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Specifying Cable Infrastructure in Hazardous Locations per NEC Standards

WHITE PAPER

Introduction

Hazardous locations are common in industrial facilities and selecting the proper cable infrastructure for an environment can be a challenge. These hazardous locations contain explosive liquids, gases or dusts which can be harmful and life threatening. Fortunately, there are years of expertise collected, reviewed, and published that provide guidance on how to avoid issues associated with the hazard. The most common electrical standard in the United States is the National Fire Protection Agency 70 also known as the National Electrical code. NFPA70-NEC uses a "Class, Division" system to rate the type of hazard and the severity. In other parts of the world, ATEX and IEC are used – see table 1, and hazardous locations are dealt with using a "Zone System". Depending on the geographical location of the equipment where the hazardous location exists, different standards and regulations may apply. These standards and regulations dictate what type of cable to use and how it shall be installed. Despite having several different standards globally, the criteria are similar from one to the next. However, when it comes to enforcement, only the standard approved for the geographical area may be utilized.

The information provided in this paper is an interpretation of the NEC and how it applies to cable types in a hazardous location. Deploying the proper cable infrastructure can be accomplished by following these three steps:

1) Determine the classification of the hazardous area

2) Review the wiring types allowed in that hazardous location and select the proper cable

3) Install the cable per the requirements of the hazardous location

While these three steps sound simple, interpretations of the regulations can present some ambiguity. All the details play an important role in a hazardous location installation. Choosing the appropriate cable must include the details of the installation and using the appropriate fittings and seals. Planning the design ahead of time, consulting with field experts, and maintaining good communication with inspectors are critical components to be successful.

Agency	Description	Symbols
NFPA 70 - NEC	The National Electrical Code (NEC) is published by the National Fire Protection Agency (NFPA) as a regional standard for the safe and secure installation of electrical equipment and electrical wiring in the United States.	
ATEX	Derived from the word 'ATmosphere EXplosibles' and is a mandatory certification for all products sold across Europe. ATEX consists of two EU directives describing what equipment and workspace is allowed in an environment with explosive atmosphere.	
IECEx	International Electrotechnical Commission for Explosive Atmospheres is a standard for hazardous locations monitored by the IEC. Common set of safety standards for participating countries; majority of Europe, Canada, Australia, Russia, China, US, and South Africa.	

Table 1: Common Agencies for Hazardous Locations

Hazardous Environment Basics

The most effective way of preventing electrical wiring from becoming an ignition source is to locate the equipment and wiring outside the hazardous area. However, this is not always possible and therefore precautions can minimize the risk. To create an explosion, three things need to be present: fuel, oxygen, and an ignition source. The "Combustion" or "Fire" triangle is commonly used to illustrate these three essential components, see figure 1. When determining the risk level of a hazardous location the elements of the triangle are utilized.

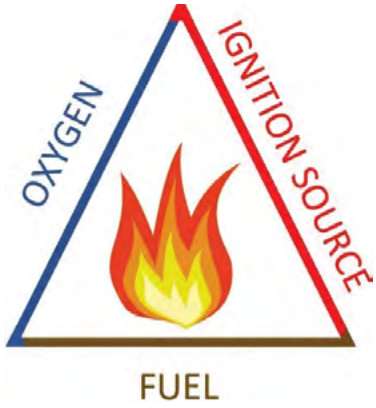


Figure 1: Fire or Combustion Triangle

According to the NEC, there are two types of locations; classified (hazardous) and unclassified. The NEC requires facilities to maintain proper documentation of classified locations. These classified locations have different levels of risk. When it comes to engineering, the design must meet the criteria of the classified location. Basically, there are three techniques to avoid a fire or explosion: containment (explosion proof enclosures and fittings), segregation (purge and pressurization of enclosures), and prevention (intrinsically safe and nonincendive circuit designs).

Introduction to the National Electrical Code (NEC)

The NFPA publishes an updated version of the National Electrical Code every 3 years, a publication cadence known in industry as the "code cycle." In addition to the NEC codebook, there is a handbook version of the Code that provides annotations and examples to help interpret meaning. The NEC was first published in 1897 and is approved as an American national standard by American National Standards Institute (ANSI). The NEC is not intended to address system performance unless the performance of a system could compromise safety. It is not intended to be a design specification or an instruction manual for untrained persons. The purpose of the NEC is the practical safeguarding of people and property from hazards arising from the use of electricity. There are no NEC police for code enforcement. Instead the NEC refers to the authority having jurisdiction, AHJ for short. The AHJ utilizes the NEC, and other documents, as a guideline for designs and installations. For more information on the AHJ, refer to Article 100 of the NEC

The NEC is comprehensive, covering a wide array of applications. When researching hazardous locations Chapter 5, which contains all the articles in the 500 range, is the best place to start. Note that the Code cross-references itself frequently to guide codebook users. Traditionally the NEC has been based on the "Class, Division" system but in response to international standards articles 505 and 506 have been added to address the "Zone" system. Article 505 discusses the traditional Class I applications and Article 506 addresses the traditional Class II and Class III applications. Table 2 provides an overview of the topics for each article. However, when researching what type of cable is permitted in each classification, there are often references to other sections of the standard. For example, you will learn in Article 502 that Power Limited Tray Cable (PLTC) is permitted for Class I Division 2 applications but to learn more about PLTC cable and its applications you will need to reference Article 725.

Article 500	Hazardous Locations
Article 501	Class I Division 1 & 2 requirements – flammable gases and liquid produced vapors
Article 502	Class II Division 1 & 2 requirements – combustible dust
Article 503	Class III Division 1 & 2 requirements – easily ignitable fibers and flyings
Article 504	Intrinsically Safe
Article 505	Zone System for Class I (parallels Article 500 & 501)
Article 506	Zone System for Class II and III (parallels for Article 502 & 503)

Table 2: NEC Articles for Hazardous Locations

Location types

The NEC classifies hazardous areas into Classes, Divisions, and Zones. The Class represents the type of flammable material, whereas the Division represents the conditions where the flammable materials are used or stored and the likelihood of the flammable material being present. Zones define the likelihood of the hazard being present, i.e. "… temporarily present but not under normal operation" or "… definitely present under normal operation." There is a further break down by groups labeled A, B, C, … that defines the type of combustible material (Acetylene, Hydrogen, metal dust, wood chips, etc.…) in each of the classes but this does not impact the type of cable that is required. Table 3 provides a description of each Class and Division.

Class	Division 1	Division 2
I Gases, Vapors, & Liquids	Explosive or ignitable gases or vapors are present under normal operation conditions.	Explosive or ignitable gases or vapors are not normally present but accidental exposure can occur.
II Dusts	Combustible dust is in the air under normal operating conditions.	Dust is not normally in the air in ignitable concentrations, but accidental exposure can occur.
III Fibers and Flying's	Easily ignitable fibers/flying's are handled, manufactured, or used.	Easily ignitable fibers/flyings are stored or handled other than in process of manufacture.

Table 3: NEC Class and Division Definitions

Classifying an area requires extensive engineering and often involves recommended best practices and techniques outside of the NEC. Therefore, in most cabling specification use cases, the classification of the area is known, and it is the responsibility of the engineering/installation team to select/install the proper equipment and infrastructure for the designated application. The classification is based on either the NEC Class/Division or ATEX Zone method, most likely dictated by geographical location. There is a relationship between the two systems as shown in Table 4.

Certain types of cable are specified for each hazardous area classification. In addition to selecting the appropriate cable, proper installation techniques must also be followed. When installing the cable, it is important to use pathways and fittings that are 'listed' for the location. The term 'listed' refers to a component that is tested to a standard by a Nationally Recognized Testing Laboratory such as UL or CSA.

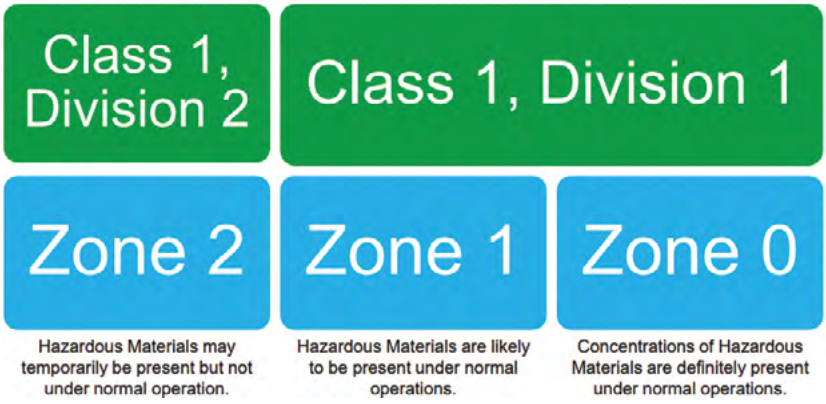


Table 4: Class/Division System Compared to Zone System.

Cable Requirements by Hazardous Location

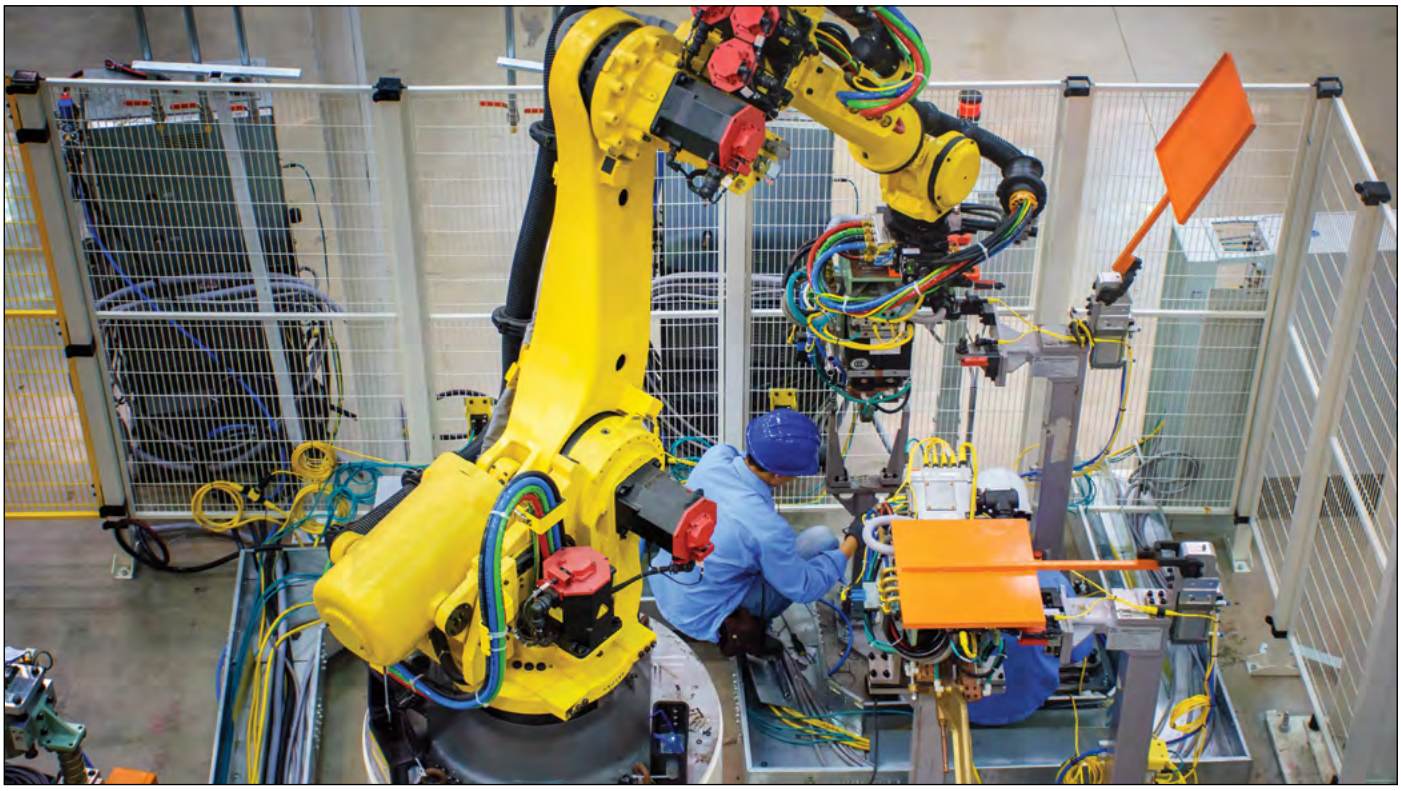
Class I Division 1 (NEC Article 501)

Class I Division 1 (CID1) is defined as an area in which ignitable concentrations of flammable gases and vapors exist under normal operating conditions. This location has a high risk since the equipment is very close to the hazard. Therefore, this type of location requires the most rigorous installation and generally the products and installation are more costly than other classified areas. Examples of Class I areas include chemical plants, petroleum refineries, spray areas for paints/plastics, pipeline pumping areas, and gas storage facilities. Installations in these hazardous locations can be accomplished with properly sealed-threaded rigid metal conduit or cabling that has an outer layer constructed for this type of environment. Table 5 shows the approved types.

Class I Division 1
➢ Threaded rigid metal conduit or threaded steel intermediate metal conduit
➢ Type MI (Mineral Insulated) cable terminated with fittings listed for location
➢ Type MC-HL (Metal Clad – Hazardous Location)
➢ Type ITC-HL (Instrumentation Tray Cable – Hazardous Location)
➢ Optical Fiber Cable types allowed: OFNP, OFCP, OFNR, OFCR, OFNG, OFCG, OFN and OFC

Table 5: CID1 Wiring Methods

Class I Division 1 rated equipment is specifically designed for the location and has undergone validation testing. The purpose of testing is to validate that if an explosion occurs it will be contained. The design of the 'explosion proof' equipment must be sufficient to confine the burning mixture to prevent ignition of any explosive mixture outside of the system. Also, an enclosure or pathway system for this application must be designed with enough strength to withstand the pressure generated by an internal explosion in order to prevent rupture.



Class I Division 2 (NEC Article 501)

This classification is the most common hazardous environment. Methods that are approved for CID1 are allowed for CID2 locations as CID1 construction is more stringent than C1D2 construction. Division 2 includes additional cable types that can be used since there is less exposure to the hazard. Cable types such as Power Limited Tray Cable (PLTC) must be mounted in cable tray with listed fittings to meet the requirements. Cables with a proper sheath, Metal Clad for example, can be mounted without a pathway as long as the cable run is properly supported. Table 6 summarizes these methods and provides the NEC article reference where more information can be found on a specific cable type. For each type of cable listed there are installation requirements that are described as part of Article 501.

Class I Division 2	Reference
➢ Threaded rigid metal conduit or threaded steel intermediate metal conduit	
➢ Type PLTC and PLTC-ER (Power Limited Tray Cable – Exposed Run)*	Article 725
➢ Type ITC and ITC-ER (Instrumented Tray Cable – Exposed Run)*	Article 727
➢ Type MC (Metal Clad)	Article 330
➢ Type MV (Medium Voltage)	Article 328
➢ Type TC and TC-ER (Tray Cable – Exposed Run)*	Article 336
➢ Optical Fiber cable types allowed: OFNP, OFCP, OFNR, OFCR, OFNG, OFCG, OFN & OFC Installed in raceways that meet Article 501 requirements	Article 770

Table 6: CID2 Wiring Methods

*The -ER suffix indicates additional crush and impact test requirements and can be used as ‘exposed’ or ‘open’ wiring. When coming out of the cable tray, and the connection is less than six feet away to an end device such as a motor, cables with an ER rating can be used if they are properly supported and given adequate mechanical protection. Mechanical protection consists of struts, angle, or channels.

In addition to the approved cable types there are other acceptable wires/cables that can be used with the proper pathway. Any suitable type of wire or cable can be used if installed in threaded metallic conduit with approved termination fittings. Defining ‘suitable’ type of wire is the responsibility of the AHJ but typically wire or cable approved for unclassified (non-hazardous) will be accepted. Many common off the shelf industrial devices, such as network switches, PLC’s, 24V DC power supplies, and Panduit 24V UPS are rated for Class I Division 2 locations. These devices are designed and manufactured to minimize the risk by addressing factors like spacing, fuses, relays, connectors, and surface temperatures. Manufactures may have a separate model that conforms to CID2 but in many cases there may be only one version. It is common for these devices to not be mounted in the hazardous area, but they have the certification regardless.

Nonincendive

Nonincendive is not a common term but it is another type of classification for hazardous areas. There are a several types of ‘Nonincendive’ (circuit/component/equipment/field wiring) as defined in the NEC Article 100. Nonincendive is defined as having electrical/electronic equipment that is incapable, under normal operating conditions, of causing ignition of the surrounding atmosphere due to arcing or thermal means. Normal operating conditions are defined as maximum voltage under open circuit conditions and maximum current under short circuit conditions. Nonincendive devices are approved for use in a Division 2 environment (also can be used for Class III Division 1) and therefore do not require protection such as an explosion proof enclosure or an intrinsically safe barrier. An advantage of this approach is cost when compared to Intrinsically Safe and explosion proof options. Nonincendive field wiring shall be permitted using any of the wiring methods permitted for unclassified locations and installed according to the control drawing.

An example of a nonincendive device for CID2 is the Panduit VeriSafe™ Absence of Voltage Tester (AVT), see figure 2. This rating allows the device to be mounted in control panels that are in the classified area. Any type of non-hazardous wiring can be used provided the manufacturer’s installation instructions are followed.

Standards Apply to VS-AVT2 Only	
ISA 12.12.01	Nonincendive Electrical Equipment rated for Class I, Division 2 area classification, Groups A, B, C, D, and temperature classification T3.

Figure 2: VeriSafe™ and Nonincendive rating

Class II Division 1 and 2 (NEC Article 502)

Class II focuses on combustible dust where material is stored or handled but no manufacturing process is performed. Examples of Class II areas include grain storage, coal storage, metal grinding, gun powder plants, and sugar/cocoa/spice or starch facilities. The equipment required in Class II locations is different from that required for Class I locations. Class II equipment is designed to prevent the ignition of layers of dust while Class I does not address this concern. Equipment suitable for one class and group is not necessarily suitable for any other class and group unless noted. For example, grain dust ignites at a temperature lower than that of most flammable vapors. Motors listed for use in Class I locations may not have dust shields on the bearings to prevent entrance of dust into the bearing race which can overheat and result in ignition of dust on the motor. Therefore, it is essential that the rating matches the hazardous location classification. In some instances, a dual rating is shown which means that the device has been tested for both locations. When installing a device with a dual rating the installation requirements for the rating where it is being installed must be followed. Table 7 summarizes the approved wiring methods for both division 1 and 2.

Class II Division 1	Class II Division 2
➢ Threaded rigid metal conduit	➢ All methods from Class II Division 1
➢ Type MI cable	➢ Type MC cable
➢ Type MC-HL	➢ Type PLTC and PLTC-ER
➢ Type ITC-HL	➢ Type MC, MI, MV, TC/TC-ER cable (requires ventilation and specific spacing)
➢ Optical Fiber OFNP, OFCP, OFNR, OFCR, OFNG, OFCG, and OFN	

Table 7: Class II Wiring Methods

Class III (NEC Article 503)

Class III focuses on textile mills where easily ignitable fibers/flyings are present in the manufacturing process. Examples of other Class III areas include cotton gins and seed mills, flax producing or handling facilities, pulverizing or shaping plants, and clothing manufacturing facilities. Sawmills and other woodworking plants where combustible fibers/flyings are present may also become hazardous locations. Fibers/flyings are hazardous because they are easily ignited but also because flames quickly spread through them. Class III locations do not have material group designations. Table 8 summarizes these acceptable methods for Class III division 1 and 2.

Class III Division 1 and Division 2
➢ Rigid metal conduit, PVC conduit, RTRC conduit, intermediate metal conduit, electrical metallic tubing, dust tight wireways
➢ Type MC or MI cable with listed termination fittings
➢ Type PLTC and PLTC-ER cable
➢ Type ITC and ITC-ER
➢ Type MC, MI, MV, TC/TC-ER cable (requires ventilation and specific spacing)

Table 8: Class III Wiring Methods

Intrinsically Safe (NEC Article 504)

Intrinsically safe equipment is defined as equipment and wiring which is incapable of releasing sufficient electrical or thermal energy under normal or abnormal conditions to create a hazardous situation. Intrinsically safe systems commonly use a standalone barrier that contains energy limiting electronics. Conceptually, the function of an intrinsically safe barrier is like that of a fuse or circuit breaker. When too much energy is detected from the barrier the barrier will react and 'open' the circuit. Any of the wiring methods for unclassified (non-hazardous) locations can be used as long as the conditions specified in the control drawings are followed. The intrinsically safe application is viewed as a circuit and each device that is part of the system must follow the design. Control drawings are typically supplied with the intrinsically safe barrier and will specify the requirements of the cabling. It is also important that the intrinsically safe wire is isolated and clearly marked so that it is not accidentally mixed with other wiring. Typically, intrinsically safe wire is blue in color and labeled so it can be easily recognized. For more information on intrinsic safety refer to UL 698A and/or NEC article 504.

Summary

The NEC has an abundance of information and guidance for hazardous locations found in Chapter 5 (Article 500 to 506). Traditionally the NEC has followed the Class/Division segmentation but with the addition of Article 505 and 506 there is now a reference to the Zone schema that is used internationally. When installing outside of the United States be sure to follow the standards and regulations for that area, ATEX and IECEx are common outside of the US. Direct cross referencing of standards is usually not allowed unless the device is provided with a dual rating. Be aware that there are differences between Classes and Divisions that are not incremental and do not transfer from one to the other. For example, a Class I device cannot be used in a Class III area unless it has been rated for that area.

Appropriate materials selection and installation practices are documented in the NEC and are used to create a safe design that can be approved by the authority having jurisdiction. Following these 3 steps will provide a proper install; determine the correct hazardous area classification, review the wiring types allowed for proper cable selection, and installing the cable per the requirements of the hazardous location. Each classified area has a list of approved wiring methods as shown in the tables within this paper. Additional details for the applicable standards of these wiring methods should be researched prior to developing a design. Interpretations of the requirements are subjective, so it is crucial to include any local codes and communicate with the proper authority for the specific location. In most cases there are several options available and having the proper information will result in a successful project.

Panduit Products

It is challenging to generally classify products due to the many details and the variety of standards that apply to different situations. The FAQ section and chart below provides guidance for common situations and a starting point for product specification. Today there are many products that offer Class I Division 2 ratings; this provides more flexibility when installing in a hazardous location.

What type of enclosure is needed for Class I Division 2? Can a Panduit Zone enclosure be used?

In CID2 locations, enclosures, fittings, and joints are not required to be explosionproof if they contain no arcing devices and the equipment used in the panel is CID2 rated. Control panels containing solid-state relays, solenoids, and control transformers (as long as the devices operating temperature doesn't exceed 80% of ignition temperature) are considered non-arcing devices per article 501.105(B)(3 and 4). Therefore, a NEMA 4 rated Zone Enclosure with CID2 rated equipment, such as a Stratix® switch or PLC, can be mounted in the CID2 classified area without the need for an explosion proof rating. This guidance is assuming that the area of installation does NOT require explosion proof seal. Division 2 wiring methods indicated in Article 501.10(B) must be adhered to for the installation.

Additionally, some motor control devices that are mounted in control panels can have CID2 ratings. For example, devices such as circuit breakers/motor controllers/switches that are sealed and not arc producing can be listed as CID2 rated devices. Article 501.115 and 501.120 provide more details on the exceptions but reviewing any equipment's labeling and/or manuals will state the rating to which it has been tested and certified.

What rating is required for cables and connectors used in a Class I Division 2 control panel?

Cables and connectors used in a CID2 control panel, not requiring explosion proof seal, do not have to have a hazardous location listing. As long as the equipment is 'listed' it can be used. To clarify, there are two types of terminology used in the NEC code; 'listed' and 'listed for the location'. Listed for the locations typically refers to an item being rating for the explosion proof area. However, the term 'listed' refers to a more general recognition such as general purpose or ordinary. The term 'listed' refers to a component that is tested to a standard by a Nationally Recognized Testing Laboratory such as UL or CSA. Therefore, for these CID2 control panels, Panduit network products such as patch cables, RJ45 plugs/jacks, and related equipment that are used inside the control panel are allowed. Any type of wiring that is outside of the enclosure must adhere to the Division 2 wiring methods indicated in Section 501.

What type of fittings are needed for Class I Division 2 installations for Zone Enclosures (or other control panels)?

Generally speaking, if the installation requires an explosionproof seal, the fitting must be an explosionproof fitting, rated, listed, and marked for either Class I, Division 1 or Class I, Division 2. If the installation does not require an explosionproof seal, all that is required is an ordinary or general-purpose rated and listed fitting compatible with the appropriate Division 2 wiring method being used. When equipment being installed does not rely on an explosionproof method of protection and does not have ignition concerns then explosionproof enclosures and fittings are not needed per section 501.10(B)(4) of the NEC.

What cable can be used inside threaded metal conduit that meets Class I applications?

Standard Panduit enterprise or industrial copper cable and fiber can be used in threaded rigid metal conduit. The media used in this pathway only needs to be listed (general recognition) and is not required to have any type of explosion proof rating. The threaded metal conduit provides the protection required

This chart contains Panduit products that can be installed in different types of hazardous locations.

Part Number	Description	Applications	Type of use in hazardous location				
			Class I Div 1	Class I Div 2	Class II Div 1	Class II Div 2	Class III Div 1&2
IURHT5C04BL-UG	Category 5e 4-pair UTP 600 V 22 AWG solid Type PLTC*	Ethernet Networks EtherNet/IP	RMC	Cable Tray	RMC	Cable Tray	Cable Tray
ESFLHT5C02FGR-X	Category 5e 2-pair SF/UTP 600 V 22 AWG stranded Type AWM, ITC, PLTC*	Ethernet Networks PROFINET Type B/C	RMC	Cable Tray	RMC	Cable Tray	Cable Tray
ESFLHT5C02GR-X	Category 5e 2-pair SF/UTP 22 AWG solid Type PLTC*	Ethernet Networks PROFINET Type A	RMC	Cable Tray	RMC	Cable Tray	Cable Tray
UPS00100DC	Maintenance-free, No battery, 100 Watts, 24VDC	Power back up for 24VDC devices	Not Rated	Yes	Not Rated	Yes	Yes
Z22U-S14 and -S15	Universal Network Zone Enclosure	Housing network switches and devices	Not Rated	Yes**	Not Rated	Yes**	Yes**
Z23U-S24 and -S25							
FODPZ12Y	OFNP plenum, 50µm OM4, 900µm buffered fibers	Indoor Distribution fiber	Cable Tray				
FODPZ24Y							
FSDP912Y	OFNP plenum, 50µm OS2, 900µm buffered fibers	Indoor Distribution fiber	Cable Tray				
FSDP924Y							
FOPPZ12Y	OFCP plenum, 50µm OM4, 900µm buffered fibers	Indoor Distribution interlocking armor	Cable Tray				
FOPPZ24Y							
FSPP912Y	OFCP plenum, 9µm OS2, 900µm buffered fibers	Indoor Distribution interlocking armor	Cable Tray				
FSPP924Y							
FOCPZ12Y	OFNP plenum, 50µm OM4, 250µm fibers	Indoor/outdoor loose tube cable	Cable Tray				
FONPZ24Y							
FSCP912Y	OFNP plenum, 9µm OS2, 250µm fibers	Indoor/outdoor loose tube cable	Cable Tray				
FSNP924Y							
FSJD912	OFNR-LS riser LSZH, OS2	Industrial Dielectric Double Jacketed	Cable Tray				
FOJDZ12	OFNR-LS riser LSZH, OM4	Industrial Dielectric Double Jacketed	Cable Tray				

* Power Limited Tray Cable (PLTC) applications reduce rating to 300 V
** When equipped with location approved equipment

Acronym decoder list:

AWM = Appliance Wiring Material

ITC = Instrument Tray cable

PLTC = Power Limited Tray Cable

RMC = Rigid Metal Conduit (thick walled threaded metal tubing)

OFCP = Fiber Optic Conductive Plenum

OFNP = Fiber Optic Nonconductive Plenum

OFNR-LS = Fiber Optic Nonconductive Riser

LSZH = Low smoke Zero Halogen

Cable tray = Unit or assembly of units and the associated fittings that form a structural system used to securely fasten or support cables and raceways. Example of cable tray is Panduit Wyr-Grid® Overhead Tray Routing System. In addition to cable tray other installations types are available, refer to NEC Article 725.

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Since 1955, Panduit's culture of curiosity and passion for problem solving have enabled more meaningful connections between companies' business goals and their marketplace success. Panduit creates leading-edge physical, electrical, and network infrastructure solutions for enterprise-wide environments, from the data center to the telecom room, from the desktop to the plant floor. Headquartered in Tinley Park, IL, USA and operating in 112 global locations, Panduit's proven reputation for quality and technology leadership, coupled with a robust partner ecosystem, help support, sustain, and empower business growth in a connected world.

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