Contents

On-Machine™ Solutions

"On-Machine" is a control design philosophy that moves the industrial controls and hardware closer to the application or on the machine while minimizing the number of components in the cabinet. Although many of these controls have always been on the machine, such as sensors, push buttons, tower lights and connection systems, the complete On-Machine strategy involves taking controls that are traditionally found in an enclosure and moving them out to the application as well.

Although the world outside the enclosure may not seem appropriate for many of today's panel-based industrial controls, the ideal On-Machine component has several key features to enable this migration. Its housing is typically "hardened" to IP67 enclosure standards in order to withstand the harsh environments often found on the factory floor. It tends to be modular and compact in design, with plug-and-play electronic capabilities to ease installation and setup. It can be used as part of a flexible communication network including both standard and intelligent devices. On-Machine solutions are also connectorized for quick system assembly using IP67 connection systems instead of traditional wiring in conduit.

The obvious benefit of moving products out of an enclosure and putting them directly on the machine is the reduced panel space required for an On-Machine system. Secondly, the wiring system is greatly simplified because many connections between components can reside on the machine instead of running back and forth between enclosures. Although the purchase cost of individual components may be slightly higher, the reduction in wiring complexity is so substantial that the decreased wiring time and conduit installation costs make the overall solution more economical.

The end result: the larger and more complex the machine, the greater the potential savings during assembly. A recent study by a consortium of European manufacturers and machine tool technology groups concluded that On-Machine assembly costs are up to 30 percent less than conventional methods.

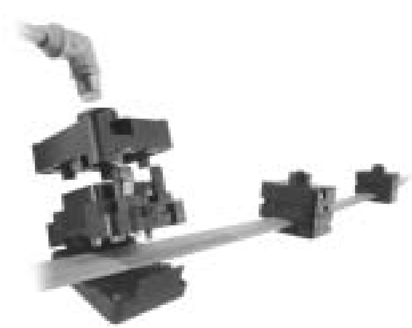
The features afforded by On-Machine components result in many other benefits, such as decreased systems troubleshooting and repair time as well as enhanced control system reliability—with prewired connection there is less manual wiring, resulting in reduced wiring errors and fewer wiring points to check. Plus, the plug-together connectorized components can often be installed by less technically-trained personnel, providing more flexibility with the workforce. Using plug-and-play components even simplifies design effort and engineering documentation.

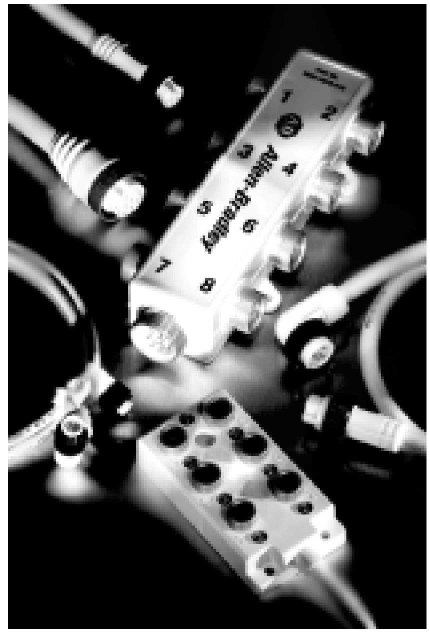
On-Machine architectures also reduce the need for maintenance technicians and operators to access a control panel every time they have to check a connection or make an adjustment. Instead, they can efficiently isolate problems and replace a starter or I/O locally, rather than sorting through a complex panel. This gets the machine up and running again both faster and safer.

Startup and commissioning time also are critical, and On-Machine solutions can reduce both considerably. Due to the modularity and simplified connectivity of components, On-Machine designs allow OEMs to more cost efficiently build a machine at their site, pretest it and then disassemble it for transport to an end user's plant.

Equally important for end users is the flexibility of being able to relocate equipment and make additions with relative ease.

The On-Machine approach also allows OEMs to provide standard product offerings once considered to be custom applications. In the material handling industry, for example, conveyors once sold as large customized systems can now be sold in standard ten-foot sections. This allows for reduced OEM engineering, quicker delivery times and increased flexibility for the end user.





The migration to the On-Machine approach, like most industrial innovations, will be driven by economics as companies continue to refine their understanding of true assembly and installation costs. OEMs and end users will see different cost advantages depending on their particular industry and equipment environment.

The ability of these solutions to reduce wiring and system costs, improve Mean Time to Repair (MTTR), enhance control system reliability, increase productivity and promote flexibility will make On-Machine solutions a common strategy for reducing costs and increasing reliability of both OEM and end user control systems.

Choosing the Best Cabling Option for Your Application

With the variety of cabling options available, it is crucial to determine which On-Machine solution best suits the application based on several considerations. Use the process outlined below as a guideline to selecting the best On-Machine solution for your needs.

1. **Number, Location and Concentration of Field Devices**. If there are only a few devices, a simple hard wired solution may be the simplest and most cost-effective solution. However, in the case of machines with relatively high device counts, a connector-based solution could prove to be the easiest to apply and troubleshoot. Those applications with high I/O counts and devices concentrated in key areas may best benefit from the same connectorized solution, but with local hardened I/O blocks. And ultimately, for installations with many devices distributed over distances, a network approach may prove most suitable.
2. **Environment**. What is the environment your field devices—and therefore the cabling system—will be exposed to? Applications where washdowns or corrosive materials are common will require all devices and the associated cabling to be IP67-rated or have stainless steel hardware, respectively. On the other hand, for machines installed in relatively clean, less severe environments, open-style connectors and terminal blocks may be appropriate. If temperature extremes are an issue, the need for high- or low-temperature control components may dictate the selection of a wiring solution.
3. **Machine Sections and Their Locations**. Large machines built in sections and disassembled for shipment only to be reassembled on site generally need modular wiring solutions. Plug-and-play wiring systems allow for the simplest commissioning/recommissioning of the control system on the plant floor, with minimal marshalling and wiring errors.
4. **Standard vs. Networked Solutions**. While standard wiring solutions can just satisfy about every need and address the bulk of industrial control applications, there are instances where system feedback and enhanced diagnostics are a must. In these cases, networks such as ControlNet and DeviceNet, which both have their own topographies and media types, must be considered.
5. **Safety vs. Nonsafety Installations**. When installing a machine safety system, there are special wiring practices and configurations that must be employed. The Allen-Bradley Safety Connection System is a connector-based system designed specifically for safety applications.
6. **Special Considerations**. Upon choosing the best On-Machine wiring scheme, it is important to take other characteristics into account for the cabling components. Component selection and installation may be impacted by the need for hi-flex cable in motion applications, device connection options, routing paths and available space, among other factors.

On-Machine System Layouts

Standard Wiring

Traditional Hardwiring Methods

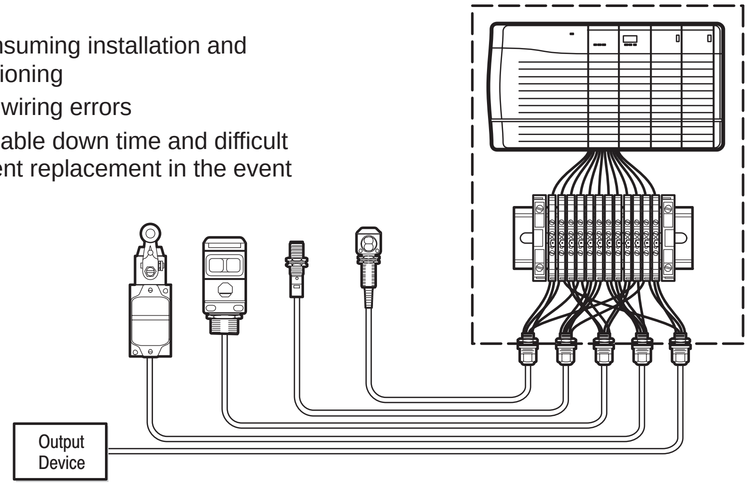
A hardwired system consists of fixed wiring from the devices routed through a cable gland and into terminal connections within the cabinet. At the device, connections may be via terminals as well; in the event of devices with built-in connectors, field attachable connectors may be employed.

Benefits

- A simple solution—requires few parts
- Since no cable lengths are specified, requires little pre-engineering
- A good solution for small machines and/or low device counts

Limitations

- Time-consuming installation and commissioning
- Prone to wiring errors
- Considerable down time and difficult component replacement in the event of failure



Introduction of Quick-Disconnect Cabling at Field Device

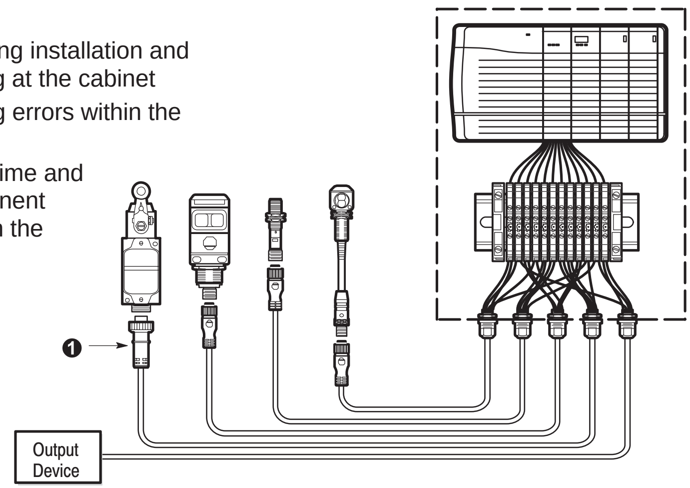
This system is characterized by fixed wiring from terminal blocks through a cable gland at the cabinet, out to connector-based field devices.

Benefits

- A simple solution—requires few parts
- Limited specification of cable lengths, requires some pre-engineering
- Devices can be placed and mounted prior to wiring installation

Limitations

- Time-consuming installation and commissioning at the cabinet
- Prone to wiring errors within the cabinet
- Longer down time and difficult component replacement in the event of cable failure



Introduction of Quick-Disconnect Cabling at Both Ends

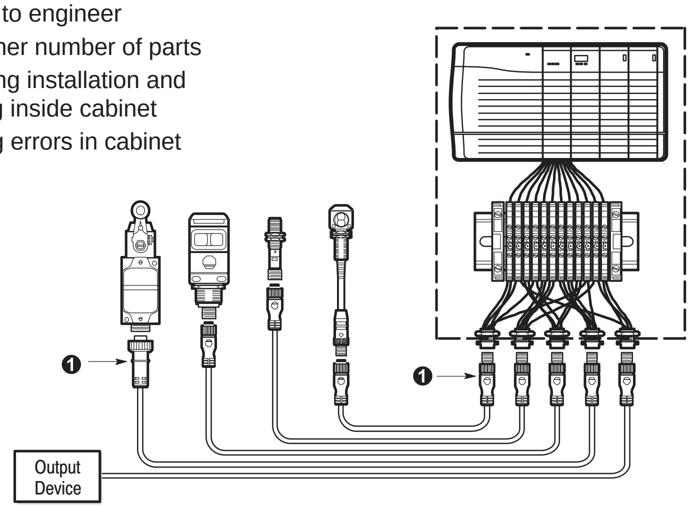
In this case, connector-based devices are interfaced with the panel via a quick-connect receptacle. Inside the panel, however, the receptacle is hardwired to terminal connections.

Benefits

- Easy replacement and reduced down time in event of field device or cable failure
- Highly modular design
- Eliminates wiring errors outside cabinet
- Less time for installation and commissioning outside cabinet

Limitations

- More complex to engineer
- Potentially higher number of parts
- Time consuming installation and commissioning inside cabinet
- Prone to wiring errors in cabinet



❶ Quick-disconnect connector

Wiring Consolidation Using Passive Distribution Boxes

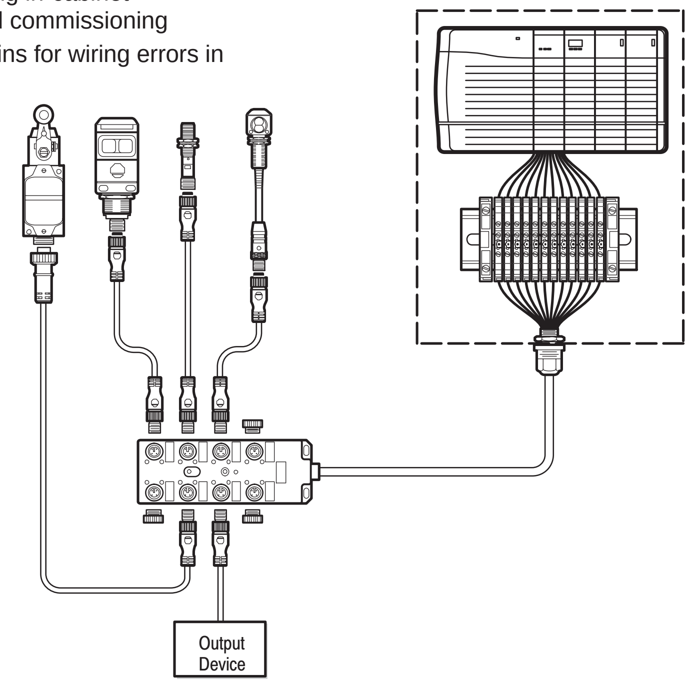
Here, the field devices are interfaced with a distribution box. All connections between the devices and the box are of the quick-connect type. The distribution box is then routed through a cable gland at the cabinet and hard wired into terminals.

Benefits

- Simplifies, neatens and consolidates field device wiring
- Minimal time to repair (MTTR) in event of field device failure
- Eliminates wiring errors outside cabinet
- Reduced installation and commissioning time outside cabinet
- More modular approach, allows replacement of shorter runs upon cable failure

Limitations

- More complex to engineer
- Potentially higher number of parts
- Time consuming in-cabinet installation and commissioning
- Potential remains for wiring errors in cabinet



Wiring Consolidation With Modular Components Outside Panel:

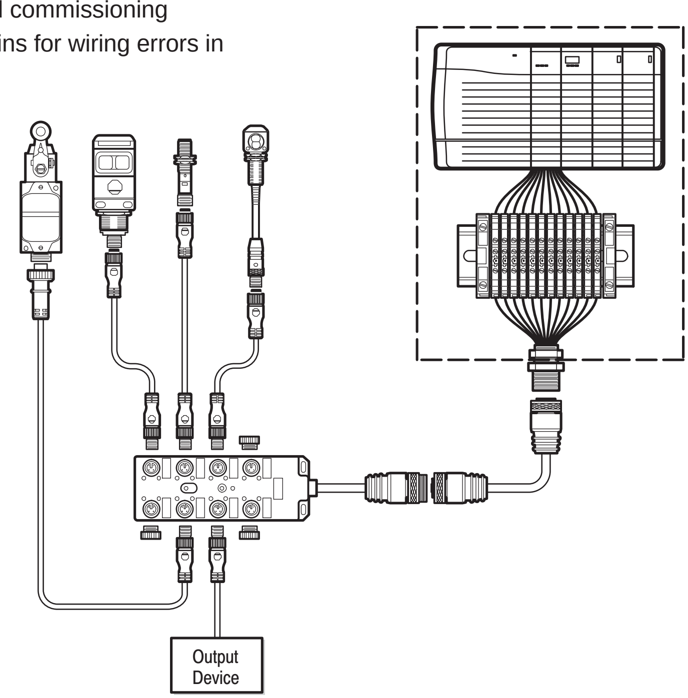
This system is almost identical to the previous example, but with a quick–connect cable between the distribution box and cabinet. The cabinet receptacle is then hard wired to terminals on the panel.

Benefits

- Simplifies, neatens and consolidates field device wiring
- Minimal time to repair (MTTR) in event of field device or cable failure
- Eliminates wiring errors outside cabinet
- Reduced installation and commissioning time outside cabinet
- Even more modular—facilitates replacement of shorter runs upon cable failure, simplifies swap out of failed distribution boxes or main cable

Limitations

- More complex to engineer
- Potentially higher number of parts
- Time consuming in-cabinet installation and commissioning
- Potential remains for wiring errors in cabinet



On-Machine System Layouts

PanelConnect Wiring

Wiring Consolidation Using Modular Components from PLC to Field Device

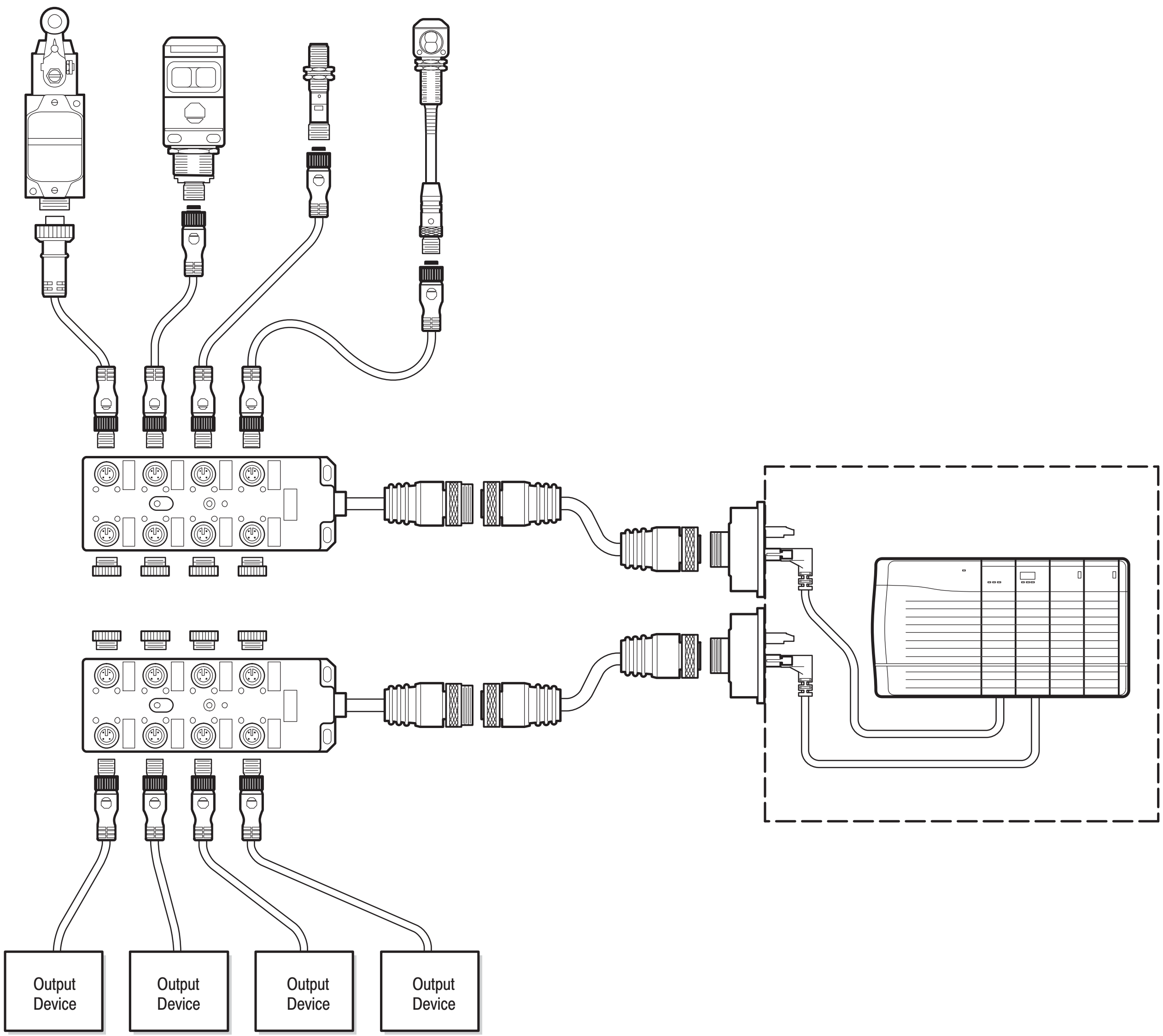
This wiring scheme is essentially the same as the previous two examples involving distribution boxes. But now the cabinet receptacle has been replaced with a PanelConnect module which allows for plug-in connectivity between the module itself and an I/O card on the panel.

Benefits

- Simplifies, neatens and consolidates wiring to field devices and in cabinet
- Minimal time to repair (MTTR) in event of field device or cable failure
- Eliminates wiring errors inside and outside cabinet
- Minimal installation and commissioning time
- Maximum modularity, which allows for quick and easy replacement of components

Limitations

- More complex to engineer
- Potentially higher number of parts
- A single PanelConnect module cannot address a combination of inputs and outputs from a single distribution box—such a case would require multiple PanelConnects (one for inputs, another for outputs)



Wiring Consolidation Using Modular Components from PLC to Field Device

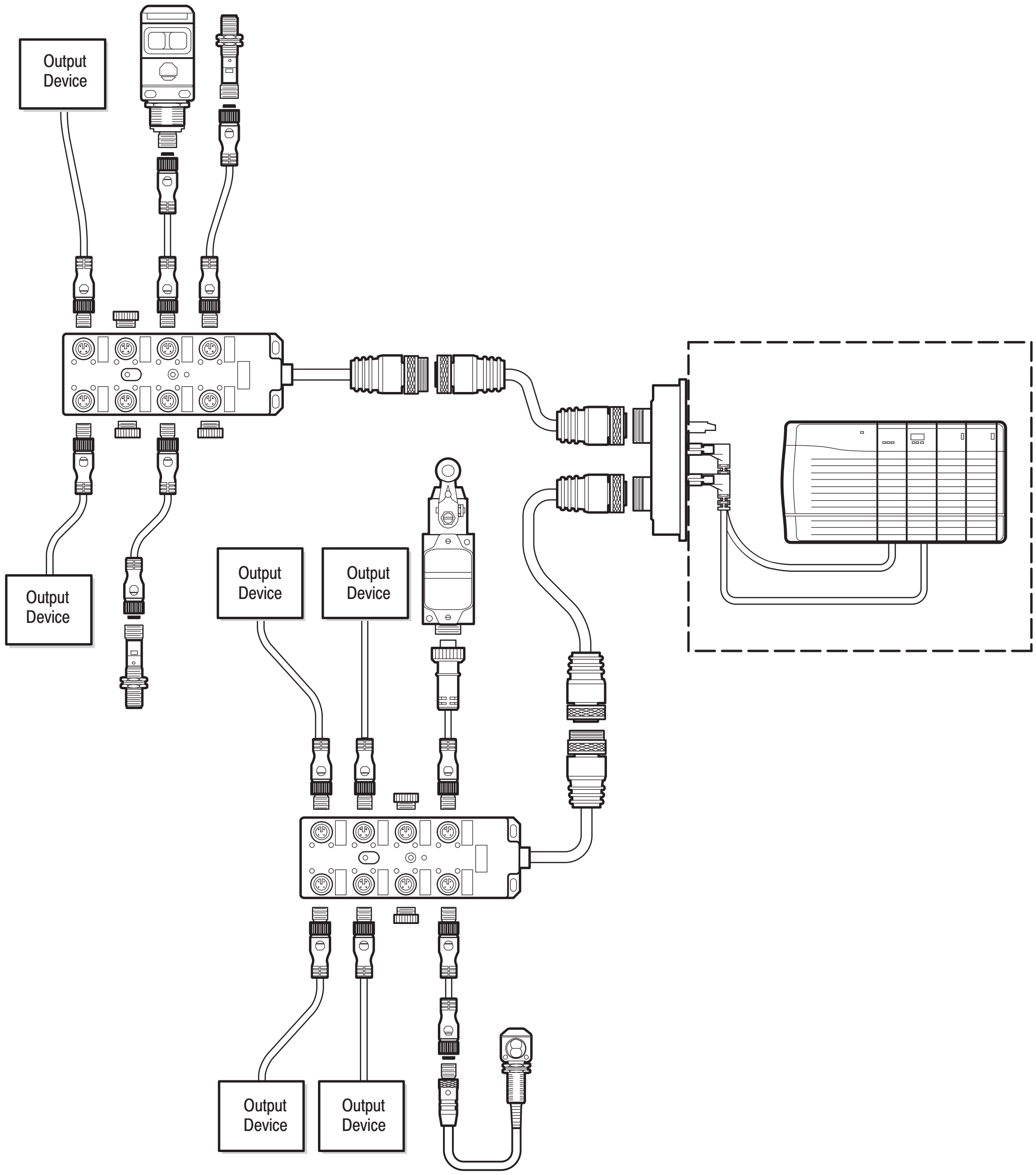
This illustration shows the same application as above, but with a Combination PanelConnect Module which allows for a mixture of inputs and outputs from a distribution box to be interfaced to a single module. Again, the same plug-in connections between the PanelConnect and I/O card apply.

Benefits

- Simplifies, neatens and consolidates wiring to field devices and in cabinet
- Minimal time to repair (MTTR) in event of field device or cable failure
- Eliminates wiring errors inside and outside cabinet
- Minimal installation and commissioning time
- Maximum modularity, which allows for quick and easy replacement of components
- Allows mixed inputs and outputs from a single distribution box to be interfaced through a single combination PanelConnect module.

Limitations

- More complex to engineer
- Potentially higher number of parts



On-Machine System Layouts

Safety Wiring

Safety Connection Systems

Allen-Bradley Guardmaster Safety Connection Systems are complete wiring solutions dedicated to machine safety. These quick-disconnect based systems are specifically intended for use with dry-contact safety switches, and offer flexible and reliable connections between safety interlocks, E-stops, cable pull switches and safety relays.

Safety Connection Systems layouts are available with or without enunciation capabilities, allowing the user the option of direct feedback for the status of individual switches in the system.

Enunciation systems utilize an auxiliary contact as input to tower lights, audible alarms, PLC input cards, etc.

Systems without Enunciation

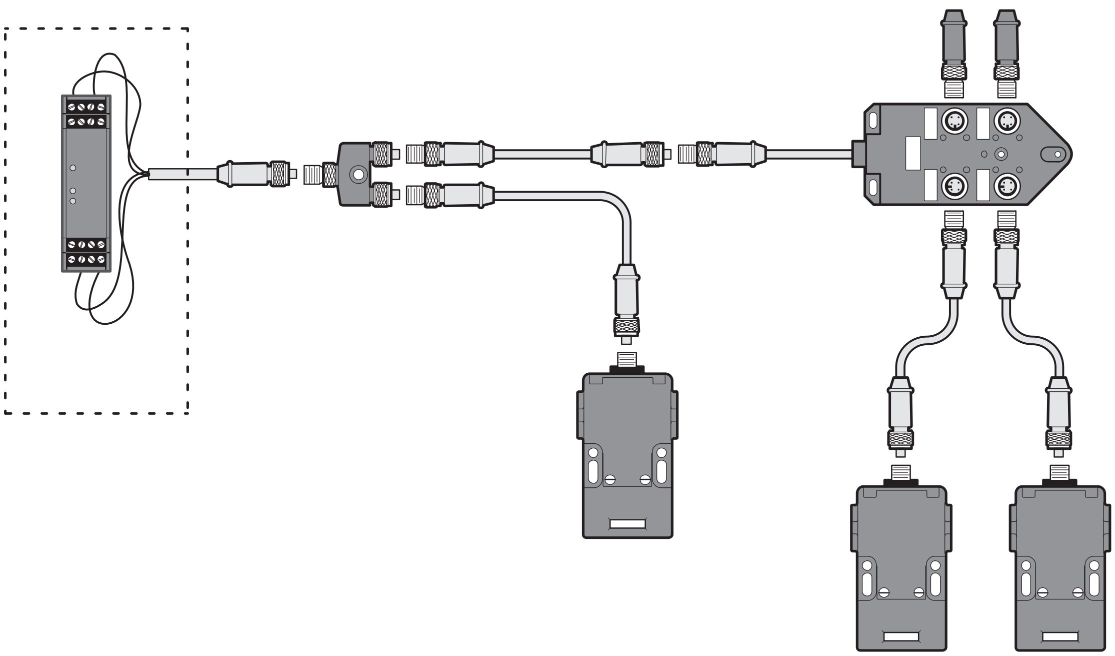
As illustrated below, wiring systems for applications not requiring enunciation use a combination of patchcords, shorting plugs, safety wired distribution boxes and T-ports for series wiring of safety circuits. Distribution boxes for such an application are dual channel models with 2 NC or 1 NC + 1 NO contact configurations. Note that shorting plugs must be used on all unused ports for the system to operate.

Benefits

- Reduced installation cost and easy system expansion
- Simplified troubleshooting
- Modularity
- Provide for Safety PLC input expansion
- Support systems up to Category 3 (per EN954–1)

Limitations

- Suitable for dry-contact switches only—no light curtains, safety mats or pressure sensitive safety edges
- No feedback from individual switches



Systems with Enunciation

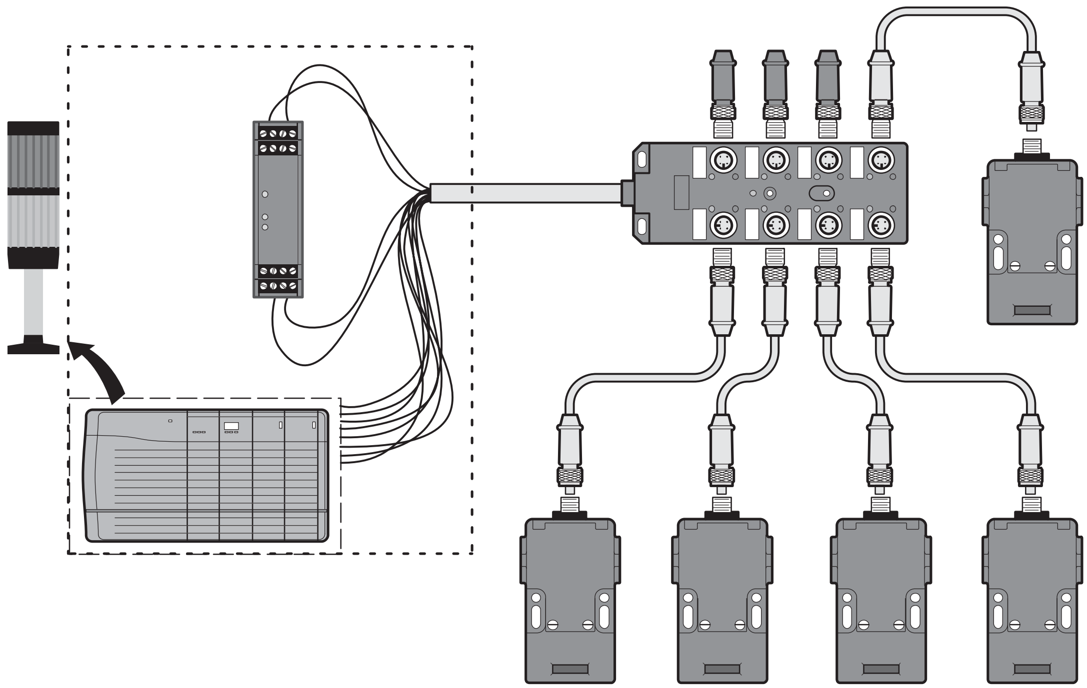
As shown in the illustration below, system layouts with enunciation require patchcords, shorting plugs and distribution boxes, which allow for series wiring of the safety circuits while providing a separate circuit for enunciation. Distribution boxes are offered for these applications in several contact configurations: dual channel with 2 NC, dual channel with 1 NC + 1 NO or single channel with 1 NC. Each type also provides a NO auxiliary contact that is interfaced with the enunciation device to provide visual or audible alarm indication. In addition, LEDs on the distribution boxes assist in the troubleshooting of this system. Again, note that shorting plugs must be used on all unused ports for the system to operate.

Benefits

- Reduced installation cost and easy system expansion
- Simplified troubleshooting and replacement of components
- Modularity
- Feedback from individual switches
- Support systems up to Category 3 (per EN954–1)

Limitations

- Suitable for dry-contact switches only—no light curtains, safety mats or pressure sensitive safety edges



On-Machine System Layouts

Network Wiring for DeviceNet™

Device Networks

DeviceNet™ is an open communication network designed to connect factory floor devices such as photoelectric sensors, inductive proximity sensors, motor starters, drives, valve manifolds, and simple operator interfaces together without interfacing through an I/O system. It increases the amount and rate of information flowing from plant floor devices to control systems, and has the potential to substantially reduce wiring costs.

The DeviceNet network consists of a cabling system that provides both power and communication to nodes. Like the previous examples, the options range from fully hard wired networks to completely connector- based systems. Below are examples designed to showcase the various media types, their features and limitations—each, in reality, is capable of supporting the same types of connections as their non-network counterparts.

DeviceNet™ Flat Media Systems

KwikLink™ General Purpose Media

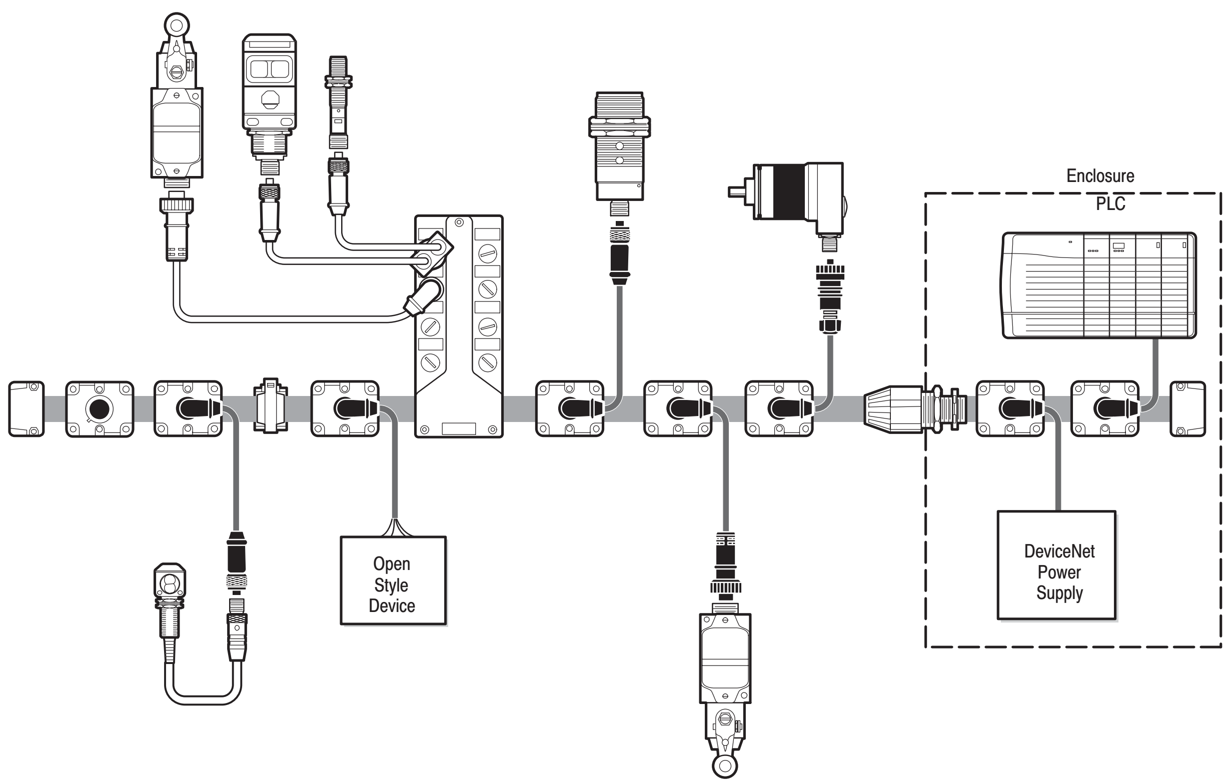
Utilizing the same flat cable design pioneered by Rockwell Automation with the introduction of the original KwikLink system, KwikLink General Purpose connectors combine the flexibility and simplicity of their predecessor in a low profile, OEM-friendly package.

Benefits

- Optimal plug-and-play capability offers drastic reduction in labor, materials and installation costs
- Devices can be added anywhere along the trunk—no need for predetermined cable lengths
- Modular, snap-on connectors eliminate cutting and stripping of cables
- Wide range of components, cable types and accessories provides optimal system flexibility
- Keyed cable and snap-on connectors prevent wiring errors
- Ideal solution for less demanding industrial applications
- Class 2 cable—even more flexible than previous flat cable—makes cable routing even easier

Limitations

- Maximum trunk line distance of 420m (1378ft)
- Single-use connectors cannot be moved or removed once applied



DeviceNet Flat Media Systems

KwikLink™ Heavy Duty Media

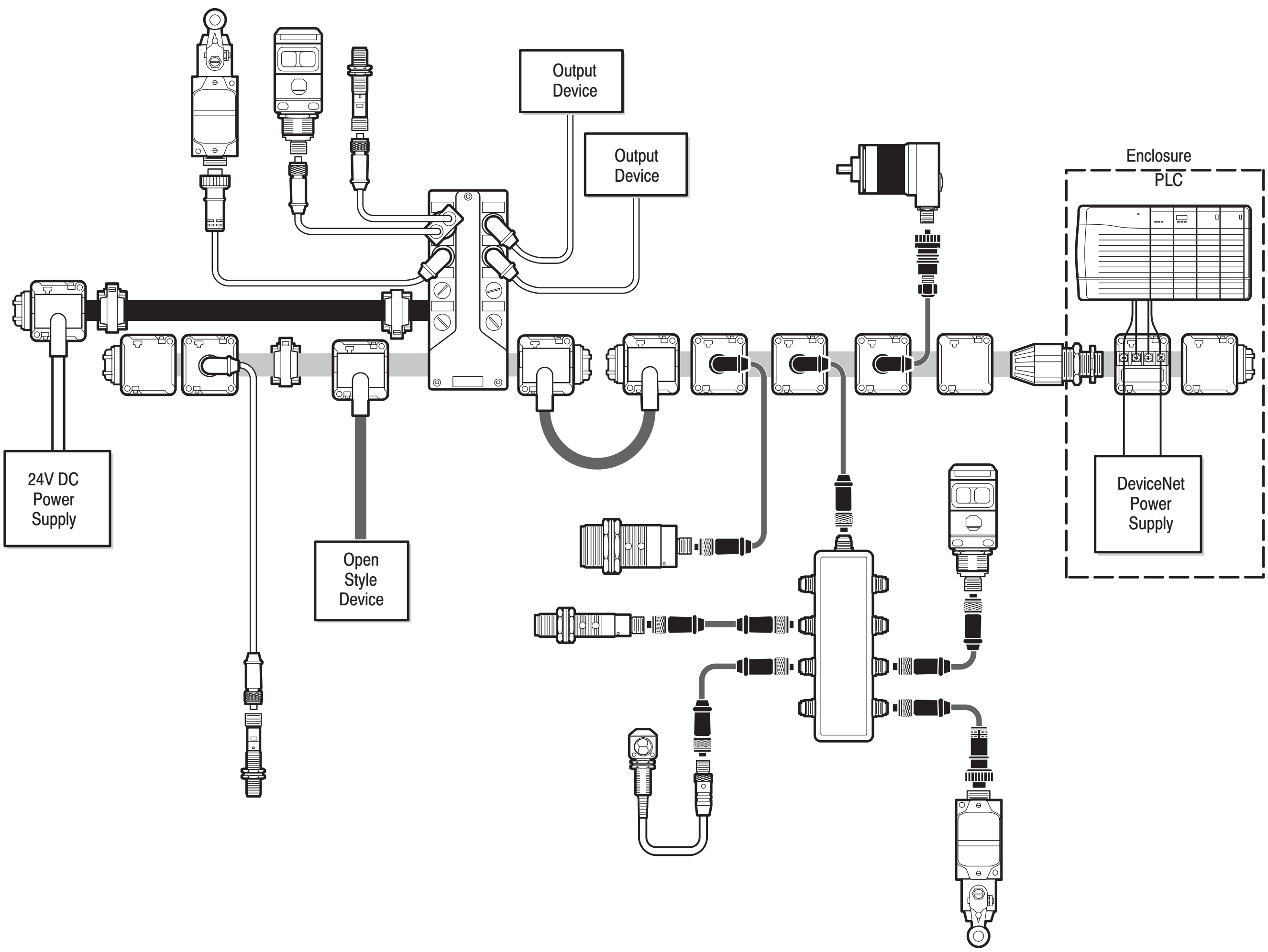
The KwikLink physical media system consists of flat trunk cable and snap-on modular connectors which can be placed anywhere along the trunk. Devices are then interfaced with the trunk via special patchcords, distribution boxes and I/O blocks.

Benefits

- Optimal plug-and-play capability offers drastic reduction in labor, materials and installation costs
- Devices can be added anywhere along the trunk—no need for predetermined cable lengths
- Modular, snap-on connectors eliminate cutting and stripping of cables
- Wide range of components, cable types and accessories provides optimal system flexibility
- Keyed cable and snap-on connectors prevent wiring errors
- Heavy duty connectors and cable allow for use in harsh environments

Limitations

- Maximum trunk line distance of 420m (1378ft)
- Single-use connectors cannot be moved or removed once applied



On-Machine System Layouts

Network Wiring for DeviceNet™

DeviceNet Round Media Solutions

Thick Trunk

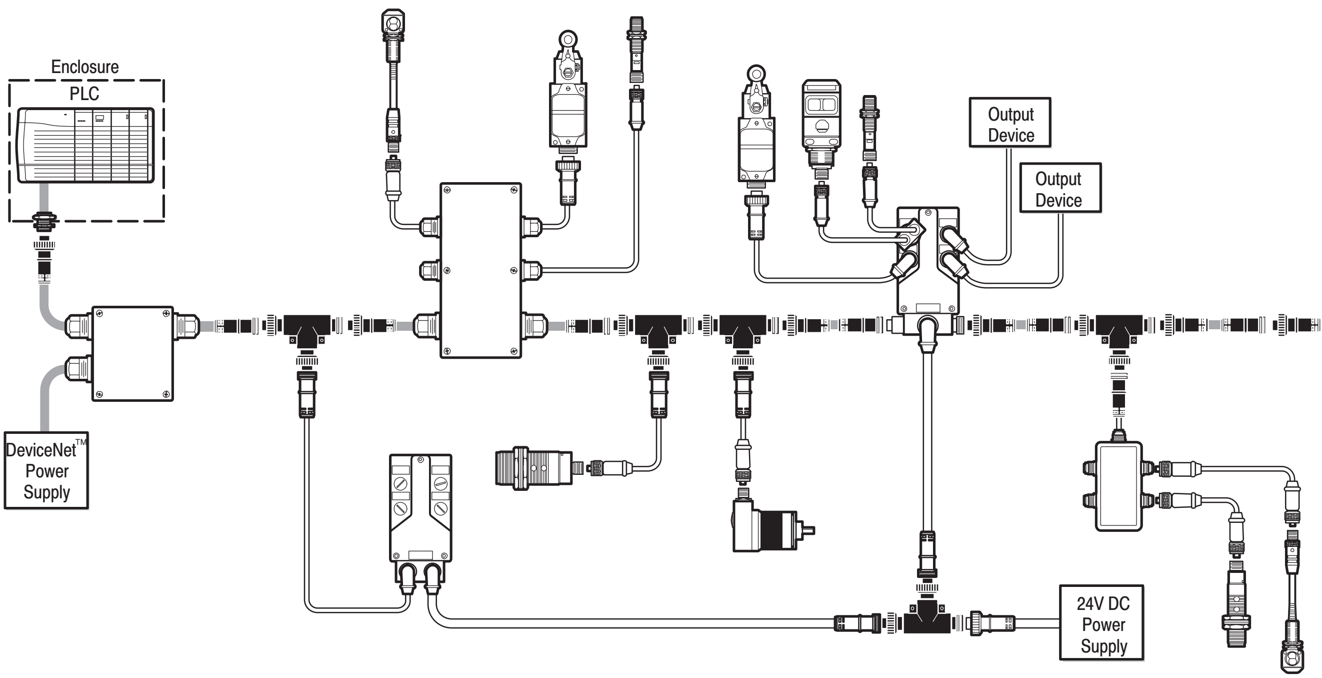
This round media thick trunk system is based on the use of “thick cable” for DeviceNet. Allen-Bradley thick trunk cable allows maximum trunk line distance and is the original DeviceNet system configuration. A full range of rugged, durable Allen-Bradley DeviceNet components are available for use in thick trunk systems. Although typically used as trunkline only, thick cable can also be used for drops to field devices.

Benefits

- Allows for greatest trunkline distance: 500m (1640ft)
- Simplified troubleshooting and replacement of components
- Reduced installation cost and easy system expansion
- PVC cable jacket offers good oil and chemical resistance
- Shielded cable provides optimal resistance to noise

Limitations

- More rigid cable than flat and thin cable counterparts
- Shielded cable makes cutting and stripping of cable time consuming in hardwired networks



DeviceNet Round Media Solutions

Thin Trunk

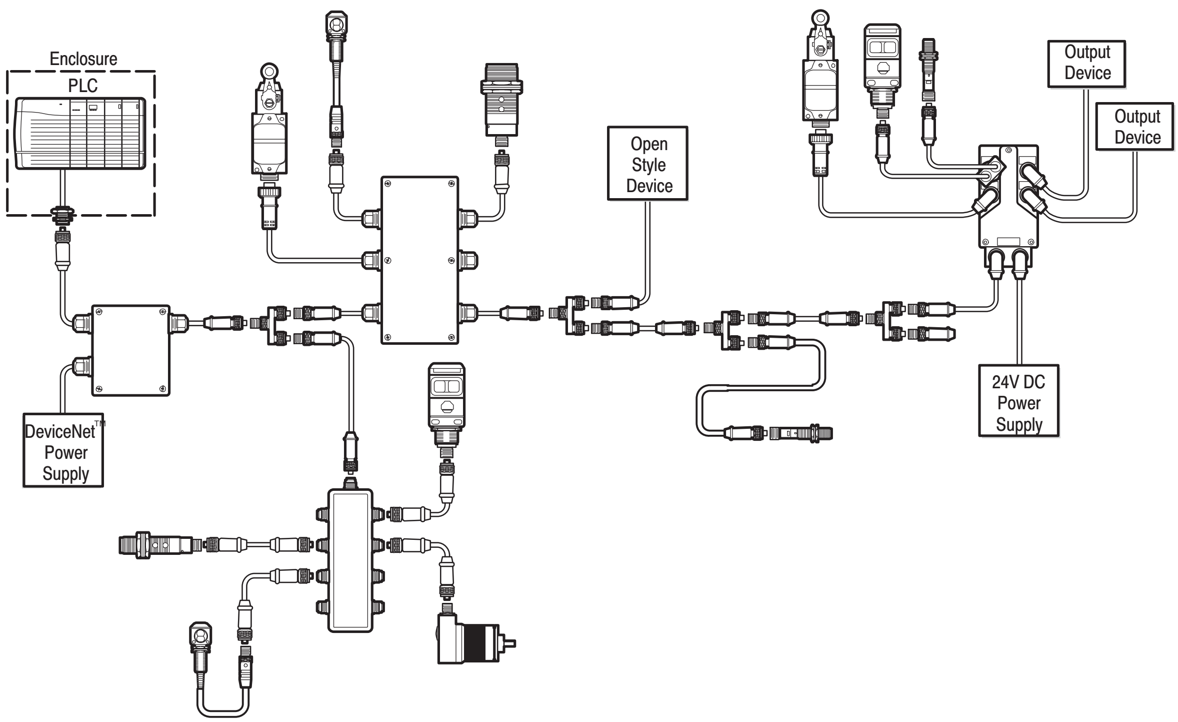
The following round media thin trunk system is based on the use of “thin cable” for DeviceNet. Here, the thin cable typically used for drops to field devices is used as the main trunkline as well. The use of thin cable reduces maximum trunk line distances but allows for a more compact and cost effective installation for some applications. And like the thick trunk system, a wide variety of rugged, durable Allen-Bradley DeviceNet components are also available for use in thin trunk systems.

Benefits

- Simplified troubleshooting and replacement of components
- Reduced installation cost and easy system expansion
- Allows for a more compact DeviceNet installation
- TPE cable jacket offers additional chemical resistance for harsh applications
- Shielded cable provides optimal resistance to noise

Limitations

- At 100m (328ft), offers the shortest maximum trunkline length
- Shielded cable makes cutting and stripping of cable time consuming in hardwired networks



Control Networks

The ControlNet network is an open, state-of-the-art control network that meets the demands of real-time, high-throughput applications. ControlNet uses the proven Common Industrial Protocol (CIP) to combine the functionality of an I/O network and a peer-to-peer network providing high-speed performance for both functions.

The ControlNet network provides deterministic, repeatable transfers of all mission-critical control data in addition to supporting transfers of non-time-critical data. I/O updates and controller-to-controller interlocking always take precedence over program uploads and downloads and messaging.

ControlNet IP67 Media

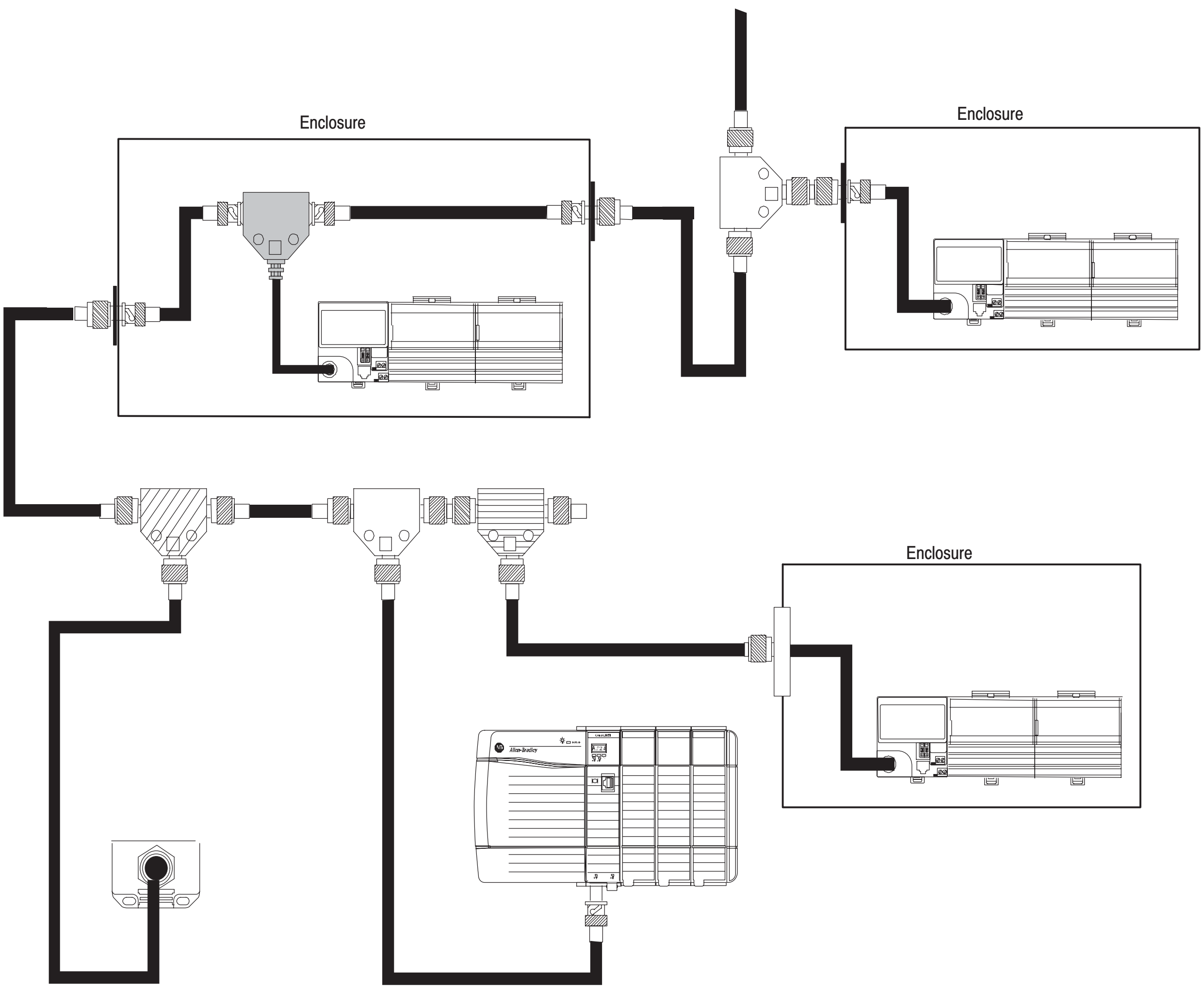
Rockwell Automation offers a variety of ControlNet media options; the decision on which media type to use is based on the environmental factors associated with your application and installation site. A typical ControlNet network consists of one or more of the following: trunk cables, taps, repeaters, terminators, and bridges. The ControlNet IP67 media system offers a modular, rugged version of taps and connectors for high vibration or IP67 type environments.

Benefits

- Variety of media options for a wide range of application needs, including fiber or coaxial media types.
- Threaded connection media type resists vibration and fluid ingress, allowing ControlNet architectures to be implemented in aggressive environments.
- Redundant media option increases network uptime.
- Passive media maximizes reliability and minimizes media failures when compared to active media components.
- High flex cable option is well suited for applications involving constant stress attributed to robotic motion and frequent connection/ disconnection.

Limitations

- Field attachable connectors rely on installation technique for both electrical and mechanical integrity.
- Thread-on connectors require additional time to install versus quarter turn bayonet versions.

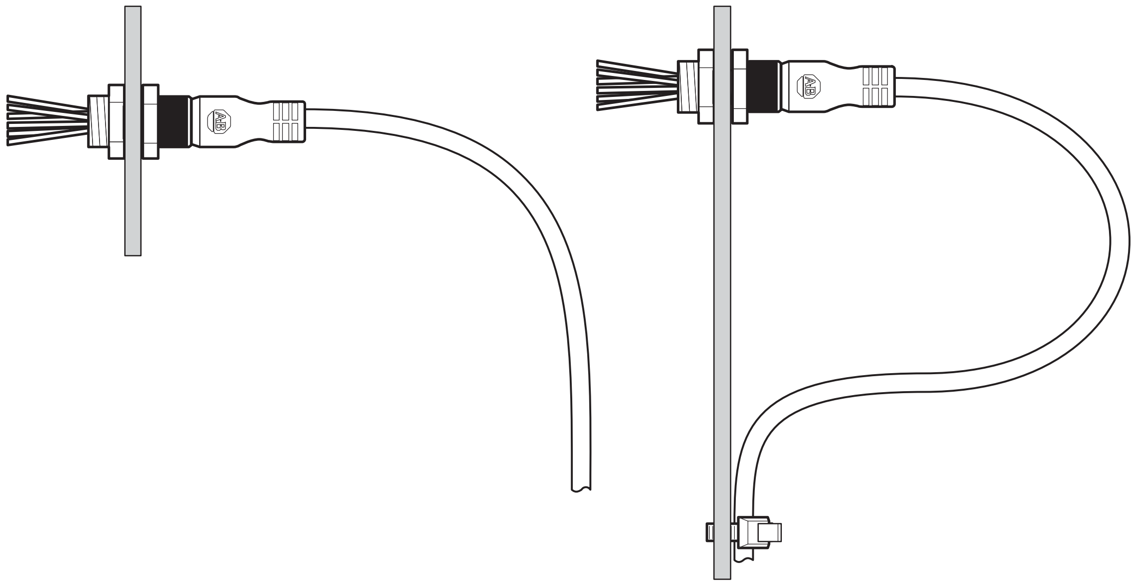


Cable Application—Best Practices

The following are examples of common wiring problems and best practices that will help prevent them. Taking these suggestions into consideration can help ensure reliable operation, extend the system life cycle and ultimately reduce costs attributed to downtime and repeated cable replacement.

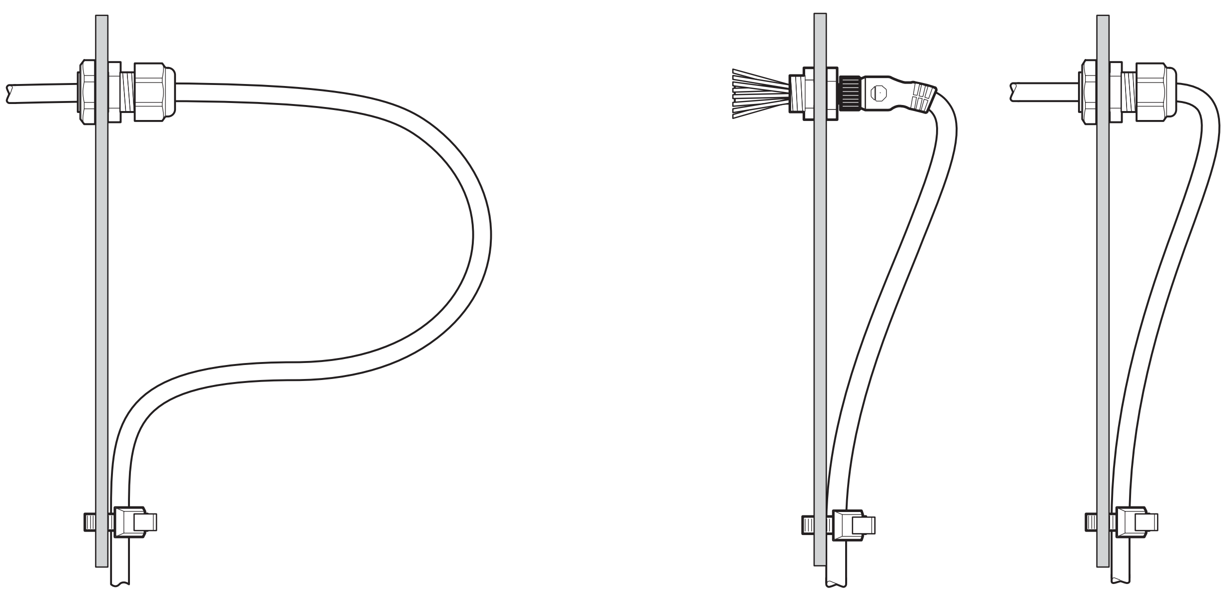
Bend Radius—Fixed and Moving Applications

Allowing for adequate bend radius is pivotal in increasing the life of the cable. When sufficient bend radius is provided, the cable can more effectively absorb the energy of the bend over a greater portion of the overall cable length.



Stress Relief—Cable Gland and Connectors

Ample stress relief at connections is another key to extended cable life. Building a sufficient stress loop into your cable installations can prevent undue stress on the cable at or close to the connector. Built-in overmolded stress relief such as that found on Rockwell Automation patchcords and cordsets offers additional protection from failures at the connector.

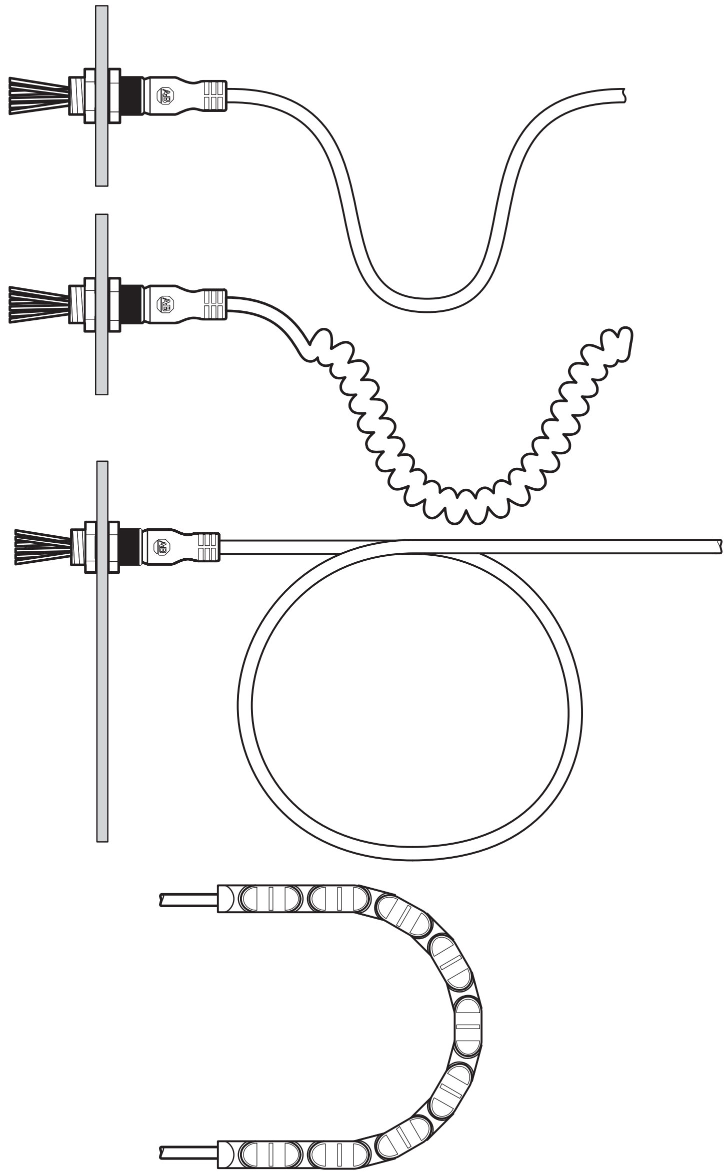


Correct

Incorrect

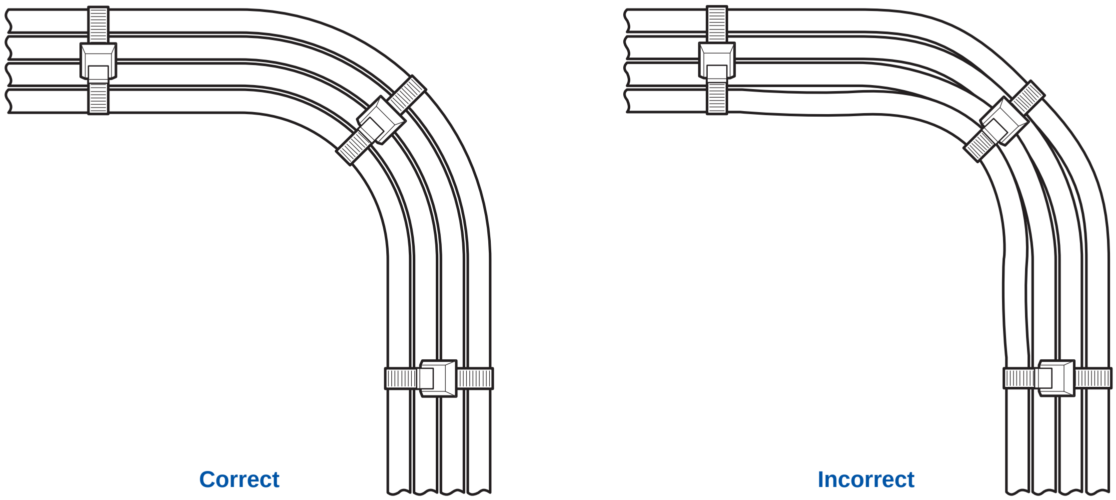
Motion Applications

When one or both of the connections are in motion, extra cable length should be designed into the system to prevent stress on the cable and connectors. In this instance, cable loops (open or closed), coiled cables or C-tracks are the best solution.



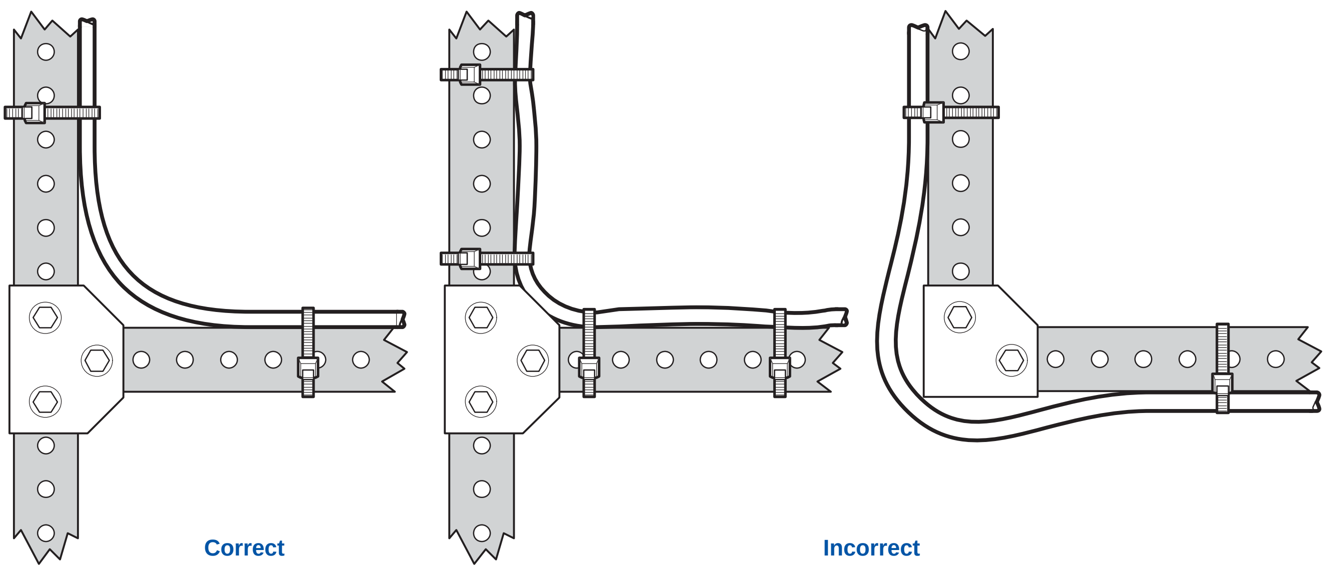
Bundling and Cable Ties

When applying cable ties to any installation, care should be taken so the ties do not pinch or compress the cable(s) in any way. Correct use of cable ties permits movement without placing undue stress on the cable(s); appropriate bundling technique should allow for relatively free movement of the cables within in the bundle.



Cornering

For cables run along corners, tie-downs should be applied in such a way as to prevent extra stress on the cable. Avoid the use of outside cornering as the corner itself is a potential pinch point.



Application Considerations

NEMA Enclosures

Enclosure Selection Criteria

Enclosures for Nonhazardous Locations

For a Degree of Protection Against:	Designed to Meet Tests No. ❶	Type: For Indoor Use 1	12	13	Outdoor Use 3R	3	Indoor or Outdoor 4	4X	6P
Incidental contact with enclosed equipment	6.2	✓	✓	✓	✓	✓	✓	✓	✓
Falling dirt	6.2	✓	✓	✓	✓	✓	✓	✓	✓
Rust	6.8	✓	✓	✓	✓	✓	✓	✓	✓
Circulating dust, lint, fibers and flyings ❷	6.5.1.2 (2)		✓	✓		✓	✓	✓	✓
Windblown dust	6.5.1.1 (2)					✓	✓	✓	✓
Falling liquids and light splashing	6.3.2.2		✓	✓		✓	✓	✓	✓
Rain (Test evaluated per 6.4.2.1)	6.4.2.1				✓	✓	✓	✓	✓
Rain (Test evaluated per 6.4.2.2)	6.4.2.2					✓	✓	✓	✓
Snow and sleet	6.6.2.2				✓	✓	✓	✓	✓
Hosedown and splashing water	6.7						✓	✓	✓
Occasional prolonged submersion	6.11 (2)								✓
Oil and coolant	6.3.2.2		✓	✓					
Oil or coolant spraying and splashing	6.12			✓					
Corrosive agents	6.9				✓	✓		✓	✓

❶ See below for abridged description of NEMA enclosure test requirements. Refer to NEMA Standards Publication No. 250 for complete test specifications.
❷ Nonhazardous materials, not Class III ignitable or combustible.

Selection Criteria

Enclosures for Hazardous Locations (Division 1 or 2) ❸

For A Degree of Protection Against Atmospheres Typically Containing: ❺	Designed to Meet Tests: ❹	Class (National Electrical Code)	Type: 7, Class I Group: A	B	C	D	9, Class II Group: E	F	G
Acetylene	Explosion Test Hydrostatic Test Temperature Test	I	✓						
Hydrogen, Manufactured Gas		I	✓	✓					
Diethyl Ether, Ethylene, Hydrogen Sulfide		I			✓				
Acetone, Butane, Gasoline, Propane, Toluene		I			✓	✓			
Metal dusts and other combustible dusts with resistivity of less than 10^5 ohm-cm.	Dust Penetration Test Temperature Test with Dust Blanket	II					✓		
Carbon black, charcoal, coal or coke dusts with resistivity between $10^2 - 10^8$ ohm-cm.		II						✓	
Combustible dusts with resistivity of 10^5 ohm-cm or greater.		II							✓
Fibers, flyings	❻	III							✓

❸ For indoor locations only unless cataloged with additional NEMA Type enclosure number(s) suitable for outdoor use as shown in table on page 2–19. Some control devices (if so listed in the catalog) are suitable for **Division 2** hazardous location use in enclosures for non-hazardous locations. For explanation of CLASSES, DIVISIONS and GROUPS, refer to the National Electrical Code.
Note: Classifications of hazardous locations are subject to the approval of the authority having jurisdiction. Refer to the National Electrical Code.
❹ See abridged description of test requirements below. For complete requirements, refer to UL Standard 698, compliance with which is required by NEMA enclosure standards.
❺ For listing of additional materials and information noting the properties of liquids, gases and solids, refer to NFPA 497M-1991, Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations.
❻ UL 698 does not include test requirements for Class III. Products that meet Class II, Group G requirements are acceptable for Class III.

IEC Enclosure Classification

The degree of protection is indicated by two letters (IP) and two numerals. International Standard IEC 529 contains descriptions and associated test requirements that define the degree of protection each numeral specifies. The following table indicates the *general* degree of protection—refer to Abridged Descriptions of IEC Enclosure Test Requirements below. **For complete test requirements refer to IEC 529.**

FIRST NUMERAL ❶		SECOND NUMERAL ❶	
Protection of persons against access to hazardous parts and protection against penetration of solid foreign objects.		Protection against ingress of water under test conditions specified in IEC 529.	
0	Nonprotected	**0**	Nonprotected
1	Back of hand; objects greater than 50mm in diameter	**2**	Vertically falling drops of water
3	Finger; objects greater than 12.5mm in diameter	**4**	Vertically falling drops of water with enclosure tilted 15°
5	Tools or objects greater than 2.5mm in diameter	**6**	Spraying water
7	Tools or objects greater than 1.0mm in diameter	**8**	Splashing water
9	Dust-protected (dust may enter during specified test but must not interfere with operation of the equipment or impair safety)	**10**	Water jets
11	Dusttight (no dust observable inside enclosure at end of test)	**12**	Powerful water jets
		13	Temporary submersion
		14	Continuous submersion
Example: IP**41** describes an enclosure that is designed to protect against the entry of tools or objects greater than 1mm in diameter and to protect against vertically dripping water under specified test conditions.			
Note: All first numerals and second numerals up to and including characteristic numeral **6**, imply compliance also with the requirements for all lower characteristic numerals in their respective series (first or second). Second numerals **7** and **8** do **not** imply suitability for exposure to water jets (second characteristic numeral **5** or **6**) unless dual coded; e.g., **IP_5/IP_7**.			

❶ The IEC standard permits use of certain supplementary letters with the characteristic numerals. If such letters are used, refer to IEC 529 for the explanation.