1

4.1.4 Documenting

The following Permanent Link data should be documented as a result of copper testing:

- Date of link testing
- Names of personnel conducting the test.
- Test Equipment details (manufacturer, model, and serial number)
- Test direction and end point locations

Using Fluke DTX 1800 field tester, the following should be set before testing:

- Date and time
- Operator, Site, Company
- Store Plot Data
- Extended
- HDTDX/HDTDR
  * Pass /Fail only (minimum)
- All AUTOTESTS (better)
- Test limit
  i.e. TIA, EN, ISO standards
- Cable type
- UTP, FTP, SSTP, or using Manufacturer
- NVP
- Outlet configuration
- T568A or T568B

4.2 Fiber Optic Media

4.2.1 Selection

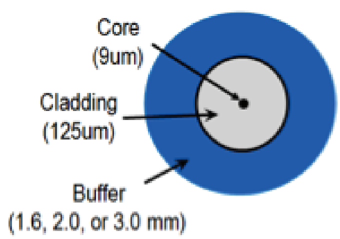
When choosing Ethernet fiber optic cabling solutions, the following criteria should be taken into consideration prior to installation to ensure system performance, reliability, and scalability.

4.2.1.1 Media Type

Two different types of fiber are available: single mode and multimode.

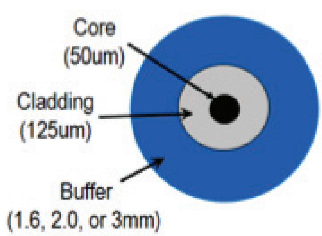
Single mode.

Singlemode fiber cable (commonly referred to as OS1 or OS2 cable) is a 125µm diameter fiber with a 9µm core that is capable of carrying very high data rates over very long lengths. The outer jacketing is colored yellow to distinguish it from other fiber cable types. OS1/OS2 fibers should meet or exceed numerous standards for optical fiber, including ITU-TG.652 (Categories A, B, C and D), IEC 60793-2-50, ISO 11801 OS2, and TIA-492-CAAB and Telecordia GR-20. Such fibers ensure performance over the entire 1260-1625nm spectrum and are compatible with legacy fiber and the geometric properties contributing to minimizing splice loss and increasing splice yield.



Multimode.

Multimode cable is a 125µm diameter fiber with either a 62.5µm or 50µm core that is capable of carrying a high data rate over very short lengths when compared to the singlemode cable. Multimode cable is categorized in six different categories: OM1, OM2, OM2+, OM3, and OM3+. OM1 cable has a core diameter of 62.5µm while the other cables (OM2 through OM4) have core diameters of 50µm. Each of these cable types are manufactured differently to allow for better performance. There is the standard multimode cable which has the outer jacketing colored orange and a 10Gig Optimized cable which has the outer jacketing colored aqua. The standard multimode cable is designed to be used with LED (laser emitting diode) technology where the optimized multimode fiber is designed to be used with VCSEL (Vertical Cavity Surface Emitting Laser) or laser type technologies.



- The types of multimode fiber used in today's networks include:
  - 62.5/125-µm (OM1) fiber, designed to achieve 10Base and 100Base data rates, and now largely a legacy fiber;
  - 50/125-µm (OM2) fiber, used to achieve 1-Gbit/sec data rates and higher; and
  - 50/125-µm (OM2+, OM3, and OM3+) fiber, used to achieve 10-Gbit/sec data rates and higher. OM2+ and OM3+ fiber grades offer nearly double the bandwidth of their parent fibers ("+" represents extended-reach OM2 and OM3 fiber).

4.2.1.2 Bandwidth and Reach

Most fiber choices are based on an application-specific consideration of bandwidth and reach (see Table 4.2-1).

- Bandwidth is the information-carrying capacity of the fiber. High-bandwidth fiber media allows longer-length channels, higher loss-budget margin, and greater design flexibility.

- Reach (length) is a site-specific physical parameter that can be used to immediately narrow your fiber options. In general, as the data rate goes up, the reach goes down. Once reach is established, you can narrow your fiber options by identifying your users' current and/or future bandwidth needs.

The preferred Physical Medium Dependent (PMD), or transceiver, for 10-Gbit/sec fiber cabling systems is the short-wavelength (850-nm) VCSEL (vertical-cavity surface-emitting laser)-based serial modular transceiver. These low-cost electronics have captured the LAN market, are optimized and standardized for use with OM3 fiber up to 300 m, and are also compatible with OM2 fiber grades. Fiber media for these devices are optimized for the 850-nm wavelength window, but maintain a minimum bandwidth of 500 MHz·km for the 1310-nm window.

The most economical 10-Gbit/sec network channels are those that deploy 50/125-µm fiber with serial transceiver electronics. The IEEE 802.3ae 10GBase-S standard specifies that only OM3 laser-optimized fiber can support 10-Gbit/sec up to 300 meters (m). The standard recognizes that other multimode cabling systems may support that rate over varying distances. For this reason, and as data center managers look toward "future-proofing" their cabling solutions, OM3 has become the 50-μm fiber of choice for 10-Gbit/sec premises and data center applications.

The typical life of the physical infrastructure can reach 10-15 years, and with regular maintenance the facilities infrastructure and structured cabling are both expected to support multiple generations of IT equipment. It also is generally predicted that most (if not all) links in the data center will need to carry 10 Gb/s in the near future with certain critical "core" links supporting even faster data rates. For these reasons, a 10-Gigabit ready cabling infrastructure is recommended, with data center speed and reach requirements favoring the deployment of OM3 fiber optic links.

Table 4.2-1.
Multimode Fiber Types and Reach / Bandwidth Characteristics

Fiber Type	Core/Cladding	Wavelength (nm)	Max Loss (dB/km)	Minimum EMBc (Mhz*km)	Max Reach @ 1G (m)	Max Reach @ 10G (m)
OM1	62.5/125	850	3.5	200	270	33
		1300	1.5	------------	550	300
OM2	50/125	850	3.5	500	550	82
		1300	1.5	------------	550	300
OM2+		850	3.5	950	750	150
		1300	1.5	------------	600	300
OM3		850	3.5	2000	1000	300
		1300	1.5	------------	600	300
OM3+		850	3.5	4700	1040	550
		1300	1.5	------------	600	300
OS1	9/125	1310 - 1625	0.35	n/a	n/a	n/a

4.2.1.3 Pre-Terminated Solutions

Pre-terminated cabling solutions are ideally suited for quick deployment in dense control room areas. The pre-tested modular construction of these cable assemblies offer several key advantages over using multi-connector cables that require time-consuming punchdown and testing:

- The **primary benefit** of using pre-terminated solutions is that they offer **consistently high** and precisely known levels of **performance for improved network integrity**. This level of reliability is crucial in all environments, where channel insertion loss budgets are very tight and channel performance issues have an immediate and negative impact on the bottom line. *The PANDUIT® QuickNet™* fiber pre-terminated solution exceeds standards for 10 GB/s performance, which leaves designers extra headroom in the channel for channel upgrades and modifications.

- Pre-terminated components also are **100% factory terminated and tested to deliver assured quality and consistent, reliable performance.** Highly controlled, precision termination processes for fiber take place in a clean factory environment to offer a strong advantage over the variability that can result from terminating many data center links under adverse field conditions.

- Quick-snap connections **reduce fiber link install times** for a very high speed of deployment. Cassette-based fiber assemblies that plug in quickly throughout the data center drastically reduce installation time and cost. When you consider the hundreds or thousands of permanent links in today's control rooms, the time and money saved using pre-terminated solutions adds up quickly and helps designers and installers to keep on schedule (and even more importantly, on budget).

- Finally, pre-terminated solutions are **engineered for high design flexibility and scalability.** These modular solutions help achieve high densities per unit of rack space and promote efficient use of floor space. The modularity of pre-terminated solutions also allows the control room to quickly and easily scale up as needed, which is especially valuable in high-growth storage areas. And the speed and ease of deployment translates into a similar ease to upgrade and maintain the system, as it takes very little time to make necessary moves, ads and changes.

4.2.1.4 Harsh Environments

Optical fibers are housed in jackets of many different kinds, for deployment under a variety of environmental conditions. The three most common cable types are non-armored, armored, and IP-rated.

- Non-armored is a standard cable that runs in cabling basket or cable ladder internal to a control, protected environment. This cabling type also can be installed in a duct system or pipe system depending on the environment.
- Armored cabling has a protected aluminum or metal housing around the fiber cable that protects the cabling from crushing or animal intrusion if it is buried underground.
- IP-rated cabling is rated for high-temperatures, is chemically resistant, and can be used in harsh environments.

Of these options, non-armored fiber optic cabling is the most cost-effective choice, as it can withstand temperatures between -40° to 167°F (-40° to 75°C) and therefore can be deployed in a majority of cases.

4.2.1.5 Hybrid Patch Cords (SC-to-LC, etc.)

New technologies have brought LC (small form factor type) connectors into the industry. Although they are becoming predominant, there are still many older legacy systems that still utilize SC, FC or ST type connectors that need to transition to this newer form factor. There are many different offerings of hybrid type patch cords that will enable this transition very easily.

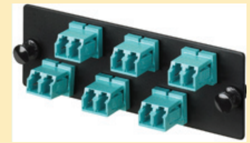
Building the Fiber Optic Channel

Opti-Core® Fiber Optic Indoor Cable

Specifications

10 GbE fiber optic, Standard singlemode and multimode indoor cable are available. Larger distribution cable features a 6-fiber sub-unit design that simplifies fiber identification, provides easy access and routing of the fibers, and increases cable durability with a dielectric central strength member.

OptiCam® Pre-Polished Cam Fiber Optic Termination Kits



Features

- Virtually eliminates operator error by providing visual indication of proper termination after the cam step has been completed
- No adhesive or electricity required for termination
- Include installation instructions and stripping templates for all PANDUIT® OptiCam® Pre-Polished Connectors

Opti-Core® Fiber Optic Indoor/Outdoor Cable

Specifications

This LSZH rated cable provides water-blocking, high density, and easy installation in duct applications and entrance facilities. Fiber optic indoor/outdoor cable meets the IEC 60794-1 standards. 10 GbE fiber optic indoor/outdoor cable as well as multimode and singlemode indoor/outdoor cables are available.

LC OptiCam® Fiber Optic Connectors – Pre-Polished Cam Termination

Specifications

LC small form factor (SFF) pre-polished connectors with rear pivot latch shall be TIA/EIA-604 FOCIS-10 compatible and contain a factory-terminated fiber, eliminating field polishing and adhesive. LC pre-polished connectors shall have an average insertion loss of 0.3dB per mated pair for multimode fiber. LC pre-polished connectors shall captivate fiber and buffer in one action allowing for up to two re-terminations with no degradation in performance.

Opti-Core® Fiber Optic Indoor Interlocking Armored Cable

Specifications

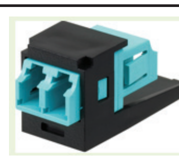
Interlocking aluminum armor eliminates the need for inner duct or conduit to provide a smaller crush resistant pathway. Available in 6- 144 fiber counts. Multimode (OM3, OM2, and OM1) and singlemode (OS1/OS2) fiber available optimized) fiber available. Opti-Core® 10Gig™ OM3 Cable is designed to support network transmission speeds up to 10 Gb/s for link lengths up to 300 meters with an 850nm source per IEEE 802.3ae 10 GbE standard; backward compatible for use with all 50/125µm system requirements

SC OptiCam® Fiber Optic Connectors – Pre-Polished Cam Termination

Specifications

SC pre-polished fiber optic connectors shall be TIA/EIA-604 FOCIS-3 compliant and contain a factory-terminated fiber, eliminating field polishing and adhesive. SC pre-polished connectors shall have an average insertion loss of 0.3dB per mated pair for multimode and singlemode fiber. SC pre-polished connectors shall captivate fiber and buffer in one action allowing for up to two re-terminations with no degradation in performance.

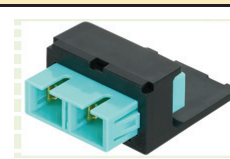
Opti-Core® Fiber Optic Indoor/ Outdoor Interlocking Armored Cable



Specifications

Interlocking aluminum armor eliminates the need for inner duct or conduit to provide a smaller crush resistant pathway for improved design flexibility and lower installed cost. OPTI-CORE ® 10GIG™ Fiber Optic Indoor Interlocking Armored Cable features the highest quality OM3 laser optimized fiber to support 10Gb/s applications while maintaining compatibility with existing 50µm multimode systems. RoHS compliant singlemode and multimode cable is available in fiber counts from 6 to 48 fibers.

Armored Cable Grounding Kit



Specifications

Crimped jumper wire assembly; 24" (609.6mm) length; LCC6-14, #10 mechanical clamp; provided with two each #12-24, M6 slotted hex head zinc-plated thread-forming screws, and black polypropylene terminal cover.

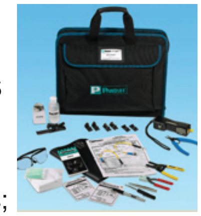
Building the Fiber Optic Channel

10Gig® 50/125um (OM3) Multimode Fiber Optic Patch Cords and Pigtails

Specifications

Patchcords shall include LC, SC, ST or MT-RJ connectors, or FJ or keyed FJ plugs or jacks on both ends. Pigtails shall include simplex or duplex LC, SC, ST, or MT-RJ connectors, or FJ or keyed FJ plugs or jacks on one end and open (unterminated) on the other end.

Opticom® Fiber Adapter Panels (FAPs)



Specifications

Fiber adapter panels are TIA/EIA-604 FOCIS Snap quickly into the front of all components. Phosphor bronze or zirconia ceramic split sleeves to fit specific network requirements; zirconia ceramic split sleeves are required for singlemode applications.

Multimode 62.5/125um (OM1) or 50/125 (OM2) Fiber Optic Patch Cords and Pigtails

Specifications

Patch cords shall include simplex or duplex LC, SC, ST or MT-RJ connectors, or FJ or keyed FJ plugs or jacks on both ends. Pigtails shall include simplex or duplex LC, SC, ST, or MT-RJ connectors, or FJ or keyed FJ plugs or jacks on one end and open (unterminated) on the other end.

Opticom® Rack Mounted Fiber Enclosures

Specifications

Rack mounted fiber enclosures house, organize, manage and protect fiber optic cable, terminations, splices, connectors and patch cords. The enclosures accommodate fiber adapter panels (FAP) and fiber mount panels (FMP) plus associated trunk cables, connectors and patch cords.

Singlemode 9/125um (OS1/OS2) Fiber Optic Patch Cords and Pigtails

Specifications

RoHS compliant fiber optic patch cords shall include simplex or duplex LC or keyed LC, SC, ST or MT-RJ connectors, or FJ or keyed FJ plugs or jacks on both ends. RoHS compliant fiber optic pigtails shall include simplex or duplex LC, SC, ST, or MT-RJ connectors, or FJ or keyed FJ plugs or jacks on one end and open (unterminated) on the other end.

Mini-Com® Modular Patch Panels

Specifications

Mini-Com® Modular Patch Panels mount to any 19” wide EIA-310 style rack and accept all Mini-Com® Adapter Modules and Jack Modules including LC, SC, and MTP* fiber adapter modules. Modular patch panels are available in a variety of sizes and styles in both flat and angled patch panel versions. Individual adapter module identification is provided via pre-numbered ports and provisions for field generated port ID labels.

LC Mini-Com® Fiber Optic Adapter Modules

Specifications

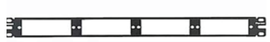
LC Sr./Sr. and Sr./Jr. small form factor (SFF) fiber optic adapter modules are TIA/EIA-604 FOCIS-10 compatible. LC adapters and adapter modules shall include phosphor bronze split sleeves for multimode applications or zirconia ceramic split sleeves for singlemode applications. They shall have phosphor bronze or zirconia ceramic split sleeves to fit specific network requirements; zirconia ceramic split sleeves are required for singlemode applications.

SC Mini-Com® Fiber Optic Adapter Modules

Specifications

SC fiber optic adapter modules are TIA/EIA-604 FOCIS-3 compatible. They shall be compatible with Mini-Com® products for complete modularity. They shall have phosphor bronze or zirconia ceramic split sleeves to fit specific network requirements; zirconia ceramic split sleeves are required for singlemode applications.

Opticom® Fiber Adapter Patch Panels



Specifications Fiber adapter patch panels mount to any 19” wide EIA-310 style rack. Standard version holds QuickNet™ MTP* Cassettes and Opticom® Fiber Adapter Panels (FAPs). Angled version holds Opticom® Fiber Adapter Panels and matches Mini-Com® Angled Patch Panel profile. Used with Opticom® Fiber Mount Tray (FMT) to protect fibers and terminations.

4.2.2 Building the Fiber Optic Cable Channel with Stratix Switches

Fiber-based media for Stratix switch systems offer advantages in distance and noise immunity over copper-based systems. The selection of both SFP module and fiber media must be made together for an optimized solution that delivers on the distance, environmental and performance requirements for the application, also keeping an eye on future needs.

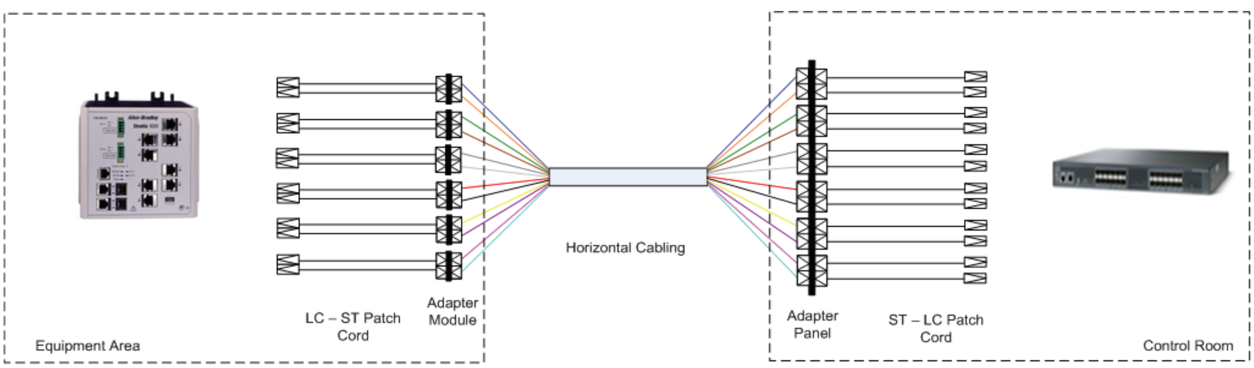
Stratix SFP modules are available in four models that support multimode (shorter reach) and singlemode fibers (longer reach) at both 100Mb (100BASE) and 1Gb (1000BASE) communication rates. PANDUIT provides fiber solutions that achieve high performance at the maximum rates and channel distances supported by these modules in a range of environmental hardening for indoor and outdoor use.

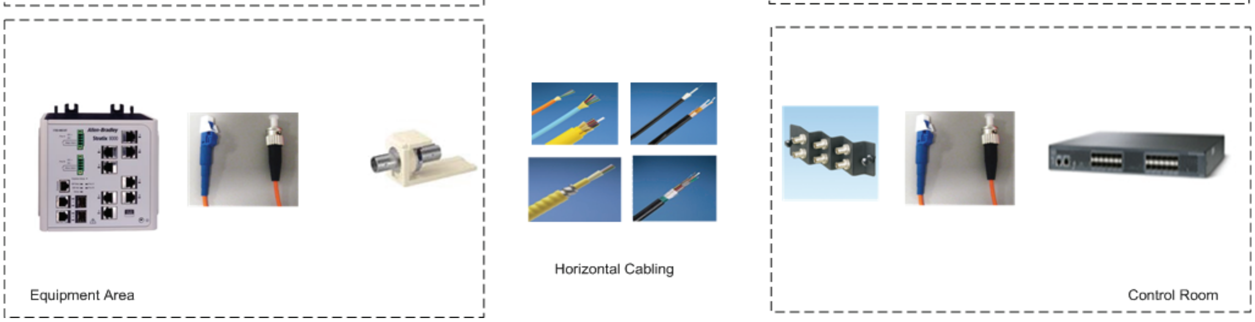
The diagram below shows elements of a basic fiber optic channel from Stratix switch to the control room. This section of the Guide provides an overview of fiber media cabling and patch cord options available for building a fiber optic channel.

PANDUIT offers an extensive range of solutions to accommodate both new installations, where the channel components can be fully specified to a standard, as well as retrofits where patching must be done from other standard connectors (FC, ST, SC, etc). PANDUIT solutions include pre-polished, pre-tested LC solutions that can be field installed without adhesives or heat, and pre-tested "hybrid" patch cords that can transition from legacy connections to the LC connector required for the Stratix switch.

PANDUIT solutions also can be utilized to easily transition between connector types when upgrading switches or cable infrastructures. For example, an existing cabling infrastructure with ST connections can remain in place when upgrading to the new Stratix (LC connector) switch. An ST-to-ST adapter can be mounted in a surface mount box or bracket to accept the existing ST cabling. Then, an ST-to-LC hybrid patch cord can then be used to connect the new Stratix switch to the existing cabling infrastructure. In this way, network stakeholders can avoid costly replacement of horizontal cabling and minimize or eliminate network disruption due to the switch upgrade. This section includes selection guide and examples for fiber channels that include adapting legacy cable to the LC connectors on the Stratix switch.

PANDUIT solutions include the related products that provide secure mounting, slack fiber management, critical bend radius control, and identification. Keyed connector solutions allow segregation of redundant or multiple rings or infrastructure levels or to lock in critical links or block out open ports.

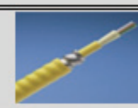




4.2.2.1 SELECTING STRATIX SFP MODULES AND SPECIFYING FIBER MEDIA

The following table correlates available Stratix SFP switch modules to fiber media options for horizontal cabling, with PANDUIT part numbers listed in right-hand columns.

It is generally predicted that most (if not all) cabling links in the data center will need to carry 10 Gb/s in the near future. For the factory floor or control room physical infrastructure, specifying 10 Gig 50 µm fiber optic links will cost effectively connect with the current 1000Base-SX SFP of the Stratix but also be ready for higher rates as 10 Gb/s communication is extended to the factory floor.

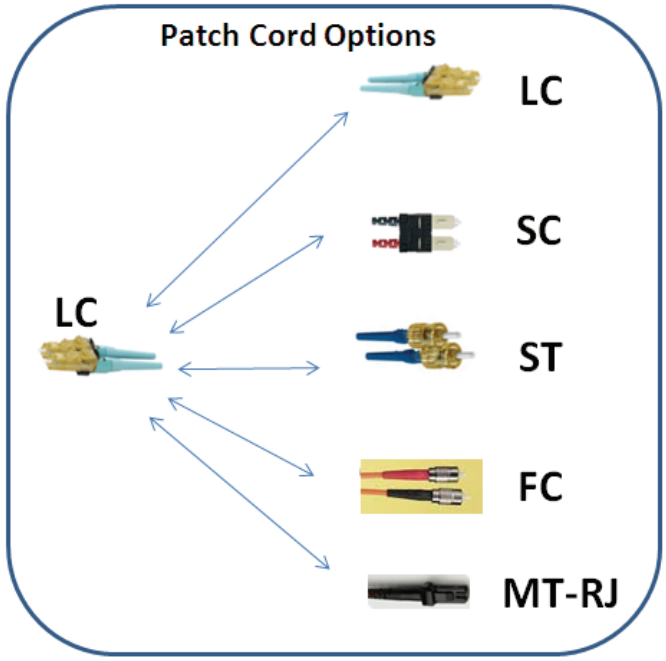
				Increasing severity			
				Fiber Type per MICE Level			
				$M_1I_1C_1E_3$	$M_1I_1C_2E_3$	$M_2I_2C_2E_3$	$M_2I_2C_2E_3$
SFP Module Type	Rockwell SFP Part Number	Core Diameter	Max Distance per Standards	Distribution Cable	Indoor/Outdoor (Dielectric)	Indoor Armored	Gel-Free Outside Plant Armored Cable
							
100BASE-FX	1783-SFP100FX	62.5µm	2km	FSDR6^^Y	FSNR6^^Y	FSPR6^^Y	FSWN6^^
		50µm	2km	FSDR5^^Y	FSNR5^^Y	FSPR5^^Y	FSWN5^^
100BASE-LX	1783-SFP100LX	9µm	10km	FSDR9^^Y	FSNR9^^Y	FSPR9^^Y	FSWN9^^
1000BASE-SX	1783-SFP1GSX	62.5µm	275m	FSDR6^^Y	FSNR6^^Y	FSPR6^^Y	FSWN6^^
		50µm	550m	FSDR5^^Y	FSNR5^^Y	FSPR5^^Y	FSWN5^^
		10 Gig 50µm	550m	FODRX^^Y	FONRX^^Y	FOPRX^^Y	FOWNX^^
1000BASE-LX/LH	1783-SFP1GLX	9µm	10km	FSDR9^^Y	FSNR9^^Y	FSPR9^^Y	FSWN9^^
1000BASE-LX/LH	GLC-ZX-SM-RGD	9µm	40km	FSDR9^^Y	FSNR9^^Y	FSPR9^^Y	FSWN9^^

Aqua	OM3 10Gig Multimode
Orange	OM1 / OM2 Multimode
Yellow	OS1 / OS2 Singlemode

4.2.2.2 Specifying Fiber Patch Cables for Stratix Cables for Stratix SFP Modules

The Stratix SFP modules use LC connectors, which are acknowledged as offering superior performance compared to other fiber connectors. However, for retrofit applications, there is often a need to transition from LC connectors to other connector types.

PANDUIT offers a wide range of “hybrid” patch cords that allow for patching from legacy cabling to the Stratix SFP modules.



SFP Module Type	Rockwell or Cisco SFP Part Number	Core Diameter	Patch Cord Type and Part Number				
			LC to LC	SC to LC	ST to LC	FC to LC	MT-RJ to LC
100BASE-FX	1783-SFP100FX	62.5µm	F6E10-10M^Y	F6E3-10M^Y	F6E2-10M^Y	F6E4-10M^Y	F6D12-10M^Y
		50µm	F5E10-10M^Y	F5E3-10M^Y	F5E2-10M^Y	F5E4-10M^Y	F5D12-10M^Y
100BASE-LX	1783-SFP100LX	9µm	F9E10-10M^Y	F9E3-10M^Y	F9E2-10M^Y	F9E4-10M^Y	F9D12-10M^Y
1000BASE-SX	1783-SFP1GSX	62.5µm	F6E10-10M^Y	F6E3-10M^Y	F6E2-10M^Y	F6E4-10M^Y	F6D12-10M^Y
		50µm	F5E10-10M^Y	F5E3-10M^Y	F5E2-10M^Y	F5E4-10M^Y	F5D12-10M^Y
		10 Gig 50µm	FXE10-10M^Y	FXE3-10M^Y	FXE2-10M^Y	FXE4-10M^Y	FXD12-10M^Y
1000BASE-LX/LH	1783-SFP1GLX	9µm	F9E10-10M^Y	F9E3-10M^Y	F9E2-10M^Y	F9E4-10M^Y	F9D12-10M^Y
1000BASE-ZX	GLC-ZX-SM-RGD		F9E10-10M^Y	F9E3-10M^Y	F9E2-10M^Y	F9E4-10M^Y	F9D12-10M^Y

^ Length of patch cord in meters

All part numbers shown are Duplex patch cords. Simplex available upon request.

4.2.3 Adapters for Legacy Fiber

The following adapter parts are used to connect legacy fiber cable to LC patch cables that mate with the Stratix switch line.

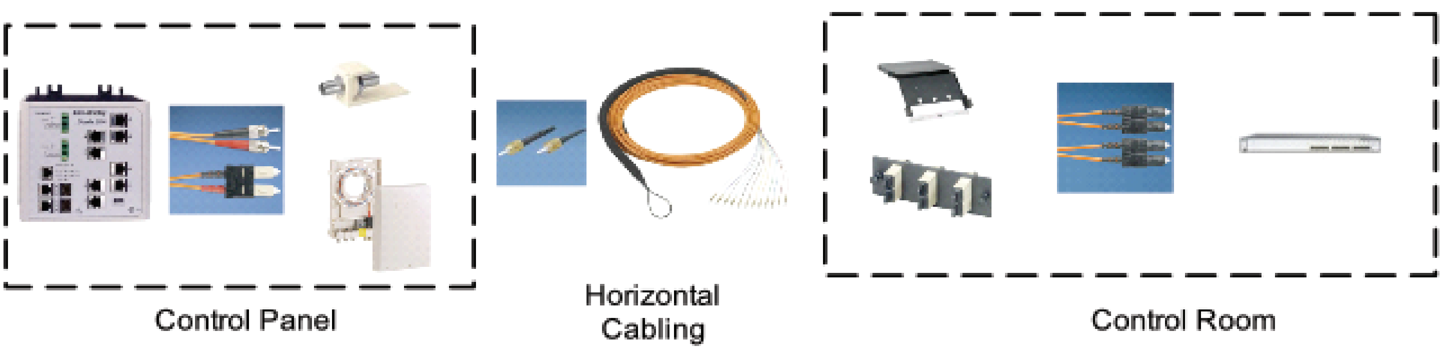
Fiber Type	Sleeve Type	Adapter Type and Part Number				
		LC	SC	ST	FC	MT-RJ
62.5µm	Phosphorous Bronze	CMDJLCEI	CMSEISCEI	CMSTEI	CMFCEI	CMMJEI
50µm		CMDJBLLCBL	CMSBLSCBL			
10 Gig 50µm		CMDJAQLCBL	CMSAQSCBL			
62.5µm	Zirconia Ceramic	n/a	n/a	n/a	n/a	
50µm		n/a	n/a			
10 Gig 50µm		CMDJAQLCZBL	CMSAQSCZBL			
9µm		CMDSLCZBU	CMSBUSCZBU	CMSTZBU	CMFCZBU	n/a

**Parts Specified are MiniCom adapter modules used in Zero RU or surface mount boxes. For fiber adapter panels to be utilized in rack mount enclosures, consult Panduit representative or catalog

**LC adapters also available in keyed configurations

4.2.4 End-to-End Channel Building

Multimode Fiber Solutions for Stratix 1783-SFP100FfX or 1783-SFP1GSX

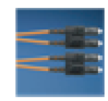
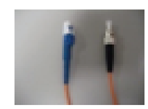
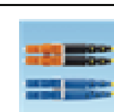
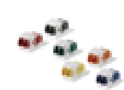
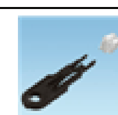
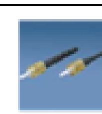


The diagram above shows a fiber link for Stratix modules 1783-SFP100FfX or 1783-SFP1GSX.

- In the control panel, the Stratix switch will connect to the surface mount box with a multimode SC to ST patch cord. The multimode horizontal cabling (pre-terminated SC to pigtail solution shown) can be terminated in the control panel utilizing either field polish connectors, OptiCam™ pre-polished connectors, or a pre-terminated pigtail solution if fiber splicing is an option (ST OptiCam™ connector option is shown).
- In the control room a rack mount enclosure will house a SC fiber adapter panel which will be utilized to connect the horizontal cabling to the switch via an SC to SC patch cord.

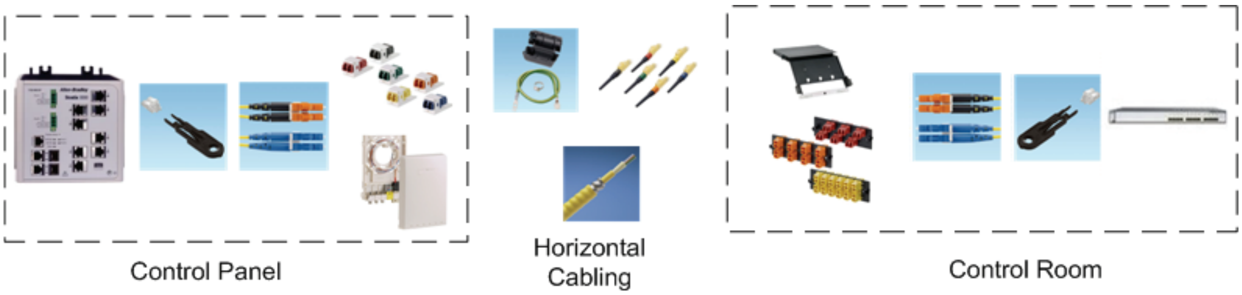
(continued on next page)

Part ordering for fiber link constructed for the 1783-SF-P100FfX or 1783-SFP1GSX includes:

Part Number	Description	Example
FCE1U	Fiber Enclosure that holds up to four QuickNet Cassettes, Fiber Adapter Panels, or FOSM splice modules.	
FAP3WEIDSC	OM2 50/125 SC FAP loaded with three SC Duplex adapters with phosphor bronze split sleeves	
F5D3-3M1Y	OM2 50/125um SC to SC Duplex patch cord	
F5D10-2M1Y	OM2 50/125um LC to ST Duplex patch cord	
CMSTEI	ST Minicom Module	
F56D3-NM30Y	OM2 30m 50/125um SC to pigtail fiber fan-out cords	
FAP6WEORDLC	Keyed 'E' (orange) LC FAP loaded with six LC duplex adapters with zirconia ceramic split sleeves	
F9E10E-10M1Y	OS1 9/125um 1m LC Keyed 'E' (orange) to LC Duplex patch cord	
CMDEORLCZ	Keyed LC Mini-Com module supplied with one LC keyed 'E' (orange) duplex fiber adapter	
FLCCLIW-X	LC duplex Lock-in clips and one removal tool	
FSTMC5BL	ST Opticam Multimode Simplex fiber connector	
CBXD4IW-AY	Surface Mount Box that accepts four Mini-Com modules	

4.2.4.1 End-to-End Channel Building

Singlemode Fiber Solutions for Stratix 1783-SFP100LX or 1783-SFP1GLX

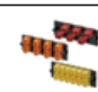
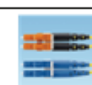


The diagram above shows a fiber link for Stratix modules 1783-SFP100LX or 1783-SFP1GLX.

In the control panel, the Stratix switch will connect to the surface mount box with singlemode LC to LC Keyed patch cords (LC Lock-In and keyed solution shown as a security feature). The singlemode horizontal cabling (armored cabling shown with grounding kit) can be terminated in the control panel and control room utilizing field polish connectors, OptiCam™ connectors or a pre-terminated pigtail solution if fiber splicing is an option (keyed OptiCam™ connector option is shown).

In the control room a rack mount enclosure will house a keyed LC fiber adapter panel which will be utilized to connect the horizontal cabling to the switch via a Keyed LC to LC patch cord.

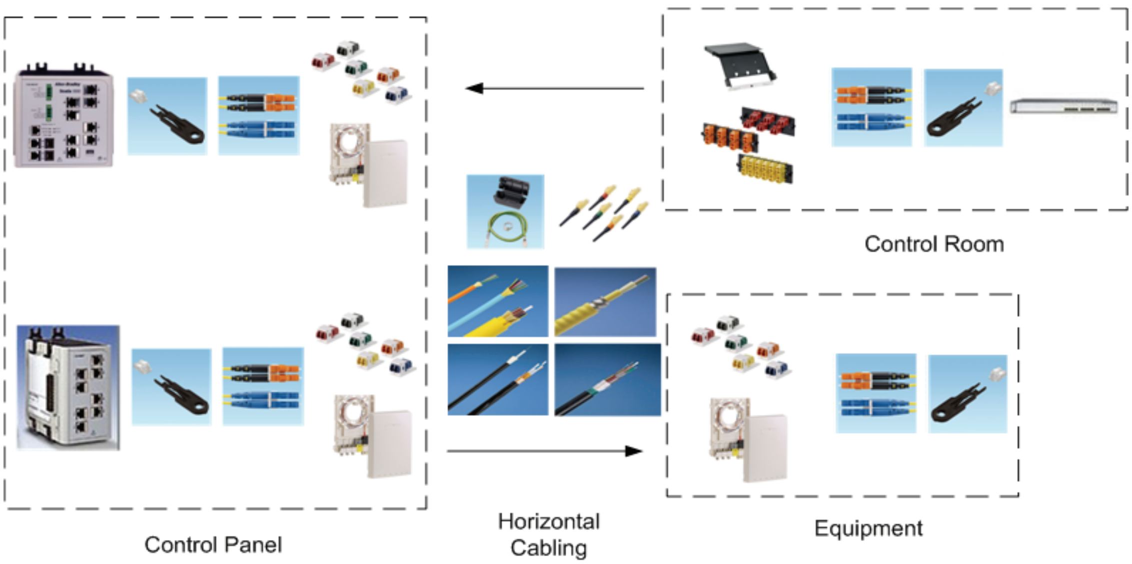
Ordering information for the option shown:

Part Number	Description	Example
FCE1U	Fiber Enclosure that holds up to four QuickNet Cassettes, Fiber Adapter Panels, or FOSM splice modules.	
FAP6WEORDLC	Keyed 'E' (orange) LC FAP loaded with six LC duplex adapters with zirconia ceramic split sleeves	
F9E10E-10M1Y	OS1 9/125um 1m LC Keyed 'E' (orange) to LC Duplex patch cord	
ACG24K	Armored Cable Grounding kit with 24" crimped jumper wire assembly	
CMDEORLCZ	Keyed LC Mini-Com module supplied with one LC keyed 'E' (orange) duplex fiber adapter	
FSPR912Y	12-fiber 9/125um (OS1/OS2) singlemode riser rated indoor interlocking armored cable	
FLCCLIW-X	LC duplex Lock-in clips and one removal tool	
CBXD4IW-AY	Surface Mount Box that accepts four Mini-Com modules	

4.2.4.2 End-to-End Channel Building

Singlemode Fiber Solutions for Stratix 8000 8-Port Fiber Expansion Unit Using 100FX LC-Style Connectors on Stratix 1783-SFP100LX or 1783-SFP1GLX

The Stratix 8000 can accommodate a maximum of one expansion unit with integrated 100FX LC-style fiber optic connectors. The following diagram shows the fiber optic elements utilized under this scenario to complete a fiber optic channel from the Control Room to factory equipment. This channel runs from a switch in the Control Room to a Stratix switch and expansion module located in a Control Panel, and then to equipment on the factory floor.



4.2.5 Installation

Both outside plant and in-building communications cable are often placed in conduit or duct. This is dependent upon the construction of the fiber cable. If it has an armoring manufactured into the cable, then the cable can usually be placed without additional protection with the exception of areas with the cable would be exposed to extreme conditions such as heat, heavy construction traffic, etc.

4.2.5.1 Cable Pulling

The most common method of installing cable is called cable pulling. If the cable is placed in conduit, a line is threaded through the conduit which will act as a pull device. Once pulled through the entire run the line is attached to the cable. The line is used to drag the cable back through the conduit. If the cable is not installed in a conduit, the cable is placed along the designed cable route and secured with manufacturer recommended cable ties or cable clamps, dependent upon the cable route.

During installation, the cable is under tension. For this reason, manufacturers provide cable tension information with their cables so damage will not incur during install. One way to minimize cable tension is to install pull boxes. Pull boxes should be located so that cables are not pulled through a continuous run with bends that exceed 180º (for example: two 90° bends, four 45° bends, or one 90° bend and two 45° bends). In addition to this, cable pulling lubricants can be applied to the cable as it is being pulled through the run to reduce friction and ease pulling tensions.

Cable bend radius is another important parameter involved in cable installation. . This is the maximum bend that can be introduced into a fiber cable before the transmit signal within the cable begins to refract or escape through the fiber cladding. Excessive bending will lead to micro fractures in the cable resulting in a higher overall cable attenuation and possible irreversible damage.

Table 4B-2 summarizes the bend radii for Panduit non-armored distribution cable. The bend radius of the Interlocking armored cable has been specified within the cable specifications sheets in Appendix B.

Fiber cable is shipped on a spool. Un-spooling of the fiber cable during installation also assists in relieving cable tensions by relieving the curving introduced in the cable created by the cable spooling process. Figure 4.2-1 shows how the cable reel would be placed on jack stands and un-spooled in a figure eight configuration.

Fiber cable is shipped on a spool. Un-spooling of the fiber cable during installation also assists in relieving cable tensions by relieving the curving introduced in the cable created by the cable spooling process. Figure 4.2-1 shows how the cable reel would be placed on jack stands and un-spooled in a figure eight configuration.

After the fiber is un-spooled, the whole figure eight can be flipped (or rolled) to allow easy cable pulling from the figure eight. If space does not allow for this installation procedure, the fiber can be installed right off the reel, but it will not have the opportunity to relax from the spooling process and some twisting of the fiber may occur, causing higher attenuation values.

Table 4.2-2. Bend Radius of Panduit Non-Armored Distribution Fiber Cable

Fiber Count	Fiber Type	Bend Radius			
		Install		Long Term	
		mm	in	mm	in
6	900 um Tight Buffer 50/125, 62.5/125, 9/125 and 10Gig	96.0	3.8	48.0	4.9
12		124.0	4.8	62.0	2.4
24	900um Tight Buffer 50/125, 62.5/125 and 9/125	277.0	10.9	183.0	7.2
24	900um Tight Buffer 10Gig	260.0	10.2	130.0	5.1
24	Side by Side 900um Tight Buffer 50/125, 62.5/125, 9/125 and 10Gig	144.0	5.7	72.0	2.8
36	900 um Tight Buffer 50/125, 62.5/125, 9/125 and 10Gig	318.0	12.5	159.0	6.3
48		310.0	12.8	185.0	7.3
72		402.0	15.8	201.0	7.9
96		440.0	17.3	220.0	8.7

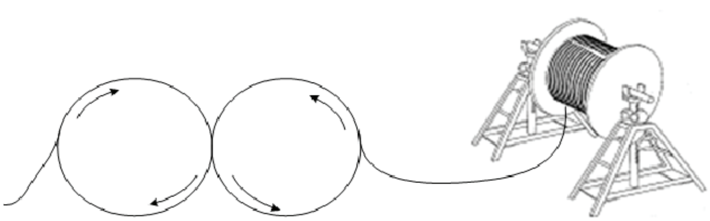
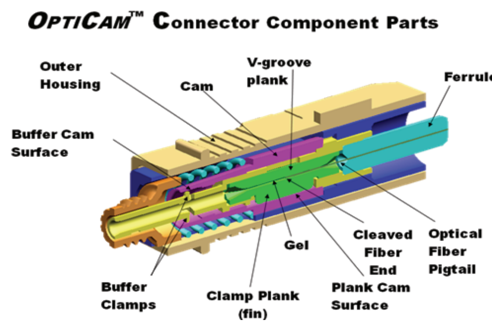
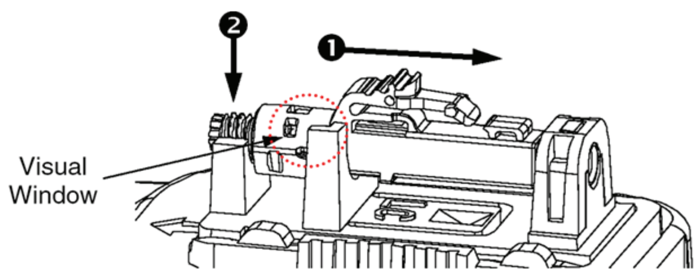
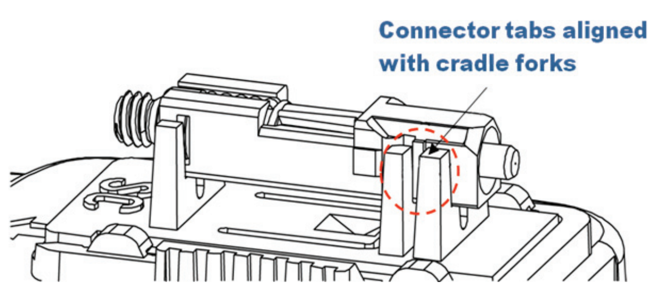


Figure 4.2-1. Fiber Cable Un-spooling For Installation.

4.2.5.2 Terminating OPTICAM® Fiber Optic Connectors

Pre-Polished Cam Termination

- Provide field termination in less than half the time of field polish connectors
- Patent pending re-termination capability provides yield rates approaching 100%
- A single OPTICAM® Termination Tool (OCTT) provides fast and easy terminations
- User-friendly tool utilizes an integrated visual fault locator (VFL) for visual indication of proper termination after the cam step has been completed
- System virtually eliminates operator error and delivers yield rates approaching 100% for lower installed costs

Prepare OptiCAM termination tool.	
Verify Opticam connector	
OPTICAM® Termination LC Connector Mounting Hold the connector body with the latch facing up and slide the connector body into the LC Cradle. The connector is inserted fully when the backbone threads rest completely on the cradle flange as shown.	
SC Connector Mounting Remove both dust caps from the connector inner housing assembly; then place the inner housing assembly into the OCTT cradle as shownat right:	

4.2.6 Testing

1. Setting a Reference Value

There are two methods for setting a reference value presented below.

Precaution:

Make sure that the tester is fully charged and within current calibration date before testing.

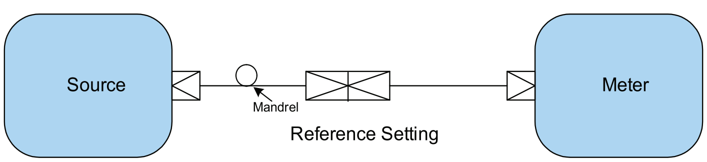
***Note:** In the event the tester has been stored in a cold environment, make no attempt to test or set reference values until the tester comes up to an ambient temperature – this will eliminate fluctuations in accuracy.*

It is important to clean all connector enfaces (reference jumpers and Link Under Test (LUT) connectors) with alcohol and lint-free wipes prior to testing. Ensure that the reference leads are in good condition and meet specifications in section 12.0 Test Lead Performance Verification before testing. Note that mandrels are not required for links with OS1 (Singlemode) fiber.

Reference Setting – Method A

Connect one reference lead to tester terminal labeled Output (A) and the other reference lead to the tester terminal labeled Input (B). Mate the other ends of the reference leads together in an adapter (Refer to TIA/EIA 526-14A Std. Method A. This method is used in conjunction with the Two Jumper and Three Jumper test methods described later in the document.

Method A for Setting Reference



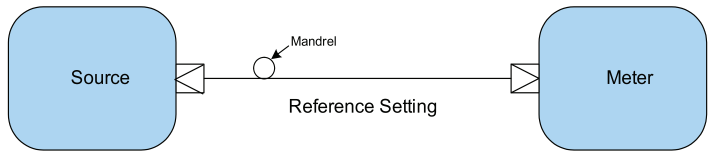
Follow test unit manufacturer's instructions for setting reference values for the applicable wavelengths, numbers of adapters, splices, etc.

Reference Setting – Method B

Connect one reference lead from tester terminal labeled Output (A) to the power meter terminal labeled Input (B). Refer to TIA/EIA 526-14A Std. Method B.

***Note:** This method can only be used when the connector types of the LUT and connectors on the reference leads are of the same type. This method is used in conjunction with the One Jumper test method described later in the document.*

Method B for Setting Reference



Even though Method "B" is proven to be slightly more accurate when setting a Ref Value, not all fiber techs have the same connector types as the Link Under Test. Therefore, most rely on Method "A" above.

Follow test unit manufacturer's instructions for setting reference values for the applicable wavelengths, numbers of adapters, splices, etc. Once the test system is referenced, the launch and receive leads may not be removed from the test equipment. Doing so will require re-referencing.

***NOTE:** On less sophisticated light source/power meters, the normal method to establish a reference value is as follows:*

1. Connect Launch and Receive leads with a mating adapter.
2. Record the loss shown on the power meter. This will be your reference value.
3. Connect Launch and Receive leads to their respective ends of the link under test.
4. Measure the loss. Record this value.
5. Subtract the value recorded in Step 2 from the value in step 4.
6. This is your actual link loss.

This is only necessary when the tester being used does not have the same adapter as the LUT.

Good reference values average around -19.0dB for 62.5/125µm, - 24.0dB for 50/125µm and around -8.0dB for 9/125µm fiber.

2. Testing a Permanent Link

Unless otherwise stated, all permanent link loss testing of a segment shall be performed with a handheld power meter/ source. This equipment will measure link attenuation, which is the most important performance parameter when installing components. Maximum allowable attenuation of Ethernet applications is shown in Table 4.2-3.

OTDR testing is not a requirement in fiber certification. In fact, this basic fiber certification (Tier 1) with a power meter and light source is the only type of testing required by TIA-568B for premises cabling. This test method measures end-to-end insertion loss by using a power meter and light source. If the attenuation is within the limits of the allotted power budget, the system will work. PANDUIT does not recommend testing links via the OTDR method.

Table 4.2-3. Acceptable Link Loss for Ethernet Applications

Application		Multimode (Loss dB)			Singlemode (Loss dB)
		62.5/125µm	50/125µm		9/125µm
		OM1	OM2	OM3	OS1
Ethernet	1000 Base-SX	2.60	3.56	3.56	n/a
	1000 Base-LX	n/a	n/a	2.35	4.56
	10G Base-SR/SW	1.60	1.80	2.60	n/a
	10G Base-LR/LW	1.60	n/a	n/a	n/a
	10G Base-ER/EW	n/a	n/a	n/a	10.90
	10G Base-LX4	n/a	n/a	n/a	6.20

Link-Loss Test Recommended Methods

There are two standard methods of completing a link loss test that Panduit recommends:

- One Jumper Method (Method B)
- Two Jumper Method (Method A)

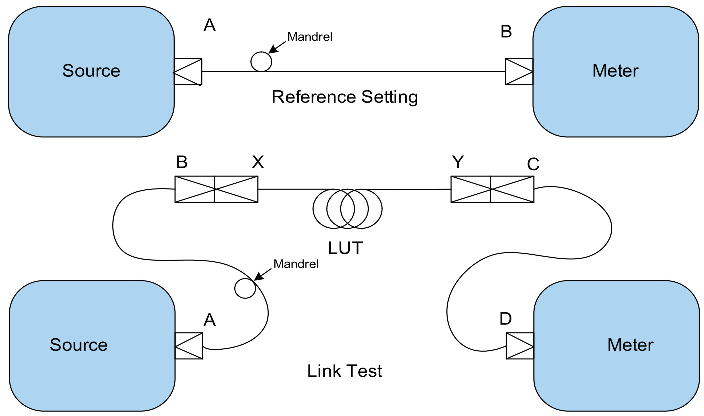
Note that in all of the methods that will be discussed "reference quality" patch cords and adapters need to be used to ensure accurate, repeatable and reproducible measurements.

One Jumper Method (Method B)

The one jumper method calculates the link loss as the loss of the two adapters and the link under test. This is the preferred method as outlined in TIA/EIA 568-B.1 and the secondary method outlined in ISO/IEC 11801. Here the power meter test lead must have the same connector type as the LUT. This has been proven to be the most accurate and reproducible method. In utilizing this method, you have to set a reference value using Method B.

Store/record permanent link loss measurement for future reference.

Figure 4.2-2. One Jumper Method



Link Loss = LBX + LXY + LYC

Where LBX is the loss value of the adapter on the transmit side, LYC is the loss value of the adapter on the receive side and LXY is the total link under test.

As shown in Figure 4.2-2 above, start by setting a reference as described previously in this document. Once the reference is set, we are ready to move on to test the LUT.

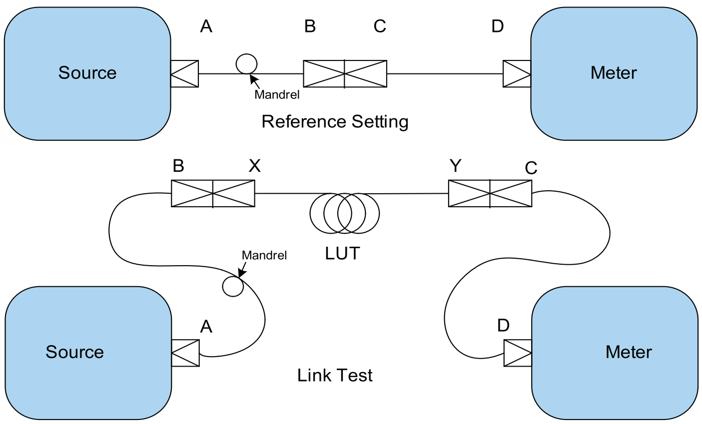
It is best to test the LUT from the fiber adapter panel to fiber adapter panel. This ensures that all splices, connections, and fiber cables in the link are included in the test. These two points are labeled as X and Y in the above illustration.

The source side remains at one end of the link while the meter side is moved to the far end receive side of the link. Link loss will be calculated by the test equipment. If not, it can be calculated by subtracting link loss minus the Reference value measured.

Two Jumper Method (Method A)

The two jumper method calculates the link loss as the loss of the adapter in the original reference setup subtracted from the sum of the two adapters and the link under test. This method is preferred by contractors even though it is not referenced in ISO/IEC 11801 because the power meter test lead does not have to have the same connector type as the LUT. This method also assumes that a majority of the loss is in the fiber cable itself and not the connectors.

Figure 4B-3. Two Jumper Method



Link Loss = LBX + LXY + LYC - LBC

Where LBX is the loss of the adapter on the transmit side, LXY is the loss of the link under test, LYC is the loss of the adapter on the receive side and LBC is the loss of the adapter in the reference setup.

As shown in the Figure 4.2-3 above, start by setting a reference as described previously in this document. Once the reference is set, we are ready to move on to test the LUT.

It is best to test the LUT from the fiber adapter panel to fiber adapter panel. This ensures that all connections, patch cables, and fiber cables in the link are included in the test. These two points are labeled as X and Y in the above illustration.

The source side remains at one end of the link while the meter side is moved to the far end receive side of the link. Link loss will be calculated by the test equipment, if not it can be calculated by subtracting the Loss of the Link measures during the link test minus the Reference value measured.

3. Interpreting Test Results

Most fiber loss test sets provide a Pass/Fail indication. Each tester has a means of manually defining the link under test (LUT) so the test results will be given based upon the amount of light loss and knowing those optical characteristics which have a direct affect on the total optical loss of the LUT. The link characteristics you need to define to the tester include:

- Core Size: 50/125µm, 62.5/125µm, or 9/125µm.
- Number of adapters in the link (normally two)
- Number of splices (mechanical or fusion)

Note: *The link length does not need to be defined; the tester will determine the link length. If the Fluke DTX-1800 is used, it measures the length by gathering the values from the fiber characteristics (such as Index of Refraction) combined with the time it takes the light source to reach the remote unit and this allows the unit to calculate the length of the fiber run. Given that the index of refraction is the speed the light travels through the fiber, all we need is the time it takes at that speed to determine the distance the light has traveled.*

Based upon the Ref Value you have set plus the Link characteristics defined to the tester, it will provide you with a PASS or FAIL based upon the Industry Standards stored within the tester's firmware. The most current tester firmware should be available from the vendor's website and should always be up to date on the tester.

PASS / FAIL:

Some testers automatically determine whether a link passes or fails depending on a number of given specifications internal to the tester that are selected before testing. If the tester does not automatically determine PASS / FAIL then use the calculation presented in Section 6.0 to determine the maximum allowable link loss (Reference TIA/EIA 568-B.1 Std., Section 11.3.3.4).

PASS or FAIL is a matter of measuring permanent link optical power loss against accepted industry standards per IEC/TIA 568-B.1. If a link fails immediately, it is possibly a polarity issue where the transmit and receive patch cords are flipped. Consider using a visual light source to manually observe whether light can travel from one end of the link to the other. This is a safe and practical means of troubleshooting. This will save time as testing post-installation will likely reveal some polarity problems, which are much easier to correct than other light loss or light obstruction problems.

Tester Link Loss Formula:

Optical Link Headroom = Permanent Link Loss Budget – Permanent Link Loss Measured

If the test results show that your Optical Link Headroom is equal or greater than the Permanent Link Loss Budget, the tester will show a **PASS**. If the Optical Link Headroom displayed is in the negative direction, your Permanent Link Loss Budget is experiencing too much optical loss and will not meet IEC/TIA 568-B.1 requirements and show a **FAIL**.

With the tester set up to correctly reflect the optical characteristics of the Permanent Link, test the link to see if the losses encountered are within the allowable limits set by the IEC/TIA that have already been loaded into the tester.

Sometimes the test results may show that more light was "gained" in the link. This result is erroneous and called a "gainer" or an increase in optical power from the referenced value to the total loss of the LUT.

For example, if the reference value for a given link is –25dB but in testing a LUT your meter now reads only –19.5 dB, your link has gained power! This is not possible and should alert you to a problem within the link.

There are two possible causes for "gainers."

(1) Your reference leads connectors enfaces were initially dirty and when you disconnected the reference leads to attach to the LUT, the dirt/debris is displaced and now you have significantly more light being received at the far end

(2) The second way to gain light is when the core-to-core alignment of the reference leads is not well centered with one another. This can be improved, insuring that proper reference cords are being used and not just "bucket" cords and by using zirconia ceramic split sleeves found in the blue singlemode adapters rather than the phosphor bronze split sleeves found in the electric ivory multimode adapters. Zirconia ceramic split sleeves maintain better core-to-core alignment than phosphor bronze split sleeves.

Assuming the initial core-to-core alignment was off-center, taking the reference value now will indicate a higher amount of loss than normally found. Continuing with the test and connecting both ends of the reference leads to the LUT can actually improve the loss amount since the core-to-core alignment can be made better without the offsets of the reference leads. Tests completed in this scenario will surely show erroneous light gains, commonly known as "gainers".

4.2.7 Documenting

In compliance with TIA/EIA-526-14A "Optical Power Loss Measurements of Installed Multimode Fiber Cable Plant" and TIA/EIA-526-7 "Measurement of Optical Power Loss of Installed Singlemode Fiber Cable Plant", the following permanent link data should be documented as a result of link loss testing:

- Date of link testing
- Names of personnel conducting the test
- Test equipment details (manufacturer, model, serial number)
- Center wavelength(s) and spectral width(s) of the test unit
- Fiber details (type)
- Test direction and end point locations
- Reference power measurement (if applicable)
- Segment link loss results
- Link loss budget

4.3 Grounding and Bonding

From the control room or data center, to the manufacturing floor and to facilities operations --in all of these areas, there are critical systems that require proper grounding and bonding. Protecting those systems, equipment and personnel helps to ensure equipment reliability and, thus, availability of services and lower operational expense. Network equipment, such as switches, routers, and storage devices can cost up to hundreds of thousands of dollars. The loss of network equipment can be very costly, but the real danger is the downtime that can be caused by the failure of this network equipment, especially with today's automated systems and processes. Downtime can have serious consequences.

A well engineered grounding and bonding system is critical to the safety and performance of power distribution, control, communications, security and IT systems. It is vital that the network equipment in Industrial Automation environments be properly bonded and grounded to protect workers and equipment from electrical surges, transient voltages, electrical noise and electrostatic discharge (ESD). While the National Electric Code provides good grounding and bonding guidance for the safety of personnel and the robust equipment within an electrical distribution system, extra attention must be paid to the protection of the sensitive electronic equipment found in today's networks.

This section of the Guide provides an overview of the different grounding and bonding systems, standards and codes and definition of key terms, acronyms to help you make better decisions in the selection of proper grounding and bonding techniques and equipment for industrial automation spaces and applications. Sometimes the amount of information can seem overwhelming even to seasoned professionals, especially in the area of grounding and bonding. However it is more important than ever to keep up-to-date with the industry standards, best practices, highest quality products and partners that know and understand what is required to install and maintain these systems.

DEFINITIONS

Bonding – The permanent joining of metallic parts to form an electrically conductive path that will assure electrical continuity and the capacity to conduct safely any current likely to be imposed.

Ground/Earth– A conducting connection, whether intentional or incidental, by which an electric circuit or equipment is connected to the ground/earth, or to some conducting body of relatively large extent that serves in place of the earth.

High Frequency Bonding – Creating equal potential between electrical devices and its infrastructure components in a system to minimize the effects of electrical noise and electromechanical interference.

Electrostatic Discharge (ESD) - When the build-up of static electricity on an object is transferred to a grounded object or an object of lower potential.

ACRONYMS

GEC – Grounding Electrode Conductor
GES – Grounding Electrode System
MCBN – Mesh Common Bonding Network
TBB – Telecommunications Bonding Backbone
TEBC – Telecommunications Equipment Bonding Conductor
TGB – Telecommunications Grounding Busbar
TMGB – Telecommunications Main Grounding Busbar

STANDARDS and CODES

ANSI/TIA-1005 / ANSI/TIA-1005-1

Publication of the Telecommunications Infrastructure Standard for Industrial Premises and its first addendum, covering Industrial Pathways and Spaces, is forthcoming is 2009. The documents are based on the ANSI/TIA/EIA-568-B and TIA-569-B series of standards, and they include appropriate allowances and exceptions to those standards for industrial premises. They also contain techniques to mitigate mechanical, ingress, climate/chemical, and electromechanical (M.I.C.E.) effects across multiple areas.

TIA/EIA-942

TIA/EIA-942 (Telecommunications Infrastructure Standard for Data Centers) specifies the minimum requirements for the telecommunications infrastructure of data centers and computer rooms.

ANSI/J-STD-607-A-2002

ANSI/J-STD-607-A-2002 (Commercial Building Grounding and Bonding Requirements for Telecommunications) specifies the minimum requirements for the telecommunications grounding and bonding infrastructure for buildings with telecom rooms, communication rooms, data centers, control rooms, network rooms and wherever sensitive electronic equipment is found.

IEEE Std. 1100-2005

IEEE Std. 1100-2005 (IEEE Recommended Practice for Powering and Grounding of Electronic Equipment) recommends a buildings power and grounding minimum requirements for sensitive electronic equipment.

IEEE Std. 142-1991

IEEE Std. 142-1991 (IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems) recommends grounding practices for the various power distribution system topologies and the equipment within those systems.

IEEE Std. 837-2002

IEEE Std. 837-2002 (IEEE Standard for Qualifying Permanent Connections Used in Substation Grounding) recommends the minimum requirements for connectors used in the grounding electrode system such as connections to ground rods, rings, meshes, ufer grounds and conductor electrodes.

NFPA 70®

NFPA 70® (2008 National Electrical Code) is the minimum requirements for electrical installations.

NECA/BICSI 607

NECA/BICSI 607 (National Electrical Contractors Association/Building Industry Consulting Service International, Inc.) recommends minimum requires for telecommunications, IT and network type of grounding and bonding systems.

According to standards TIA-942, J-STD-607-A-2002, and IEEE Std. 1100 a properly designed grounding system as shown in Figure 4C-1 has the following characteristics:

- Has an intentional design – each connection must be engineered and installed to properly handle the anticipated currents
- Bonds all metallic components to the grounding system (e.g., equipment, racks, cabinets, access floors, ladder racks, cable trays, water pipes, conduit, building steel, etc.)
- Is visually verifiable and generally arranged for ease of inspection and testing
- Provides equalization paths and ports for ESD protection wrist straps
- Supports the proper operation of surge protective devices for ITE and power circuits
- Promotes electromagnetic compatibility (EMC) within the data center environment
- Must adhere to all local electrical codes, and should be listed with a nationally recognized test lab (such as Underwriters Laboratories, Inc.).

In addition to meeting these standards, all grounding and bonding components should be listed with a nationally recognized test lab (such as Underwriters Laboratories, Inc.) and must adhere to all local electrical codes. The PANDUIT® StructuredGround™ System for data center grounding provides robust connections that have low resistance, are easy to install, and are easily checked during the inspection process.

4.3.1 End-to-End Grounding & Bonding System Elements

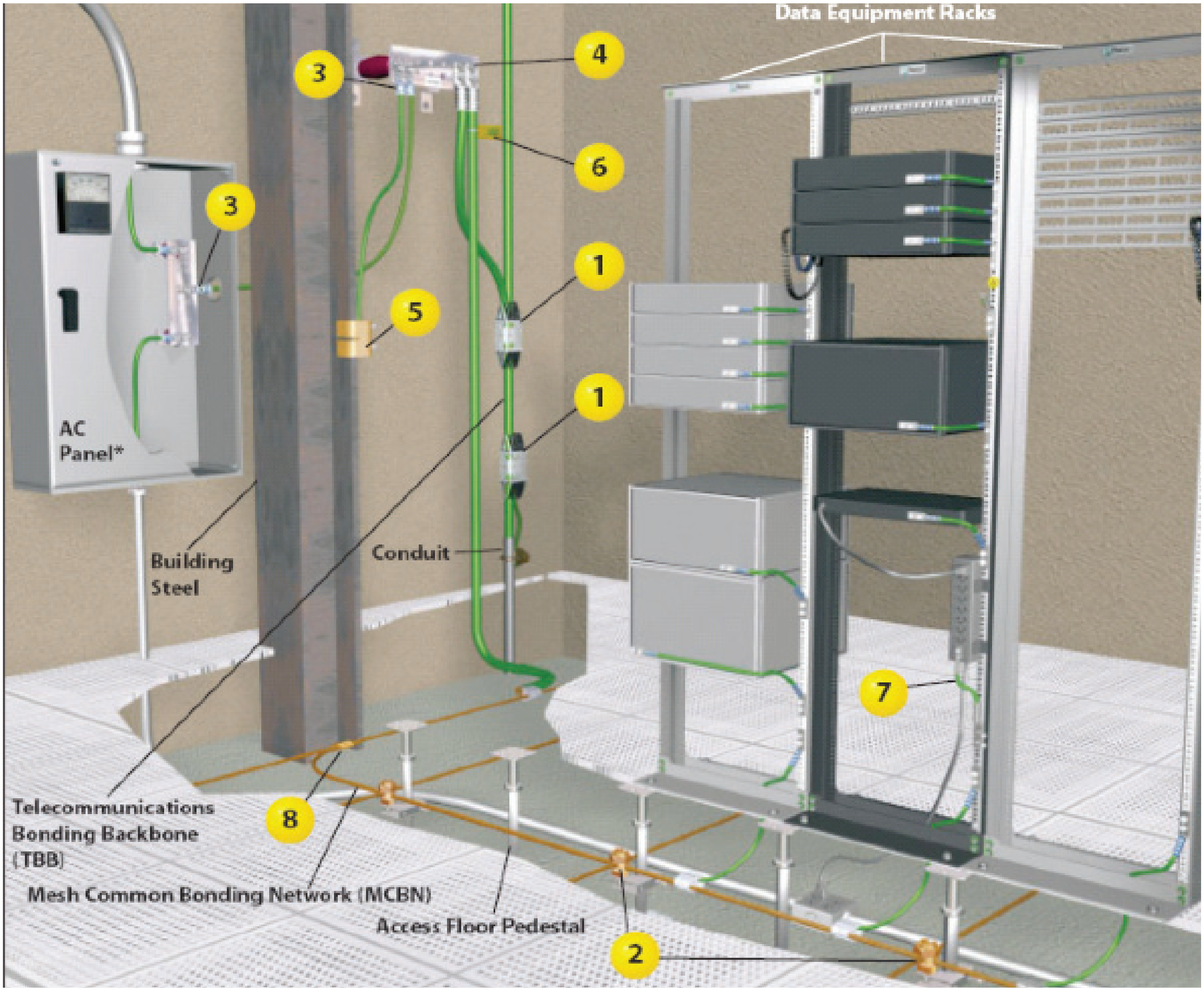


Figure 4.3-1. Example Grounding and Bonding System in a Control Room with Access

The following are the basic elements of an end-to-end grounding and bonding system for industrial buildings and environments. Each requires proper design and installation by trained and qualified personnel, and is discussed in further detail below.

- Grounding electrode system
- Utility entrance facility / grounding and bonding infrastructure
- Telecommunications system grounding for the Control Room
- Control system grounding

4.3.1.1 Grounding Electrode System (GES)

The most critical part of any grounding system is the connection to earth which is the function of the grounding electrode system (see Figures 4C-2 and 4C-3). Design and installation of the grounding electrode system should be performed by qualified and trained personnel. The GES is compromised of grounding electrodes which may be present in an installation depending on particular applications. Grounding electrodes include ground rods and pipes, ground rings, Ufer grounds, structural steel, water pipes and ground meshes.

The schematic diagram in Figure 4.3-2 shows a generic layout of a facilities grounding infrastructure including the GES, the entrance facility bonding and the distribution of the grounding system. Figure 4.3-3 shows a graphic representation of the elements of a GES. The requirements for the GES are described in the NFPA 70®, 2008 National Electrical Code. Components that are used in the GES should be listed with a testing agency (UL). For a higher quality GES it should be constructed of high grade copper conductor and connections that are IEEE 837-2002 approved. Each building and each application can be different so each situation has unique requirements that need to be considered.

Selection of the GES components must be done during the planning phase of any project. The ground electrode system is the first part of the electrical system that gets installed when constructing a new building. Since the GES is buried directly into the soil, high quality, tested connections help lead to higher reliability. Every ground connection is important all the way to the network equipment and it starts here in the grounding electrode system. See Appendix C-1 for a sample connector specification that can be used for writing project specifications.

Building the Grounding Electrode System

PANDUIT Part#	Description
E-Style Grounding Connectors	
GCE1/0-1/0	E Style Grounding Connector, Main/Tap #6 SOL - 1/0 STR
GCE250-1/0	E Style Grounding Connector, Main 1/0 STR - 250Kcmil, Tap #6 SOL - 1/0 STR, Ground Rods 1/2” - 5/8”, Rebar, 3/8’ - 1/2’
GCE250-250	E Style Grounding Connector, Main/Tap 1/0 STR - 250Kcmil, Ground Rods 1/2” - 5/8’, Rebar 3/8” - 1/2”
GCE500-1/0	E Style Grounding Connector, Main 250 - 500 Kcmil, Tap #6 SOL - 1/0, Ground Rods 1/2’ - 3/4’, Rebar 5/8” - 3/4’
GCE500-250	E Style Grounding Connector, Main 250 - 500 Kcmil, Tap 1/0 STR - 250 Kcmil, Ground Rods 1/2’ - 3/4’, Rebar 5/8” - 3/4’
Grounding Gross Connectors	
GCC6X61/0-1/0	Grounding Cross Connectors, #6 SOL - 1/0 STR.
GCC6X6250-1/0	Grounding Cross Connector, (A) #2 SOL - 250 Kcmil, Ground rods 1/2” - 5/8”, Rebar 3/8” - 1/2” (B) #6 SOL - 1/0 STR
GCC6X6250-250	Grounding Cross Connector, (A/B) #2 SOL - 250 Kcmil, Ground Rod 1/2” - 5/8”, Rebar 3/8’ - 1/2”
GCC6X6500-1/0	Grounding Cross Connector, (A) 250 - 500 Kcmil, Ground rods 1/2” - 3/4”, Rebar 5/8” - 3/4” (B) #6 SOL - 1/0 STR
GCC6X6500-250	Grounding Cross Connector, (A) 250 - 500 Kcmil, Ground rods 1/2” - 3/4”, Rebar 5/8” - 3/4” (B) #2 SOL - 250 STR
Misc Components	
GPC4H250-2	Grounding Plate Connector, #2 SOL - 250 Kcmil
GUBC500-6	Universal Beam Grounding Clamp, #6 AWG - 500Kcmil

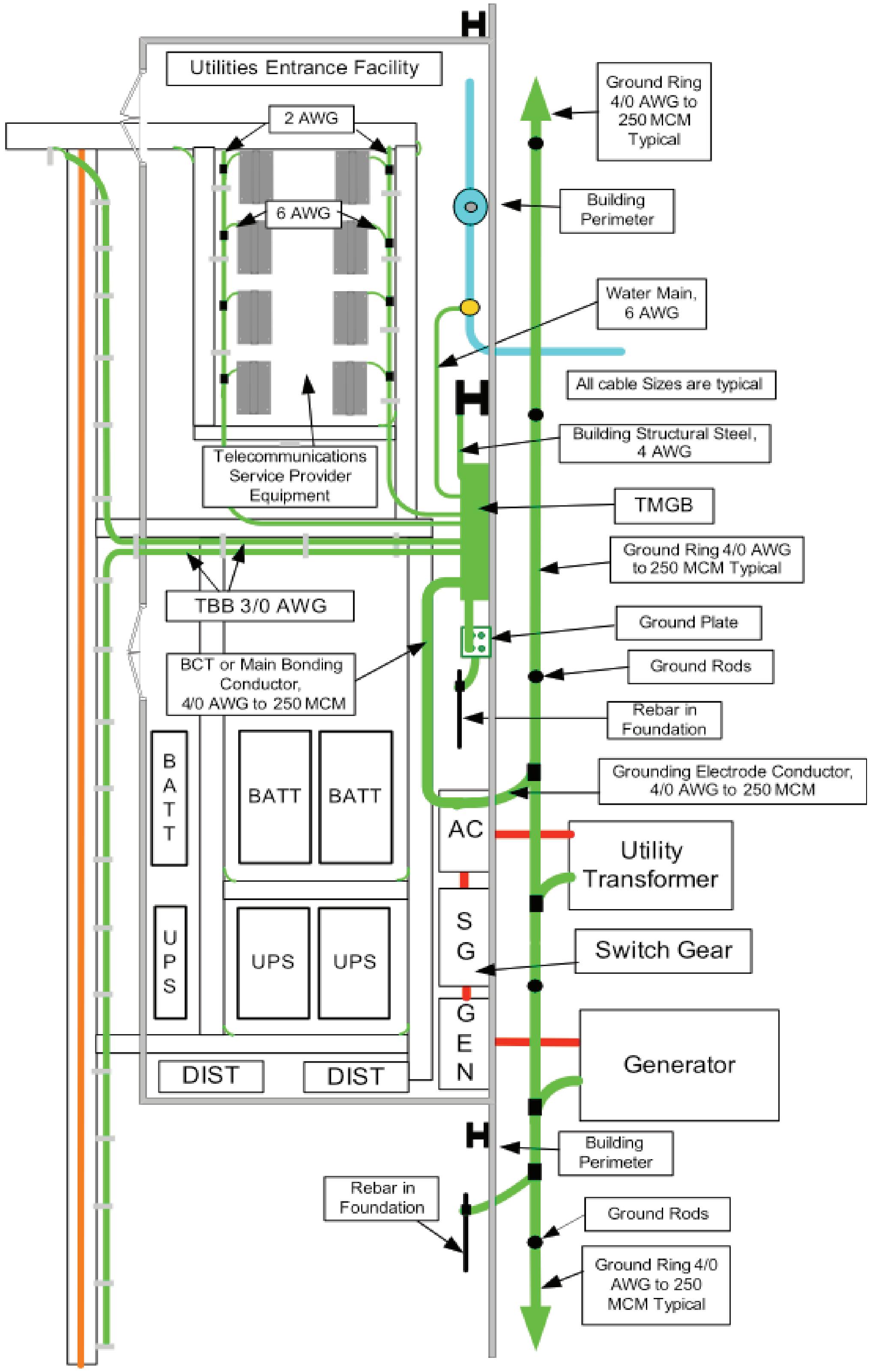
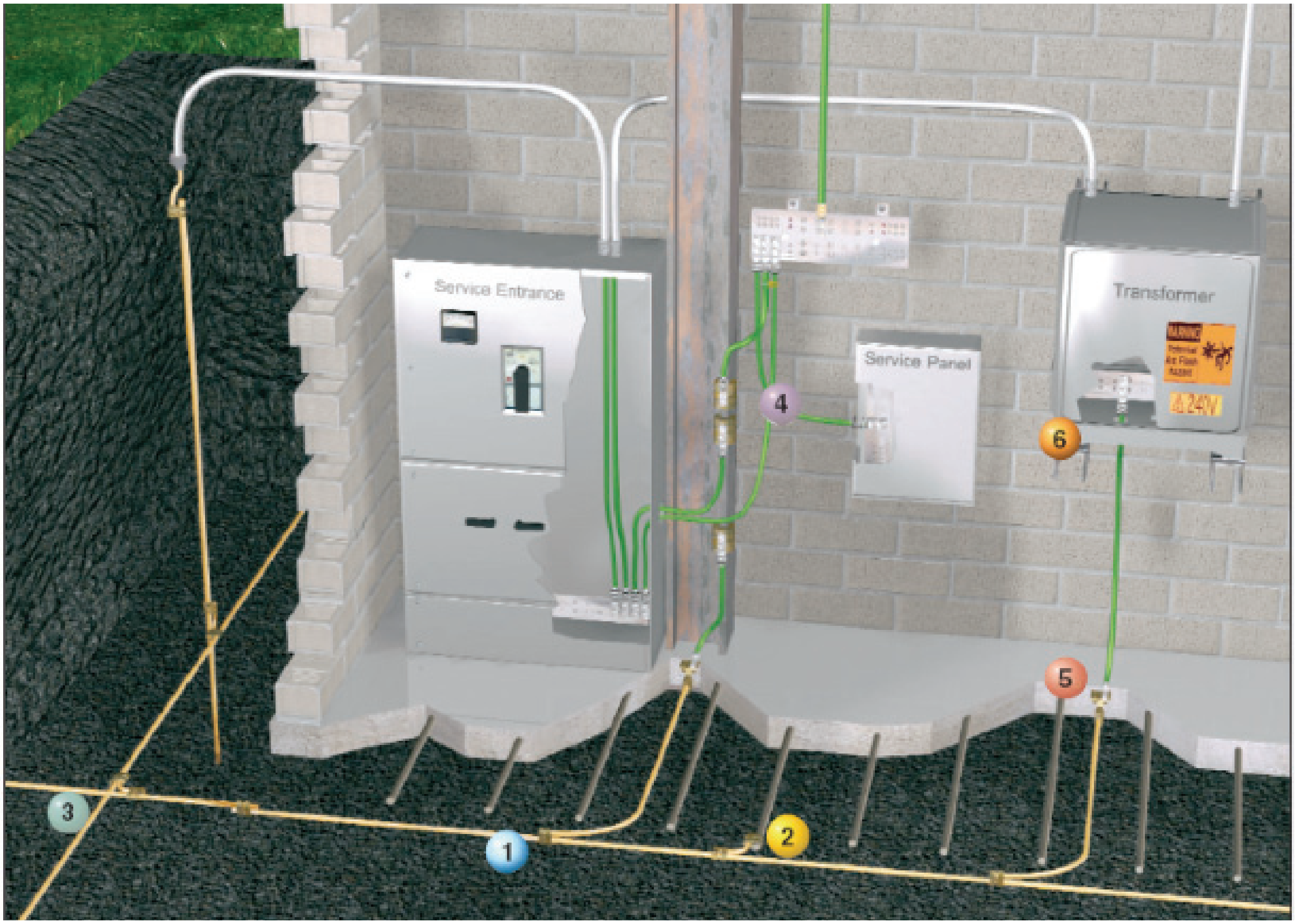
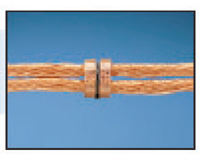


Figure 4.3-2. Schematic View of a Generic Grounding Infrastructure



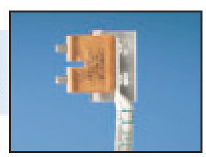
1 Conductor to Conductor



E Style Grounding Connectors:

Creates bonds between parallel grounding conductors.

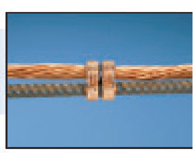
4 Conductor to Building Steel



Universal Beam Grounding Clamp:

Bonds structural steel to grounding conductor system.

2 Conductor to Rebar



E Style Grounding Connectors:

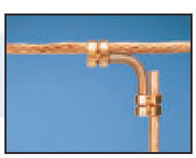
Allows bonds to reinforcing bars.

5 Conductor to Grounding Electrodes

Grounding Plate Connector:

Allows bonds through concrete.

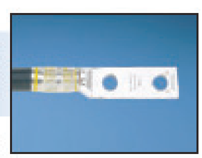
3 Conductor to Ground Rod



Grounding Cross Connectors:

Creates bonds between perpendicular grounding conductors.

6 Related Product LCC-W



Long Barrel Two-Hole Code Conductor:

For use with stranded copper conductors.

Figure 4.3-3. Grounding Electrode System Graphical Reference

4.3.1.2 Utility Entrance Facility/Grounding and Bonding Infrastructure

Once the connection is established to the ground or earth by the Grounding Electrode System, the next critical link is the bonding of that GES to the rest of the building systems. That bonding should be done at the building's utility entrance facility (see Figures 4.3-2, 4.3-4, and 4.3-5).The main connection from the GES outside the building to inside of the building is called the Grounding Electrode Conductor. The Grounding Electrode Conductor enters the building and typically terminates at the main ground bus in the AC main service panel or to a main ground bus external to the AC main service panel. See Appendix C-2 for a sample grounding and bonding specification that can be used for writing project specifications.

Once the main ground bus is established in the entrance facility, grounding connections can be distributed to various areas of the building. Those areas could be telecom rooms, server rooms, data centers, control rooms and other similar type installations where sensitive electronic equipment is located. To establish a high quality, reliable and flexible grounding and bonding infrastructure, ANSI/J-STD-607-A principles should be applied.

The grounding system starts in the entrance facility with the Telecommunications Main Grounding Busbar (TMGB). The TMGB is independent of the AC grounding system, but is bonded to the main ground bus in the AC main service panel or to another main ground bus external to the AC main service panel. The following graphical representation of a building entrance facility serves as an example, keeping in mind that every building presents unique challenges. Although every entrance facility can look different, the basic requirement of bonding the various components and/or systems together is the goal.

ANSI/J-STD-607-A also requires a ground bar, called the Telecommunications Grounding Busbar (TGB) to be placed in each equipment room to establish the grounding reference. Each TGB will then be bonded back to the TMGB via the Telecommunications Bonding Backbone or TBB. The TBB should be a continuous conductor when possible to keep the resistance to a minimum. The TBB should bond to each TGB by "tapping" off of the TBB as shown in Figure 4C-7. It is important to properly size the TBB so it is adequate to carry the current that is likely to be imposed on it. Table 4C-1 is from the standard and provides guidance for sizing the TBB properly for the distance.

Some of the other important requirements from the standard are related to the types of products and workmanship requirements. The use of copper conductors, types of busbars and the types of connectors are called out in the standard. One of the more important requirements of the standard is the use of two-hole compression connectors for making terminations at the TMGB and TGB. These types of connectors will provide a more reliable connection for the life of the installation. They will resist coming loose at the busbar and will not loosen up at the connector like a mechanical type of connector would over time.

Table 4C-1. Sizing the Telecommunications Grounding Busbar (TBB)

TBB Length in Linear meters (feet)	TBB Size (AWG)
Less than 4 (13)	6 ($16mm^2$)
4-6 (14-20)	4 ($25mm^2$)
6-8 (21-26)	3 ($25mm^2$)
8-10 (27-33)	2 ($35mm^2$)
10-13 (34-41)	1 ($35mm^2$)
13-16 (42-52)	1/0 ($50mm^2$)
16-20 (53-66)	2/0 ($70mm^2$)
Greater than 20 (66)	3/0 ($95mm^2$)

Source: ANSI/J-STD-607-A

Building the Utility Entrance Facility Grounding System

PANDUIT Part#	Description
GB4B0632TP-1	Telecommunications Main Grounding Busbar (TMGB) 1/4” x 4” x 24”, Solid Copper, Tin Plated
HDW1/4-KT	Stainless Steel Hardware Kit, 1/4”, (2) bolts, (2) nuts, (4) flat washers, (2) Belleville washers
HDW3/8-KT	Stainless Steel Hardware Kit, 3/8”, (2) bolts, (2) nuts, (4) flat washers, (2) Belleville washers
HDW1/4-A-KT	Stainless Steel Hardware Kit, 1/4”, (2) bolts, (2) nuts, (4) flat washers, (2) Belleville washers
HDW3/8-A-KT	Stainless Steel Hardware Kit, 3/8”, (2) bolts, (2) nuts, (4) flat washers, (2) Belleville washers
LCC250-38DW	Two-hole, long barrel lug w/window, 250 MCM, 3/8” stud hole, 1” spacing
LCC4/0-38DW	Two-hole, long barrel lug w/window, 4/0 AWG, 3/8” stud hole, 1” spacing
LCC3/0-38DW	Two-hole, long barrel lug w/window, 3/0 AWG, 3/8” stud hole, 1” spacing
LCC2-38DW	Two-hole, long barrel lug w/window, 2 AWG, 3/8” stud hole, 1” spacing
LCC4-38DW	Two-hole, long barrel lug w/window, 4 AWG, 3/8” stud hole, 1” spacing
LCC4-12W	Two-hole, long barrel lug w/window, 4 AWG, 1/2’ stud hole, 1 3/4” spacing, NEMA
LCC6-14AW	Two-hole, long barrel lug w/window, 6 AWG, 1/4’ stud hole, 5/8” spacing
GUBC500-6	Universal Beam Grounding Clamp
GPL-8	Grounding Clamp, U-Bolt. 1/2” to 3/4” pipe. #8 AWG to #4 AWG
GPL-16	Grounding Clamp, U-Bolt. 1” pipe. 2/0 AWG to 250 MCM
GPL-34	Grounding Clamp, U-Bolt. 2” pipe. 2/0 AWG to 250 MCM
KP1	Grounding Clamp for Water Pipes 1/2” to 1”, #10 AWG to #2 AWG
KP2	Grounding Clamp for Water Pipes 1 1/4” to 2”, #10 AWG to #2 AWG
LTYK	Telecommunications Grounding and Bonding Label Kit
GACB-1	Auxiliary Cable Bracket
GACBJ68U	Auxiliary Cable Bracket Jumper Kit, 8”
GACBJ612U	Equipment Jumper Kit, 6 AWG, 12”,terminated at both ends
GACBJ618U	Equipment Jumper Kit, 6 AWG, 18”,terminated at both ends

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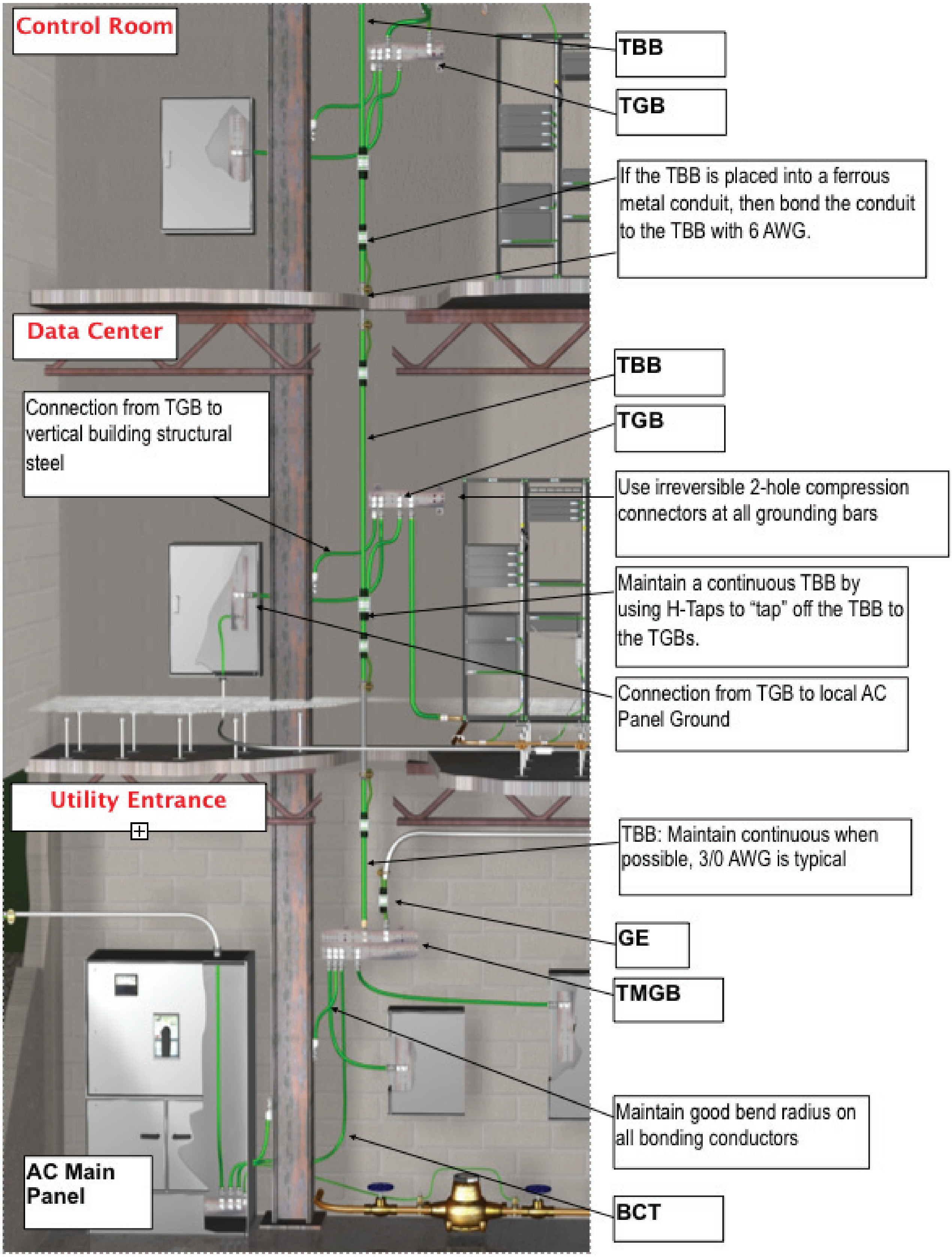

Figure 4.3-4 Utility Entrance Facility

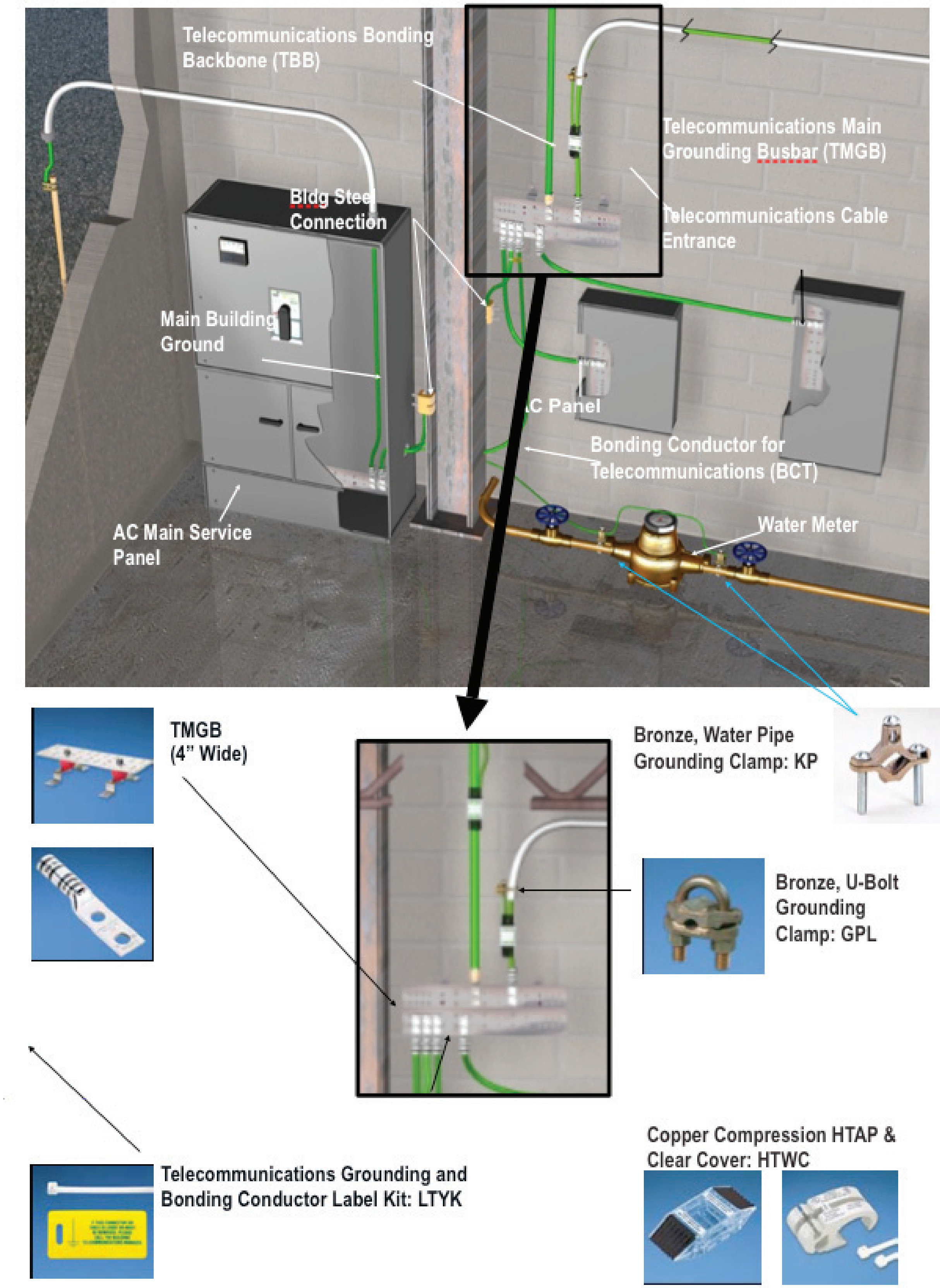

Figure 4.3-5. Grounding and Bonding Infrastructure Requirements of the ANSI/J-STD-607-A