Transmission Systems

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6 Engineering Factors In Selection Of Wire Types For Electronic Systems

This section describes wiring practices for signal transmission systems for instruments commonly used. For each typical application, one type of wire or signal conductor is suggested. The wire types are identified with Roman Numerals and are defined in Table 4.

Table 4—Types of Wire or Cable for Signal Transmission

Type	Description
I	Untwisted copper wire
II	Single, unshielded twisted-pair copper wire
III	Single, shielded twisted-pair copper wire
IV	Multipair cable of Type II wire
V	Multipair, overall shielded cable of Type II wire
VI	Multipair, overall shielded cable of Type III wire

Note: In the above, replace the word *pair* with *triple* or *triad* for wiring certain items such as some resistance bulb sensors (RTD), or strain gauges, and others like these.

6.1 PROCESS CONTROLS WITH MILLIAMPERE SIGNALS

Most process control instruments use DC milliampere current signals in wiring that goes from a transmitter to a display station, or a control system, a controller, and/or other receivers, and from the controller to a final control element. The standard signal is 4–20 milliampere DC.

6.1.1 Wire Type

Although a pair of untwisted, unshielded, stranded copper wires (Type I) may be used to interconnect most industrial process control equipment, such use is not recommended. For installations where the possibility of magnetic-field interference exists, single, unshielded twisted-pair wires (Type II) can be used. In runs of three or more pairs, multipair cable (Type IV) should be considered for economic reasons. Where excessive interference is due to electrostatic coupling, shielded (Type III, V, or VI) should be used. Type VI is more expensive and might not be justified.

These wires or cables can be enclosed in conduits or laid in trays, but DC signal wiring should not be mixed with AC signal wiring or power wires.

6.1.2 Mixing Signals

It is considered poor practice to mix wiring of significantly different signal levels. In other words, wiring with low energy/voltage should not be mixed with wiring carrying AC signals, DC pulses, or any power. Wiring with 4–20 maDC signals should separated from 120 VAC to solenoids, 120 VAC alarms and power wiring, and power signals. See Table 5.

Table 5—Guidelines for Grouping Wires Bearing Signals of the Same Magnitude

Type of Signal	Suggested Range
DC Voltage	
Low	0 millivolts < Signal < 100 millivolts
Medium	100 millivolts < Signal < 5 volts
High	5 volts < Signal < 75 volts
AC Voltage	
Low	0 millivolts < Signal < 100 millivolts
Medium	100 millivolts < Signal < 5 volts
High	5 volts < Signal < 75 volts
DC Current	0 milliamperes < Signal < 50 milliamperes

6.1.3 Resistive Loading

Instrument manufacturers publish limits on the resistive load that can be put on each signal generator for specified supply voltages.

Installations should be in accordance with the manufacturers' recommendations. The maximum transmission distance for a loop can be determined by using data from Table 6, the input resistance of the various receivers, power supply voltage, and the maximum resistive loading. This is rarely a problem except for Intrinsically Safe applications.

Table 6—Resistance of Copper Wire-Per Conductor

AWG	Diameter, inches	Ohm/1000 ft	Ohm/mile
10	0.1019	0.9989	1.588
12	0.08081	1.588	8.384
14	0.06408	2.525	13.33
16	0.05082	4.016	21.20
18	0.04030	6.385	33.71
19	0.03589	8.051	42.50
20	0.03196	10.15	53.59
22	0.02535	16.14	85.21
24	0.02010	25.67	135.5

Note: ft = feet; AWG = American Wire Gauge.

6.1.4 Grounding

Noise from ground loops can be avoided by limiting grounds to only one ground point per circuit (see also Section 20).

6.2 PROCESS CONTROLS WITH VOLTAGE SIGNALS

Voltage signals are seldom used for long-distance transmission because of voltage-drop considerations. One exception is vibration monitoring systems.

When a voltage signal is used, precautions must be taken to ensure that the transmission system does not degrade the measurement signal.

6.3 DIGITAL COMMUNICATIONS SIGNALS

Digital Communications Signals (DCS) are normally interconnected with data-highway cables. The control system manufacturer specifies the cable and recommends the installation details.

6.4 PROCESS CONTROL LOW ENERGY/ VOLTAGE SENSORS

Low energy/voltage sensors include thermocouples. Resistance temperature detectors (RTDs) and strain gauges generate low DC voltages when energized with a DC power supply.

6.4.1 Grounding

Circuits that contain resistance temperature detectors and strain gauges should not be grounded at more than one point. The preferred location is near the source of power and on the lower voltage wire. Grounded thermocouples should have no other grounded point than that in the primary sensor. Sneak circuits can easily occur because the extent of isolation and grounding within instruments varies with their function and make. The selection of grounded-junction or ungrounded-junction is beyond the scope of this standards (also see Section 20).

6.4.2 Thermocouple Burnout Circuit

Frequently the electronics used with a thermocouple will include provision for *upscale (downscale) burnout.* This provision is typically accomplished by imposing a small circulating current on the thermocouple circuit. If the thermocouple or the connecting wiring is broken, the output signal is driven to the maximun (minimum). It is necessary to consider this current in any special thermocouple circuits which would put electronic devices in parallel, since the burnout circuits may interfere with each other.

6.5 PROCESS CONTROL WITH PULSE OUTPUT METERS

Pulse output meters are usually connected to devices that have a relatively high input impedance.

The recommendations of the manufacturer concerning the preamplifier and the wiring should be carefully considered.

Power wires and other types of signal wires should not be mixed with pulse signal wiring. The wire type and the grounding of the signal circuit should follow the manufacturer's recommendations.

6.6 LOW-IMPEDANCE SENSORS TO COMPUTERS

Low-impedance sensors to computers are the same as those listed in 6.4.

Shielded twisted pair wires (Types III and VI) should be used . A multipair cable with only an overall shield (Type V) can normally be used if the distance is less than 100 feet (30 meters) and common-mode interference is small. Individual shielding (Type III or VI) may not be needed, depending on the design of the receiver. For thermocouples, the extension lead wire should consist of shielded, twisted pairs. This wire should comply with ANSI MC96.1

6.7 TURBINE METERS

The suggestions of the manufacturer concerning the preamplifier and the wiring should be carefully considered.

Most turbine meters are supplied with integral converters to amplify the pulses or to convert for transmission of 4–20 milliamperes DC. Wiring for integral or field converters may require more than two wires (see 6.5).

6.8 MAGNETIC-FLOW TRANSMITTERS

The electric signal from magnetic flow electrodes is generally less than 50 millivolts. The low signal level requires that the electrical interference be minimized. Minimizing is done by using a two-conductor, shielded, twisted-pair cable whose length is limited by the manufacturer's recommendations. The recommended cable length is a function of the measured fluid's conductivity and the grade of the cable.

The recommendations of the manufacturer should be followed. The transmitter, cable, and receiving instrument are designed and sold as a unit. The spacing requirements given in Table 3 should be followed. Alternatively, an integral amplifier/converter may be used.

7 Specifications For Wires And Cables In Electronic Systems

General wiring requirements, such as those for twisted-pair, shielded, and other types of wire, are given in Section 6. The frequently used wires can be classified into one of the six types that are described in Table 4.

7.1 WIRE SIZE

The smallest wire size that will not cause an excessive voltage drop and that has sufficient strength and workability should be selected. Normally, the size used for single conductor wire is 14 gauge, that for single twisted-pair wire is 16 gauge, and that for multipair cable is 20 gauge. Other wire gauges may be selected for reasons of economy, space, or application.

7.2 STRANDED WIRE

Stranded wire is preferred because of its flexibility and resistance to breakage by bending. Where great flexibility is needed, wire with 19 strands is suggested; otherwise, seven-strand wire should be used.

In areas of high corrosion, solid conductors may be preferred. Thermocouple wires and 20-gauge multipair cables are normally solid conductors. Consider using tinned stranded wire for additional protection in high corrosion areas.

7.3 INSULATION

The insulation of signal wire should be adequate for the operating voltage and current. Most electric signals are less than 95 volts to ground and lower than 5 watts. Wire insulated for 300 volts is satisfactory for signals of this low operating level. To meet NEC requirements, wires in the same raceway must have insulation adequate for the highest voltage on any of the wires.

7.4 TEMPERATURE RATING

The wire or cable should have a temperature rating high enough for the anticipated environment. It is suggested that 75°C be specified as a minimum temperature requirement. In very cold localities, the lowest temperature at which the wire or cable is rated is also of interest. High temperature insulation should be used in areas of expected high temperatures, such as furnace areas. When protection from flash fires is required, an arrangement of thermal barriers and/or fire retardants can be provided. Some users prefer to purchase fire-rated cable; it is possible to retain control for a reasonable time, 15-20 minutes of exposure to fire. An alternative is to bury the conductors underground. See also 13.2.6.

7.5 OVERALL JACKET

The overall jacket material should be moisture resistant, abrasion resistant, flame retardant, and compatible with the environment.

7.6 SHIELDING

The preferred shielding is aluminized polyester film with an overall spiral wrap that has 25-percent overlap. The shield should be electrically in contact with a copper drain wire that is as long as the pair of signal wires. The shield should be electrically insulated both inside and outside. For multipair cables, overall shielding should have the same specifications and should also be insulated both inside and outside.

7.7 NUMBER OF CROSSOVERS

Twisted wire should have a minimum of six crossovers per foot (2 inch lay)(20 crossovers per meter). Eight crossovers per foot (26 crossovers per meter) is a typical specification.

7.8 WIRE AND PAIR IDENTIFICATION

Either number coding or color coding is required in multipair wiring.

7.9 COMMUNICATION WIRES

Inclusion of communication wires in any multiple-pair cable is recommended to assist in the checkout of wiring and maintenance using sound-powered headphones.

7.10 LIGHTNING PROTECTION

Refer to Section 16 for information on lightning protection.

8 Typical Applications of Wire Types Used in Electronic Systems

Six common types of wire and cable are described in Table 4. Table 1 provides a quick guide for selecting the minimum type of wire that can be used for a given application. Generally, the following rules of thumb can be applied with good results:

Wiring from a field mounted electronic instrument to a field mounted junction box or multiplexer box should be Type III.

Wiring from the field junction box to the control building or "rack room" can be multi-pair Type V cable for signal levels one volt or greater; but should be Type VI for signal levels less than 1 volt and for thermocouples.

9 Guidelines for Separation of Wires in Electronic Systems

Most industrial plants will require signal transmitting systems of several different types. Guidelines for separating the various systems from each other and from power wiring and equipment are presented below (see also 6.3).

9.1 SIMILAR SIGNAL LEVELS

All the signals in one cable or conduit should be of similar magnitude. Whenever it is necessary to combine different signal levels in a single cable or conduit, each pair should be individually shielded and grounded at a single point. Floating (balanced) wiring is used and minimizes intereference in many systems; however, it may be difficult to maintain.

Wiring from some types of sensor should be completely separated from other circuits. Magnetic flow meters, turbine meters, pH electrode wiring, chromatograph detector wiring, and AC-powered bridge circuits are just a few examples. Thermocouple wiring should not be mixed with milliampere signal wiring. Wiring for circuits in which sharp voltage pulses are transmitted (such as relay contact closures, relay coils, and solenoids) should also be segregated from other wiring.

A practical exception to the preceding is the situation of one conduit to a control valve with the wiring for the 4–20 maDC signal for the valve, the 24 VDC for an associated solenoid valve, plus the wiring for the limit switches.

9.2 SIGNAL AND POWER WIRING

Where signal wiring is run along a parallel route with AC power circuits, separation of conduits, cable, and trays should comply with Table 3. This table applies to instrument signal circuits for analog signals, high and low speed digital pulses, and high, medium, and low noise level circuits.

If groups of cable trays are stacked vertically, the signal wiring should be in the top tray, and high-voltage feeders should be in the bottom-most tray. With this arrangement, the signal wiring is not in the electric field that exists between all voltage lines and ground

The circuits. might be arranged top to bottom as follows:

a. Signal wiring.
b. Light-capacity power circuits.
c. Medium voltage AC and DC feeders.
d. High-voltage feeders.

9.3 PROXIMITY TO AC FIELDS

Although direct routing is desirable for all types of wiring, the sensitivity of signal wiring to electrical magnetic interferences may call for special routing precautions. Magnetic field interference occurs when signal wires pass through strong AC fields which are present near large motors, generators, electric furnaces, and transformers. As a general rule, a minimum of 5 feet (1.5 meters) of clearance should be allowed between the noise generating equipment and signal carrying wires. If steel conduit is used, clearances can be reduced by half.

Signal leads should, if possible, enter or exit AC power equipment at right angles to the equipment's magnetic field. When power and signal wiring cross in close proximity to each other, the crossover should be made at right angles and no closer than 12 inches (0.3 meters).

10 Effect of Transmission Distance on Electronic Signal Installations

The design of an installation is largely governed by economics: for example, more expensive signal multiplexing equipment using fewer wires or fiber optic systems may be justified for long distances, but less expensive direct connected wiring may be more economical for short distances. The economics of various types of transmission systems should be evaluated on an individual project basis.

The length of the transmission line also affects the magnitude of electrical interferences. Generally, the longer the distance the greater the possibility of noise. Lightning also creates problems in longer lengths of cable. The spare conductors in a multiconductor cable should be grounded at one point so that they do not induce large voltage surges on signal circuits when lightning strikes nearby.

AC powered solenoid valves connected to wire runs of 1000 feet (3000 meters) or more may fail to switch on the opening of the control contacts due to electrostatic coupling to AC lines. DC is recommended with adequate wire size.

11 High Temperature Areas

When wire is run next to fired heaters or other heat radiating equipment (as occasionally is required with thermocouples), every effort should be made to keep the wire in areas where temperatures are not excessive. If this condition is not practical, wire with a moisture resistant, high temperature insulation should be used. A common junction box should be provided in a safe area, away from the heat source, to allow connection to regular wire which can be run the remaining distance.

12 General Information On Installation Methods For Electronic Systems

Although signal wires may be installed and protected from physical damage by methods that are similar to those for power wiring, such methods are not always sufficient for good signal transmission. Information on methods and hardware that result in a good signal transmission system is given in Sections 13 through 20. Routing of redundant data highway cables requires consideration of the need to maintain redundancy by avoiding exposure to common hazards.

13 Installation Of Trays For Electronic Systems

13.1 LOCATIONS AND ADVANTAGES

Cable trays may be used advantageously to support a large number of cables between two points if their use is permitted by the NEC and other applicable codes for the application in question. Tray use is generally limited to Division 2 and nonclassified areas unless Intrinsically Safe wiring is used. The primary advantage of trays over conduit is their lower initial cost. Power Limited Tray Cable (PLTC) is normally required.

13.2 DESCRIPTION

The different types of trays are discussed in the following

13.2.1 Applications and Limitations

Many varieties of metal trays are available for either horizontal or vertical mounting. Prefabricated trays are usually purchased, but some users prefer to have trays made in their own shops or by local steel fabricators. The general types of prefabricated trays for horizontal mounting are ladder, trough, and channel. A ladder tray is a prefabricated metal structure consisting of two longitudinal side rails connected by individual transverse members (rungs). A trough tray is a prefabricated metal structure greater than 4 inches (100 millimeters) in width with a continuous bottom, either ventilated or solid, contained within integral or separate longitudinal side rails. A channel tray is a prefabricated metal structure consisting of ventilated channel sections not exceeding 4 inches (100 millimeters) in width. These trays are normally used at the processing unit and are not run to control centers.

The selection of the proper horizontal tray design will vary with the size of tubing loads and with environmental conditions.

Although protective covers are not necessarily required, their use on horizontal trays should be considered. Continuous solid covers for horizontal trays are advisable to protect the plastic tubing or bundle sheath in plant areas.

13.2.2 Horizontal Trays

The proper design of a horizontal tray system will vary according to the weight of the cables, environmental conditions, and the need for additional electrical shielding. In general, where cables of small size are to be installed, ventilated, or solid bottom trays are preferred over the ladder type. Although protective covers are not necessarily required, their use on horizontal trays should be considered. Continuous solid covers are advisable for protecting cables in areas where damage from falling objects, sunlight, ice, snow, rain, etc. may result. Temporary plywood covers may be used during construction for protection.

13.2.3 Vertical Trays

Some users prefer vertical trays to horizontal trays. Figures 1 and 2 show methods of mounting vertical trays. The primary advantage of vertical trays is that they require much less pipe rack space. Other advantages include the following:

a. The upper surface of the tray is available for mounting an additional tray.
b. Support design is simpler because of the tray rigidity.
c. Peaked tray covers minimize problems from falling objects and debris.

The assembly and support of vertical trays utilize the same hardware used for horizontal trays. However, additional labor is required for installing the wiring.

13.2.4 Selection of Materials

Environmental conditions should be considered when tray materials are selected. Steel trays should be used where the best electrical shielding is desired; aluminum or any other nonferrous material is not effective in reducing electromagnetic noise. Each installation has unique requirements, and each material and coating should be thoroughly investigated. Fiberglass trays may be used in more corrosive environments.

Prefabricated trays are commonly made of steel or aluminum. Steel trays can be galvanized or coated with epoxy or polyvinylchloride (PVC). A popular material selection for process plants is galvanized steel in accordance with ASTM A123. This type requires hot-dip galvanizing after all fabrication and welding operations are completed. ASTM A525 is not recommended because it specifies that the metal is to be galvanized before fabrication and welding are completed. In certain environments, aluminum has proved to be a more economical choice. Several aluminum material specifications can be used. Copper-free aluminum is often recommended.

The structural design of tray systems is similar to that of other structures in that dead loads (cables, trays) and live loads (ice, snow, wind, earthquakes, and installation pulling-in forces) are necessarily considered. However, there are substantial differences in the structural design of trays as contrasted with other structures. These differences are discussed in detail in 13.2.5.

CAUTION: Trays are not designed as walkways or hoisting beams, and employees should be advised not to use them as such.

13.2.5 Structural Design

One should refer to tray vendors' catalogs of structural design for information and should apply good judgment. One should also consider spacing of horizontal supports to prevent sagging of the trays.

To ensure the safety of all personnel who come in contact with tray installations, specifications should require that all fabricated pieces be free from burrs and sharp edges.

13.2.6 Routing

The successful installation of 12-inch-and-over cable trays requires layout studies and detailed drawings. This effort should not be left to the judgment of field erection crews, especially at the entrance and inside of buildings. Tray runs should be made as straight as possible, but should avoid exposure of the cables to excessive heat, moisture, strong electrical interference, and mechanical damage.

Tray runs should follow routes that contain a minimum number of fire hazards. Placing trays near hot piping should be avoided, since this can cause deterioration of the cable insulation over a period of time. One should also avoid areas where hydrocarbons or corrosive or washdown fluids are likely to fall on or flow into the trays.

Also avoid placing cable runs or trays over mechanical equipment or over air coolers or any location that may interfere with maintenance or rigging operations on nearby equipment.

One good location for tray runs is above pipe racks. Trays may also be installed under pipeways. A discussion of the procedures for arranging trays for various services is given in Section 9.2.

13.2.7 Fireproofing

Specialty designers of fireproofing systems may be consulted for assistance in designing fireproofing for trays in areas containing fire hazards. Materials that can be used to fireproof trays and their structural support include lightweight industrial insulating and fireproofing blankets and intumescent mastics or paints. Intumescent paints should be applied in the field according to the manufacturer's recommendations, normally on the tray covers. A material with a fire resistance rating of 1 hour for structural steel should not be expected to give signal wire with its plastic insulation integrity for more than a few minutes. A time of 10 minutes for fire protection is suggested. The use of high-temperature wire insulations should be considered.

14 Installation Of Raceways In Electronic Systems

14.1 GENERAL

The general term *raceways* includes rigid conduit, electrical metallic tubing (EMT), flexible metal conduit, surface metal raceways, under-floor raceways, busways, wireways, and auxiliary gutters. Process plant raceways for control signals are, for the most part, rigid conduit. Surface metal raceways, under-floor raceways, and auxiliary gutters are usually limited in application to control center installations. Flexible conduit is frequently used to connect a field-located instrument to the raceway, and is sometimes used to isolate selected signal cables inside pull and terminal boxes. Raceway sizing is covered in the NEC.

The guidelines for selecting a tray size for control and signal cables are different from those for selecting a tray size for power cables. Power cables are normally placed in a single layer, with a ventilation space maintained between the cables to allow for heat dissipation and free air rating. Control and signal cables in trays may touch each other and may be in one or more layers. Metal barriers approximately twice the height of the largest cable have been used to separate different types of signal cables, and for separating Intrinsically Safe (IS) wiring from non-IS wiring (see 4.3.1).

The sizing of cable trays for control circuits depends only on the space required to accommodate the cables at various locations in the system. This space requirement also indirectly determines the tray capacity. Enough space should be provided so that at least 20 percent more cables can be installed in the future.

14.2 ABOVEGROUND INSTALLATIONS

14.2.1 Applications

Aboveground conduit runs are used for individual instrument wiring to junction boxes and are often used for handling wires and cables from junction boxes to the control centers when cable tray is not appropriate.

14.2.2 Materials

The conduit material should be suitable for the environmental conditions and should possess the required electrical shielding properties. Galvanized steel is the most commonly used material. Aluminum and steel conduits coated with polyethylene or PVC are also used. Nonmetallic conduit is seldom used aboveground in process plants and is not recommended for instrument wiring, since nonmetallic conduit provides no electrical shielding.

14.2.3 Installation

Recommendations for the support and arrangement of conduit systems are as follows:

a. Do not use piping to support conduit.
b. Provide for thermal expansion and other equipment movement.
c. Fasten conduit to support with pipe clamps or bolts.
d. Install conduit runs with a minimum number of bends and offsets.
e. Provide conduit drains at low points.
f. Provide fireproofing where fire damage is possible, similar to fireproofing for trays (see 13.2.6). Protecting conduit with suitable pipe insulation, such as calcium silicate, fiberglass, and similar materials, will help to protect against flame. Stub-ups from underground conduit may be enclosed in concrete for fire protection. Fireproofing should be designed to provide protection from fire for 10 minutes circuit integrity or more.
g. Provide junction boxes, considering ease of pulling the cables, places where the type of wire or insulation changes, or places where single pairs change to multipair.
h. Provide solid connection between the conduit and tray for electrical ground continuity.

14.3 UNDERGROUND INSTALLATIONS

14.3.1 Conduit Materials and Installation

The most widely used underground installation is galvanized steel or plastic conduit arranged in banks that have a protective red-dyed concrete cover envelope. Aluminum conduit is not recommended for underground use. Refer to the NEC requirements for duct bank installation details.

Where underground conduit routes cross beneath roadways, railroads, or other areas subject to heavy loading, or where required by soil conditions, conduit banks should be adequately supported or the envelope should be reinforced to prevent shearing, crushing, or other damage from uneven settlement.

Aboveground pull boxes are preferred; underground pull boxes should be avoided. If an underground pull box is required, it should be made of reinforced concrete and have a removable cover designed to adequately support loads from maintenance vehicles. Pull box covers should be

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one package of devices will fit every case. Each signal line that requires surge protection should be individually examined in order to select the correct array of devices that will provide the desired protection without sacrificing signal fidelity.

Surges usually enter on an AC power line, which may be protected by surge protection at that point. Thus, the actual surge on the DC line contains less energy, requiring less protection. Analysis must be made of the anticipated surges at the protection point to choose the device with the correct parameters.

Vendors who specialize in the design and manufacture of electronic surge protection equipment should be consulted. For the vendor to be responsive, however, he must have a thorough knowledge of each component in the transmission loop, as well as the component's tolerances. In a telecommunication installation, this requirement would probably mean meeting with only one vendor. In contrast, a digital process control system installation would require consultation with several different vendors.

Since no constructive generalization can be presented, the discussion below provides guidelines by which individual situations can be evaluated and understood as they are encountered.

16.4.1 Protection Of Personnel

The NEC, Article 800, is very specific in its requirements for personnel protection devices. A typical installation is shown in Figure 4. Note that each signal line must have its own fuse and air gap arrester. The transmission system should be designed so that the signal accuracy is not impaired by the addition of the fuses. If shielded pairs or a cable shield is required for the integrity of the transmission signal, then the shield should be solidly connected to ground as shown. A hermetically sealed, gas-filled gap arrester can be substituted for the air gap arrester shown in Figure 4.

As shown in Figure 4, the receiving equipment should be capable of withstanding a common-mode voltage of 700 volts and a normal-mode voltage of 350 volts. Using a gas-filled gap arrester of a specific design, for example, the line-to-ground value could be 175 volts +/- 15 percent, and the line-to-line value could be 200–400 volts (resulting in a common mode of 175 volts +/- 15 percent and a normal mode of 52.5 volts maximum).

Such high normal-mode voltages are damaging to modern-day solid-state electronics. The fuse provides no protection, since the solid-state electronics are critically damaged before the fuse can blow. Additional devices, such as a diode shunt (see Figure 5 and 6), are required to provide the desired equipment protection.

16.4.2 Protection Of Process Controls With Milliampere Signals

A typical processing plant could have hundreds of analog 4-20 mA and discrete 24VDC signal transmission loops, either

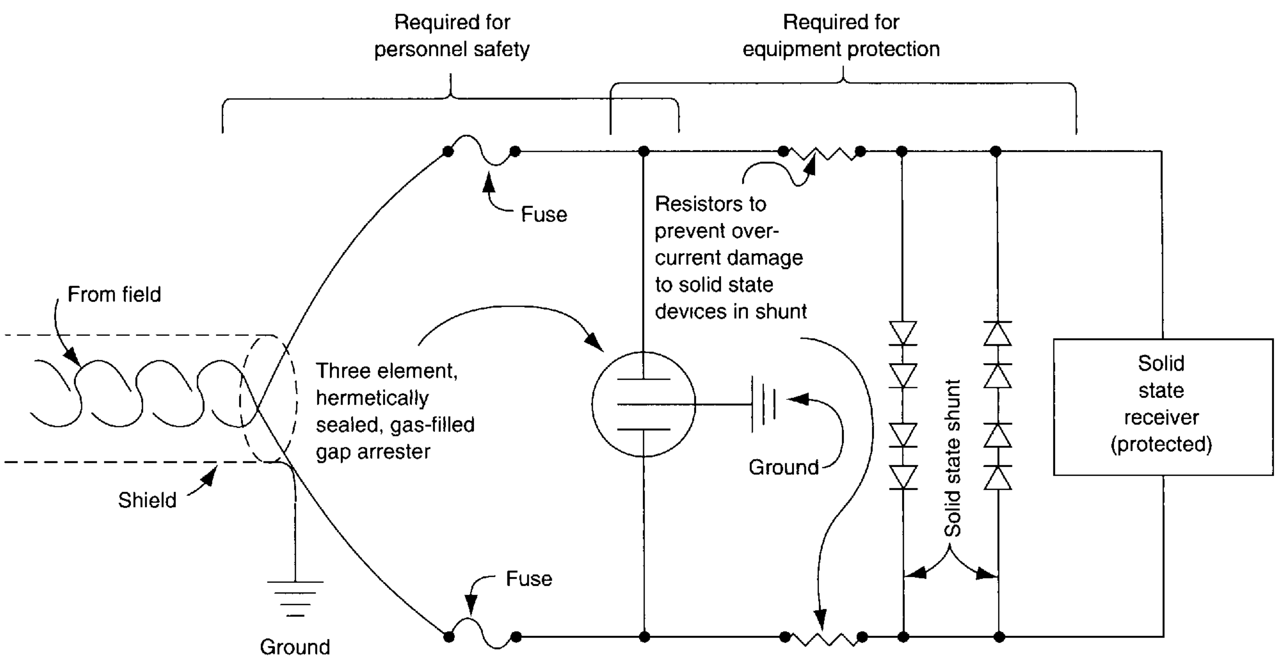


Figure 5—Typical Three-Terminal Gas-Filled Gap Arrester and Diode Shunt Lightning Protector

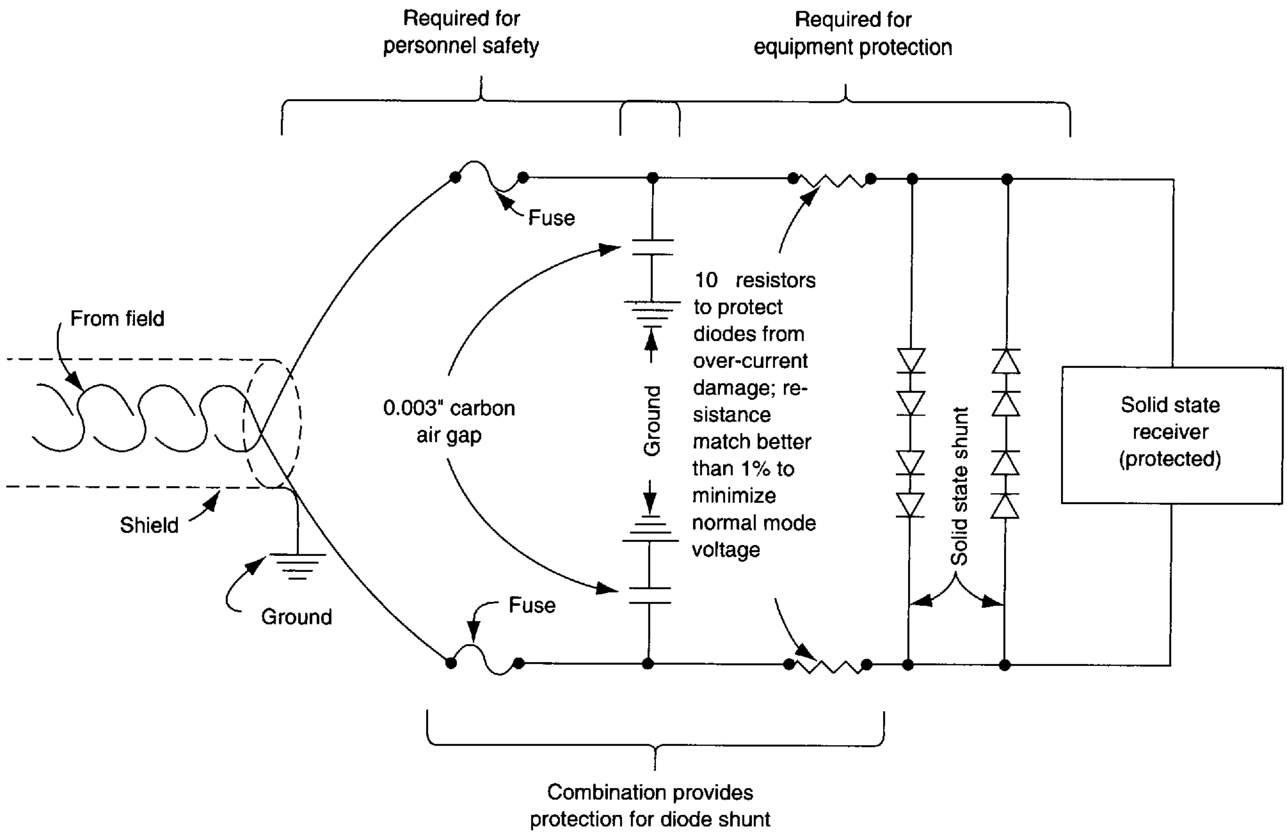


Figure 6—Typical Carbon Air Gap and Diode Shunt on A-C Signal Transmission

from single loop electronic controllers or from a Distributed Control System. Not all loops may have the same power-supply and transmitter designs, so different performance characteristics and surge limits would exist between loops, requiring a design variation in the surge protection devices.

It is apparent that an approach other than the design and installation of surge protection devices for individual lines is warranted. The economics of process plant design and installation dictate the protection of the signal transmission cable from transient surges only where there is a real threat of surges, such as in long runs to remote areas. The most obvious choices for protection are fiber optics or metallic shielding. In these instances, many signal transmission cables can be grouped together and protected in a common run. All spare conductors in a cable should be grounded at one point so that they do not act as antennas and impose high voltages on the signal circuits when lightning strikes nearby.

16.4.3 Protection Of AC Transmission Signals

Refer to Figures 5 and 6 and assume that the solid-state receiver is not damaged by a sustained common-mode voltage of 400 volts or a sustained normal-mode voltage of 5 volts, and that the pulsed, phase-modulated, or frequency-modulated transmitted signal is to be +/- 2 volts. This example could be considered typical for a telecommunication installation. For such an installation, silicon diodes can be used to shunt to ground the potentially damaging normal-mode voltage (5 volts). This proceses is done by shunting to ground through the first gap arrester activated.

The diodes, installed as shown in the figures, have a low shunt conductivity for the 2-volt signal level but become highly conductive when 0.9 volts per diode is exceeded (four diodes in series would become conductive at 3.6 volts). The break-over voltage must be higher than the operating signal voltage so that the signal pulses will not be clipped.

The diodes selected normally have a peak current rating of 50–80 amperes and require protection from surge damage. For this reason, limiting resistors or some other devices that increase impedance are installed ahead of them. These impedance-increasing devices should be matched so that they do not induce unwanted normal-mode voltages on the signal lines.

Care must be exercised to ensure that the capacitance introduced by the diodes as well as the resistance added by the resistors and fuses do not impair the accuracy of the transmission signal.

If the maximum common-mode voltage of the receiver is limited to 250 volts, a carbon-air gap arrester cannot be used.

A specially designed three-element, hermetically sealed, gas-filled gap arrester with a break-over voltage of less than 250 volts is required, as illustrated in Figure 5.

In the case of communication systems, conductors are usually small and cannot transmit large transient currents. Thus the protectors can be smaller with lighter-duty requirements. However, operation is usually at higher frequencies where protector insertion losses could be significant. Over-voltages must be limited to a much lower level than with power systems, since the protected circuitry contains integrated circuits, etc. Protection of audio frequency systems is best done with varistors or Zener diodes; whereas, protection of radio frequency systems (VHF and higher frequencies) is best done with a spark gap device, due to the unacceptable capacitances of varistors and semiconductor devices.

17 Wiring For Field Mounted Process Instruments

17.1 LEAKAGE OF PROCESS FLUID

Electronic components shall be located in that part of the instrument which is isolated from the process. This isolation will prevent damage to the electronic components, and eliminate the potential for process fluids to enter the wiring system.

Type MI (Mineral-Insulated) cable from the instrument to the wiring system is one method used successfully to effectively block process flow .

17.2 MOISTURE

Moisture may affect instrument performance and may cause corrosion of the electrical components.

Type MI (Mineral-Insulated) cable has been used for this purpose.

17.3 TEMPERATURE

The manufacturer's specifications for high and low environmental temperature limits should be consulted, particularly for instruments that require heat tracing. Instruments and connecting wiring must be suitably designed and located to withstand abnormal temperatures. Thermocouple wiring around furnaces should be given special consideration if it will be exposed to high temperatures.

17.4 TYPICAL WIRING PRACTICE

Article 501 of the National Electrical Code (NEC) gives specific electrical requirements for the installation of field wired electrical instruments in Class I hazardous (classified) locations.

It is not the intent of this section to repeat the detailed requirements of the NEC.

17.5 FACTORY SEALED ENCLOSURES

NEC 501-5(c)(5) allows assemblies with the arc, spark, or high temperature element located in a "factory sealed" compartment separate from the compartment containing the splices or taps to be approved for Class I installations without an external conduit seal.

Note: Special attention should be given to NEC 501-5(f)(3),which requires that instruments which depend only on a "single compression seal, diaphragm, or tube to prevent flammable or combustible fluids from entering the electrical conduit system" must have an additional approved seal, barrier or other means "to prevent the flammable or combustible fluid from entering the conduit system beyond the additional devices or means, if the primary seal fails." A conduit seal does not meet this requirement.

17.6 NON-INCENDIVE DESIGN (DIVISION 2), INTRINSICALLY SAFE DESIGN (DIVISION 1), PURGED ENCLOSURES, AND MI CABLE INSTALLATIONS

Non-Incendive Design (Division 2), Intrinsically Sage Design (Division 1), Purged Enclosures, and MI Cable Installations are various methods which in general allow the relaxation of explosion-proof or sealing requirements for the various hazardous areas in which they are approved. Specifically, Intrinsically Safe installations allow wiring methods suitable for unclassified locations. Refer to the NEC, ISA, and NFPA standards for specific requirements concerning these installations.

17.7 DRAINAGE REQUIREMENTS

NEC 501-5(f) requires that if an enclosure is likely to trap liquid or condensed vapor, an approved means must be provided for periodic draining. Combination drain/breathers should be considered.

17.8 OTHER SEAL REQUIREMENTS

In addition to the seals mentioned above adjacent to instrument enclosures, the NEC should be consulted concerning additional seals required when entering termination boxes, when conduit passes between different hazardous area classifications, etc.

18 Junction Boxes

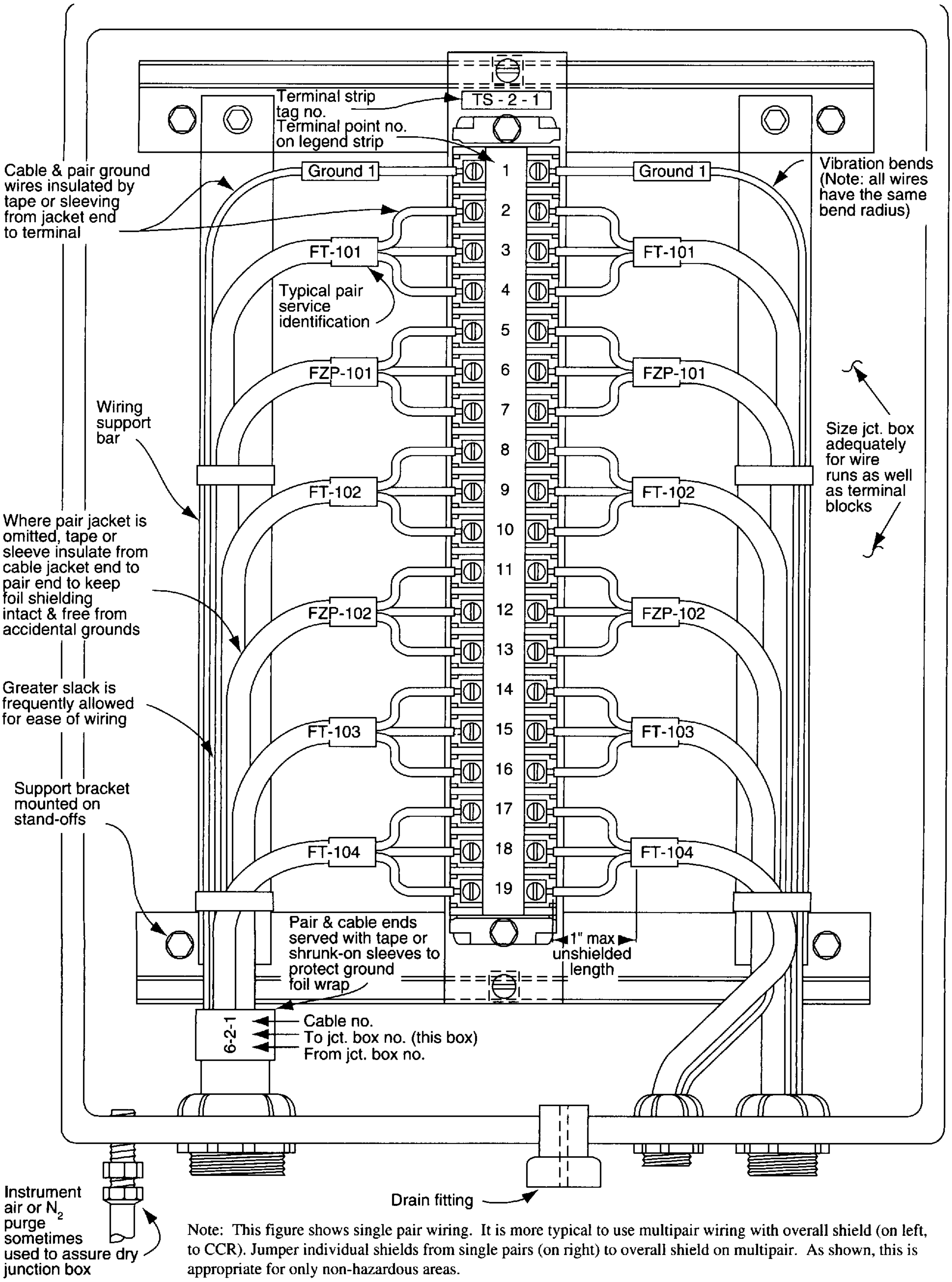
18.1 USE OF BOXES

Junction boxes (see Figure 7), should be used to provide a convenient location in which to connect instrument wiring. These junction boxes should be used to identify wires, to join wires in an orderly arrangement, to enable reasonable lengths of cable to be purchased and installed, to break out into smaller cables or wires, and to do the testing and repairing associated with instrument circuits and wiring. Wire splices should not be used.

Normal practice is to run a single-pair wire from the field instrument to the junction box, and multipair cable from the junction box to the control room.

18.2 FACTORS IN BOX SELECTION

Junction boxes for instrument wiring should be suitable for the service required. Although this principle is elemen-



Note: This figure shows single pair wiring. It is more typical to use multipair wiring with overall shield (on left, to CCR). Jumper individual shields from single pairs (on right) to overall shield on multipair. As shown, this is appropriate for only non-hazardous areas.

Figure 7—Typical Junction Box

tary, it is often overlooked. The following factors are involved in box selection and design:

a. Indoor versus outdoor location.
b. The electrical area classification.
c. Intrinsically Safe versus non-Intrinsically Safe installation.
d. The presence of a corrosive atmosphere or dripping liquids.
e. The need to exclude nest-building insects, rodents, and other wildlife.
f. The materials of construction for the box, which may be painted, galvanized, or aluminized carbon steel; painted, galvanized, or aluminized cast iron; aluminum; stainless steel; or fiberglass or plastic resin. Some caution is suggested in the use of fiberglass or plastic resin boxes: limited life has been experienced in some cases, due to ultraviolet damage.
g. The material of construction for the hardware (hinges, fasteners, and similar items), which may be the same material or one superior to that used for the rest of the box.
h. Security requirements (key locks or other deterrents).
i. The size of the box, based on the number of terminal strips involved; the wire space between, behind, above, and below the terminal strips; and the side or bottom area required for the entry or exit of cables, ducts, or conduits.
j. The need for access to the box, and the number and type of doors or cover plates.
k. The need for fire and blast protection.
l. The minimum cost that is consistent with the service requirements.
m. Allowance of adequate terminals for the shields.

18.3 BOX DESIGN

A single box design cannot meet all possible requirements. NEMA Type 12 design, is appropriate for indoor use. NEMA 4 is used outdoors and NEMA 4X is appropriate for corrosive areas. Under very corrosive conditions, boxes made entirely of stainless steel, fiberglass, cast iron, epoxy-coated steel, or aluminum have been used, together with dry-air or nitrogen purges to protect wiring within the box. Although sheet metal is the usual material of construction, heavy steel plate has been used for blast protection where critical services have to be maintained. This protections allows correct and orderly shutdown after a blast has affected the area. Light sheet metal offers notoriously poor blast resistance and should not be used if blast damage is critical. Some users have indicated a preference for NEMA Type 4 construction (see ANSI/NEMA 250) because these

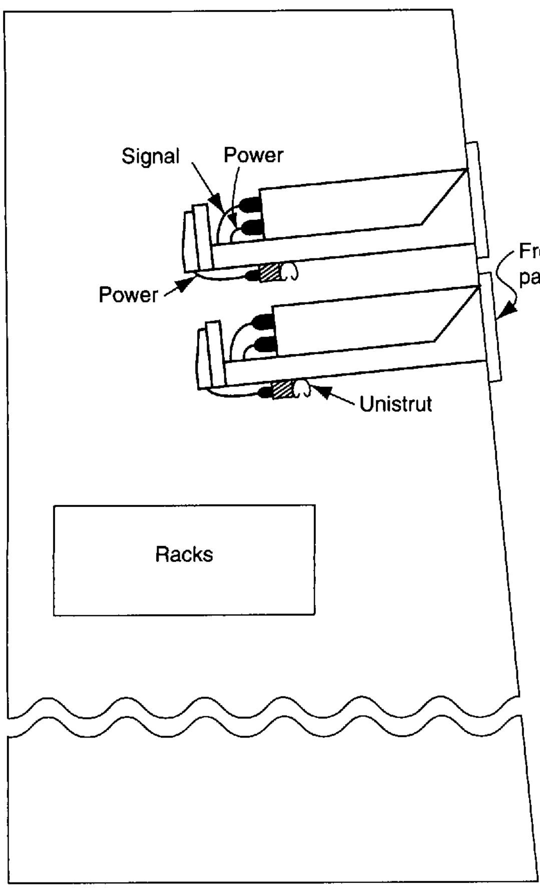


Figure 8—Panelboard Wiring Terminating Field Wiring at Instruments

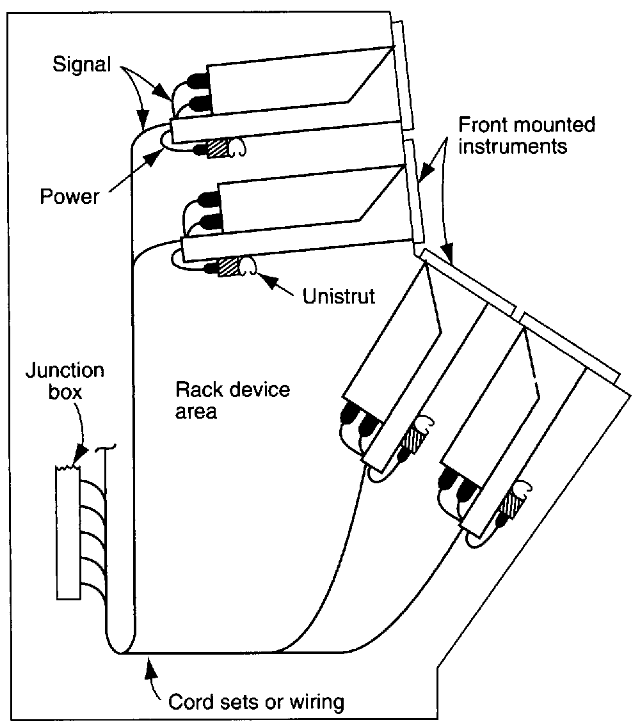


Figure 9—Panelboard Wiring Terminating Field Wiring at Panel-Mounted Junction Box

boxes remain watertight during washdowns. Where Type 4 boxes are used, oil-resistant gasketing should be specified, since NEMA does not require Type 4 boxes to have such gasketing. NEMA 4X is used where corrosion is severe (see Figure 9).

18.4 INTERIOR COLOR

The interior of junction boxes should be white to improve visibility.

18.5 MOUNTING OF BOXES

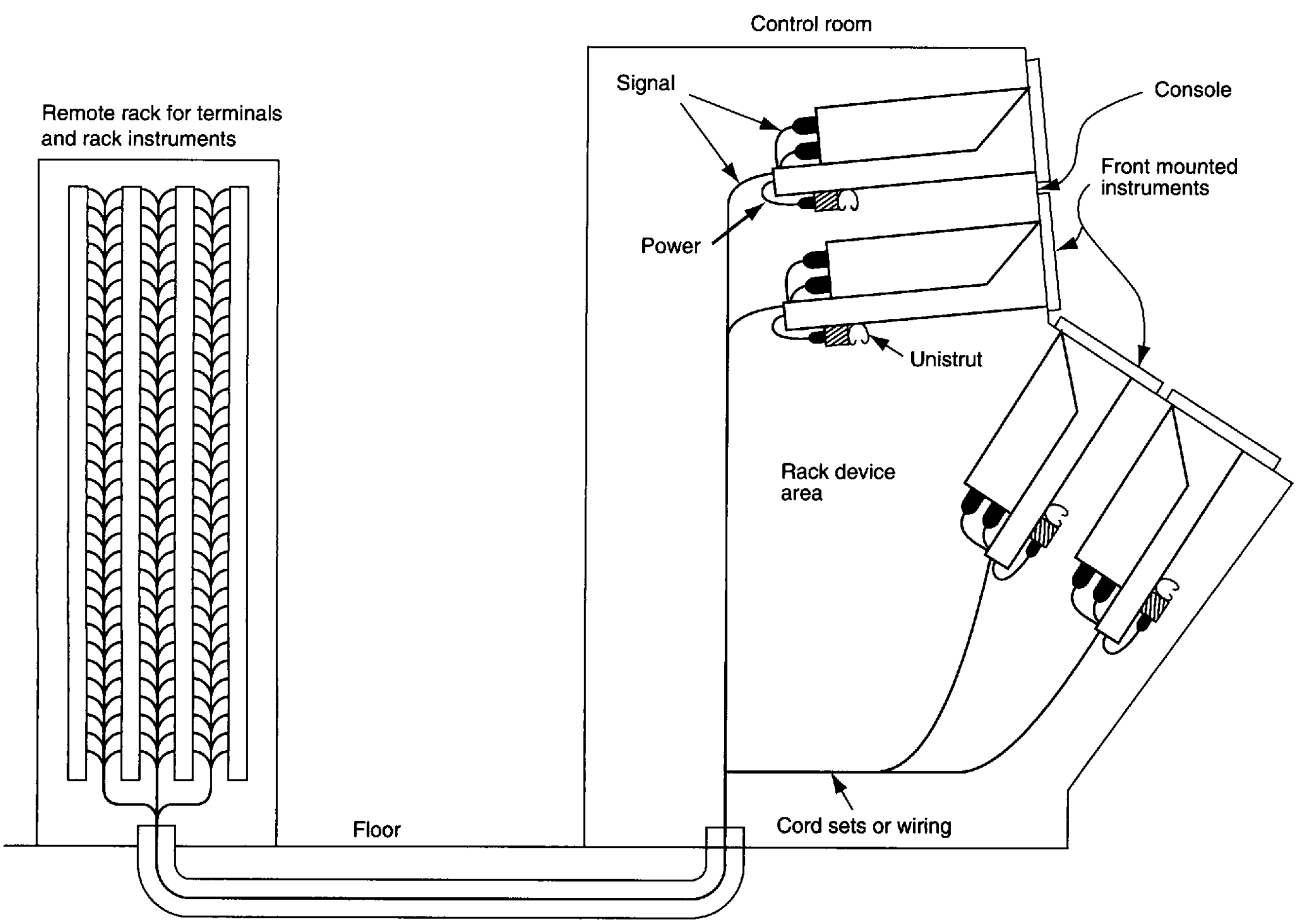
Practices for mounting junction boxes vary widely.

Where cables runs are underground, junction boxes should be mounted at an easily accessible height. Mount the top of the junction box about 6 feet (1.8 meters) above grade and encase all conduit from grade to the box in concrete or another fire-resistant material. This design minimizes cable repair after a fire. The protected wire below the box will probably survive a fire, but wire in and above the box will probably be damaged beyond use. If such damage occurs, the protective material is removed and a junction box is mounted closer to grade; the underground wire runs are long enough to tie into the new terminals in the lower box.

Boxes are usually mounted on columns, pipe supports, or other vertical supports, when these are available. Separate footings and support steel are provided if needed.

Conduit and cable entry through the top of the box is to be discouraged due to the loss in water-tight integrity.

Bottom entry is preferred for wiring simplicity. Side entry is permissible. Bottom drains, possibly with screens to discourage insect nests, will reduce the accumulation of water. The cables entering the box may also be sealed to reduce the entry of water.



Note: Wire may be as shown or overhead. The conduit as shown may be below the floor but is above grade.

Figure 10—Panelboard Wiring Terminating Field Wiring at Separate Junction Box

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18.6 MOUNTING OF TERMINAL STRIPS

Terminal strips should be mounted on sub plates for convenience, improving access for construction and maintenance and maintaining better watertight integrity.

18.7 GROUND CONTINUITY FOR SHIELDS

To comply with the requirement for grounding shields at only one point, use a terminal point to carry each shield through the terminal box. Insulate both the shield end and the shield drain wire between the end of the cable jacket and the terminal strip (see Figure 7). Since only one end of a shield is grounded, each cable has an ungrounded end. This cable end is finished with no ground, and insulation is applied over the trimmed cable end to avoid accidental grounds on any exposed shield or the shield drain wire.

19 Control Room Wiring

19.1 GENERAL

The available space within a control room is usually limited, and care must be taken to prevent the space limitations from resulting in poor wiring practices.

The guidelines for junction boxes in Section 18 apply to large boxes in control rooms, but the size of control room boxes presents unique problems. Sometimes entire rooms are set aside for use as junction boxes. Although the room itself is, in effect, a large junction box, boxes are still desirable to prevent dust from collecting on terminals and to provide shielding to isolate one type of wiring from another.

19.2 FIELD WIRING TERMINATIONS

Field wiring may be terminated at any of two locations:

a. The connections in a panel instrument (Figure 8).
b. Terminal strips mounted in separate junction boxes.

Terminating the power and field wiring, including shields and shield drain wires, at the instrument connections is best suited for high-density instrument systems, since the instrument terminal blocks are closely grouped. This method has the advantage of reducing the number of connections, thus reducing panel cost and simplifying instrument checkout. However, this method can have the disadvantage of increasing wiring time if the instruments are not closely grouped (see Figure 9).

When the field wiring is terminated at terminal strips mounted in separate junction boxes, prefabricated cables are used to connect the junction boxes to the panelboard or DCS, Figure 10. Shield drain wires are often tied to a ground bus in the junction box. With this method, the previously mentioned practices of insulating shield ends and drain wires should be followed to avoid accidental grounding at more than one point. Terminal strips on the panelboard itself may or may not be used. In addition, rack-mounted equipment can be mounted near the terminal space where rear panel space is limited or its use is undesirable.

Marshalling panels or cabinets are used to accomplish the following:

a. Provide for "Scramble" wiring; the arrangement of wires from the field are re-arranged to match the needs of the control system.
b. Provide a location for IS or surge barriers.
c. Allow pre-wiring from the field before the control system is available.

19.3 OTHER CONTROL WIRING

Wiring between the control system racks and other areas may be located overhead or under the floor and may be in conduit, ducts, trays, trenches, or other raceways. Guidelines for installation are given in Sections 13 and 14.

On a large job, the use of the two methods, both overhead and under the floor, can minimize congestion and aid in system segregation. One method is to use elevated flooring, or Computer Floors, to provide space for wireways (see Figure 11).

19.4 PRECAUTIONS FOR POWER SUPPLY WIRING

Wiring for AC or DC power should be separated from signal wiring to reduce electrical interference (see Table 3, Section 6, and 9.2).

Interference can be picked up by DC power-supply wires and fed back through the power supply to other instruments.

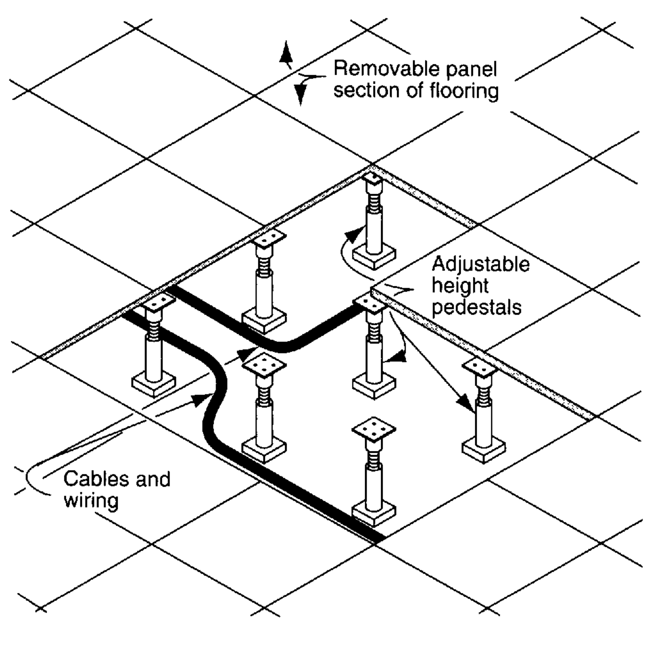

Figure 11—"Computer" Floors

FOREWORD

This publication reflects the current practices in the transmission of instrument measurement and control signals in a refinery.

Throughout this publication, soft-conversion (calculated) units are provided in parentheses following actual units. Soft-conversion units are provided for the user's reference only.

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