ENGINEERING STANDARD

FOR

TRANSMISSION SYSTEMS

CONTENTS :

PAGE No.

APPENDICES:

ILLUSTRATING FIGURES :

TABLES :

1. SCOPE

This Standard discusses recommended practices for design and engineering of the two main kinds of signal transmission systems, i.e., pneumatic and electric signals.

Digital signals transmission and communication protocols are covered by IPS-E-IN-250 "Distributed Control System". It is intended to be used in oil,gas, and petrochemical industries.

2. REFERENCES

Throughout this Standard the following standards and codes are referred to. The editions of these standards and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, from a part of this Standard. The applicability of changes in standards and codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the vendor.

API (AMERICAN PETROLEUM INSTITUTE)

RP 550 "Installation of Refinery Instruments and Control Systems"
Part I "Process Instrumentation and Control", Section: 3&7 "Transmission Systems & Temperature Measurements"

ISA / ANSI (INSTRUMENTATION SOCIATY OF AMERICA / AMERICAN NATIONAL STANDARDS INSTITUTE)

MC 96.1 "Temperature Measurement Thermocouples"

IPS (IRANIAN PETROLEUM STANDARDS)

E-IN-250 "Distributed Control Systems"

3. UNITS

This Standard is based on International System of Units (SI), except where otherwise is specified.

4. GENERAL

4.1 The use of transmission systems, that permit operation of one or more large process units from a remote control center, increases personnel safety and convenience. Because the measuring device or transmitter is at, or as near as possible to the point of measurement, certain advantages accrue. This arrangement reduces the following requirements, to a minimum:

a) The amount of connecting piping carrying process fluids which may be unstable, corrosive, toxic, viscous, or subject to freezing.

b) The need for purging, sealing, heat tracing, and winterizing.

c) The presence of hazardous or noxious fluids in, if not totally excluded from, the control center.

4.2 The correct design and installation of measurement and control signal transmission system shall be essentially based on the consideration of the following points:

4.2.1 The design and construction of the transmission systems shall result in satisfactory performance at an acceptable cost.

4.2.2 The installation of leads (electrical, pneumatic) shall be so as to minimize the possibility of damage by fire, mechanical shock continuous vibration, leakage and electrical interferences.

4.2.3 Use of viscous, unstable, corrosive, toxic, or freezing fluids, slurries,and crystals etc., shall be avoided.

4.2.4 Hazarddous or noxious fluids shall be excluded from control rooms. Also high voltage shall be excluded from control boards cabinets, assemblies etc., both in control rooms and local control centers.

4.2.5 It is essential that transmission systems shall not introduce obstacles which prevent access to instruments. Provision shall be made for manual control, testing and ready access for normal preventive maintenance, modification etc., to the instruments.

5. LOCATION AND ROUTING

5.1 Overhead conduits shall be routed in such a way to minimize possible accidental mechanical abuse and damage to wires, tubes from fire or overheating. Conduits shall not be installed close to hot lines.

5.2 Air lines, etc., may be run along pipe racks but generally shall be supported throughout the installation.

5.3 Consideration shall be given to the underground runs, which often may be shorter, better protected against fire or mechanical damages and more economical than overhead lines. However they shall be avoided in locations where flooding with hydrocarbons or corrosive liquids is possible.

5.4 It is essential to include sufficient spare tubing and conductor cables in underground multitube and multicore cables.

5.5 Trays may be used advantageously when a large number of single tubes or bundled cables are run. This construction provides an advantage in maintaining a system made up of single tube runs because any tube can be individually traced, repaired, or replaced with the minimum disturbance to rest of the system.

6. PNEUMATIC SYSTEMS

6.1 Pneumatic signal transmission systems shall have a pressure range of (0.2-1.0 bar). However (0.4-2.0 bar) may be used, by agreement with the user for actuating operators which stroke control valves with abnormally high pressure drops.

6.2 Penumatic transmission lines shall be ¼ or 3/8 inch outside diameter tubing. The ¼ inch size is preferred, with typical wall thickness variation from 0.762 mm to 1.016 mm. The tubing shall be PVC sheathed copper for single runs and bundles. Underground multitube polyethylene cable with galvanized steel flexible armour and protected overall against corrossion by a polyethylene jacket may be used when practical and economical by agreement with the user. Where specified, multicore tubing shall include a pair of telephone wire. ¼ inch size gives optimum performance, based on minimum transmission time constant versus cost, for the air handling capacity approximately 1 standard cubic foot per minute (SCFM) of the majority of available transmitters and controllers.

6.3 Tubing of 3/8 inch outside diameter with a typical wall thickness variation from 0.762 mm to 1.524 mm is used in instances where the transducer and controller have greater air handling capacity than 1 scfm, and transmission time constants must be reduced for good overall control.

6.4 Long continous tubing runs should be used to minimize the number of joints.

6.5 Bare ends and fittings should be protected against corrosion by protective covering which is either corrosion resistant compound or self sealing plastic tape.

6.6 Dead soft annealed copper tubing is generally preferred. Stainless steel may be used in special cases.

6.7 The pneumatic transmission lines shall be properly supported and protected against mechanical damage or overheating. The troughing shall be adequately supported throughout its run in the plant (see Fig. 5).

6.8 When installing multitube cables, each tube must be appropriately coded throughout its length to permit positive identification.

6.9 In multitube cable systems, at least 10 per cent or not less than two tubes per bundle, shall be provided as spares. In overhead installations, 25 percent of spare spacing shall be provided for future expansion.

6.10 When specified, aboveground multitube cables shall be run on trays.

6.11 When the length of the transmission line between a controller and the corresponding control valve exceeds 75 m the line shall terminate in a small volume device (e.g., a valve positioner).

6.12 Provided the characteristics of any control system are not adversely affected, transmission distances may be up to 200 m. For distances greater than 200 m the system shall be agreed with the user.

6.13 For control loops requiring fast response, the length of tubing shall be kept as short as possible, the controller may be field mounted if necessary.

6.14 Single or bundled tubes may be run from field mounted instruments to the central control room. The selection of either single or bundled tubes is based on engineering economics. Single or bundled tubes run from various field mounted instruments to collection points around a processing unit. From the various collection points the tubes meet and follow a common route to the control room. Individual tubes are run to junction boxes, which serve as collection points,and then from each of the junction boxes, bundled tubes are routed together to the panel in the control room (see Fig. 3).

6.15 Junction boxes provide neat installation, and protection against flash fire corrosion, weather, and prolong the legibility of tubing tagging information.

6.16 Individual tube installations are always mounted above ground and are supported by trays, these tray designs can differ, they may be "trough" or "ladder" types.

Bundled tubing should be run underground unless otherwise specified. When it is run above ground, it may be supported by trays messenger cable, or clamps (brackets). When run under ground, the bundles may be in sand filled trenches or in conduit which is embedded in concrete (see Figs. 4&5).

7. ELECTRICAL SYSTEMS

7.1 General

7.1.1 The discussion of electric signal transmission necessarily includes signals, analog or digital that are used in measurement and control systems. The instruments include sensing elements, transmitters, analyzers, controllers, and display devices.

7.1.2 It is essential that all electrical systems (i.e., specification for equipment, enclosures, wiring and installation methods) shall strictly conform to the requirements of electrical systems standards of IPS.

7.1.3 Instrument signal systems for analog direct current signals, shall be in the range of 4-20 mA, normally.

7.1.4 The polarity with respect to references potential of instrument system voltages shall be compatible throughout the earthing system.

7.1.5 In order to ensure maximum interchangeability between transmitters and receivers, the voltage drop across the transmitter in two wire systems shall not exceed 12 volts at maximum current.

7.1.6 The grounding practices in instrumentation are divided into two classes, those concerned with personnel safety and those concerned with signal accuracy (see 7.11).

7.2 Reducing Electrical Interference

7.2.1 Electrical interference is any spurious voltage or current arising from external sources that appears in the signal transmitting circuit. When these voltages become too large, the system has a poor signal to-noise ratio (see APP. A).

7.3 Engineering Factors for Wire Type Selection

7.3.1 Selection of wire size should be based on using the smallest wire size which will not cause an excessive voltage drop and which has sufficient strength and workability.

7.3.2 Normally the largest size used for single conductor wire is 2.5 mm^2 (13 AWG), for single twisted pair is 1.5 mm^2 (15 AWG), and for multipair cable is 0.75 mm^2 (18 AWG) other sizes can be selected for reasons of economy, space or application requirements (see Tables No. 1& 2).

7.3.3 Stranded wire is preferred because of its flexibility and resistance to breakage by bending. Normally seven strand wire is used.

7.3.4 The insulation of signal wire should be adequate for the wire's operating voltage and current. Wires in the same raceway must have insulation adequate for the highest voltage on any of the wires.

7.3.5 Wire to wire and wire to ground resistance should normally exceed 10 megohms on most application. This requirement is also applicable to the shield drain wire, as accidental shorts or grounds is expected.

7.3.6 The wire or cable should have a temperature rating high enough for the anticipated environment. In the very cold location the lowest temperature at which the wire or cable is rated is also of interest.

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

7.3.8 The preferred shielding is metallic foil with an overall spiral wrap and with 25-percent overlap. The shield should be electrically in contact with a copper drain wire which is as long as the pair of signal wires. The shield is electrically insulated both inside and outside. The overall shielding for a cable should have the same specifications and should also be insulated on both sides.

7.3.9 In twisted wire the minimum number of twists per meter should be (18), (24) twists per meter is a typical specification.

7.3.10 For wire pair identification, either a number code or color coding can be used.

7.3.11 Inclusion of communication wires in any multiple pair cable should be considered.

7.4 Guides on Separation

7.4.1 All the signals in one cable or conduit should be of the same magnitude. When wires for a wider range of signals must be placed in the same cable or conduit, individual pairs should be shielded and the shield grounded at one point. Wires conducting AC signals should also be segregated from wires conducting DC signals of comparable magnitude (see Table No. 3).

7.4.2 As a guide for grouping wires bearing electric signals of the same magnitude, generally refer to the following list:

DC voltage signal
signal < 100 mv
100 mv < signal < 5 volts
5 volts < signal < 75 volts
AC voltage signal
Same boundaries as for DC voltage signals
DC current signal
Signal < 50 mA

7.4.3 The wiring from some sensors must be completely separated from other sensors or signal circuits. The sensors whose wiring should be completely separated are glass PH electrodes, magnetic flow meters, turbine meters, detector in chromatographs, and AC powered bridges.

7.4.4 Thermocouple wiring should not be mixed with wires bearing milliampere signals, because of the great difference in electrical potential.

7.4.5 Wires for circuits in which sharp voltage pulses are transmitted, such as relay contact closures, relay coils, solenoid, and the like, should be segregated from other wiring.

7.4.6 Signal and power wiring should not be in the same conduit, tray or junction box. (See Table No. 3.)

7.4.7 Intrinsically safe wiring should be physically segregated from other wiring.

7.4.8 Wires operating at more than 100 volts AC or DC are considered power wires.

7.4.9 The power level in signal wiring is generally below 5 watts.

7.4.10 Enclosure in steel conduit effectively reduces the interference.

7.4.11 Magnetic field interference occurs when signal wires pass through strong AC fields which are present near large motors, generators, electric furnaces, or transformers. As a general rule, a minimum of 2 meters of clearance should be allowed between noise generating equipment and signal carrying wires. If steel conduit is used, clearance can be reduced to half this value. (See App. A.)

7.4.12 Signal leads should, if possible, enter or exit AC powered equipment at right angle to its magnetic field. Cross-overs that bring power and signal wiring in close proximity to each other (300 mm) should be made at right angles.

7.4.13 Common mode voltage is a voltage which appeares between the measuring circuit terminals and ground.

7.4.14 Errors due to the presences of common mode voltage are reduced by balancing the line resistance and making the impedence between ground and line equal and as large as possible. refer to API RP 550, Part I, Section 7, transmission systems and Appendix A.

7.5 Effect of Transmission Distance Installations

7.5.1 The following is normally used for demarcation between short, medium, and long-distance installations:

Short	0	to	200	meters
Medium	200	to	1000	meters
Long	over	1000	meters	

7.5.2 The length of the transmission line affects the magnitude of the electrical interference which is mixed up with the signal. Wiring that traverses a relatively short distances does not need the same protection against electrical interference as a longer run which goes through the same environmental conditions.

7.5.3 Signal level to be transmitted should be considered. A high level signal is easier to accurately transmit than a low level signal.

7.5.4 Normally signals less than 100 millivolts, are considered as a low level signal. considerably higher levels are desirable when possible. A good combination is a high level signal and a wire which is less susceptible to electrical interference.

7.6 Trays and Conduits

7.6.1 Unless otherwise specified cable trays, should be used to support a large number of cables between two major points. (See Fig. 5.)

7.6.2 Tray use is generally limited to runs from field terminal boxes to the control room and to the distribution of cables within the control room.

7.6.3 Trays are either horizontal or vertical type.

7.6.4 For cable tray system protection from device failures, cable failures, lightning, and accidental contact with other electrical wiring, the tray system must be effectively bonded and grounded. A bare copper bonding cable is frequently installed in the tray to provide electrical continuity for grounding. Usual structural mounting practices will ground trays at many points.

7.6.5 Control and signal cables in trays, may touch each other and may be in one or more layers.

7.6.6 Metal barriers approximately twice the height of the larger cable shall be used to separate different signal types as needed.

7.6.7 Environmental conditions must be considered in selection of tray and conduit materials. Galvanized steel trays and conduits should be used where the best electrical shielding capability is desired.

7.6.8 Dead loads such as the weight of the cable and tray and live loads such as ice, snow, wind, earthquake, and pulling in forces must necessarily be considered, during tray system structural design.

7.6.9 In order to ensure the safety of all personel who come in contact with tray installation's specifications should require that all fabricated pieces be free of burrs and sharp edges.

7.6.10 Trays may be covered with insulation in fire hazard areas.

7.6.11 The pulling tension should not exceed the cable manufacturer's recommendations

7.6.12 Above ground conduit runs may be used for individual instrument wiring to terminal boxes for handling wires and cables from terminal boxes to the control room.

7.6.13 Non-metallic conduit materials are seldom used above ground in process plants outside control rooms and they are not recommended for instrument wiring, since these provide no electrical shielding.

7.6.14 When conduits are used for electrical transmission signals, they shall be supported at least once every 2000 mm. They should never be supported from process piping.

7.6.15 The shielding effect of steel conduit is seriously reduced if electrical continuity is lost. Conduit runs should be solidly connected to assure continuity for their entire length. Taper thread connection's should be used on rigid conduit.

7.6.16 Trenches and conduits are used primarily, because they offer the possibility of more direct routing, avoid any overhead obstruction, make for a better appearing process plant, and if properly designed, are less subject to mechanical and fire damage. The possibility of damage to cables because of fluid immersion is greater, however underground installations require particular design and installation care when used in plant areas that may be saturated with hydrocarbons or corrosive chemicals particularly aromatics.

7.7 Lightning Protection

7.7.1 Instrument signal cables may be exposed to high voltages caused by lightning, atmospheric electrostatic phenomena, power line transients, or power lines falling on them. Ordinarily, no protection is required if transmission cables are enclosed in trenches, or grounded metallic conduits.

7.7.2 Consideration must be given to installation of protective devices, for personel safety and instruments protection.

These devices are as follows:

1) Shield wires
2) Carbon air gap arresters.
3) Hermetically scaled, gas-filled gap arresters.
4) Solid-state devices.
5) Fuses.
6) Inductive and resistive limiters.

Refer to API- RP 550, Part I, Section 7, for additional information.

7.8 Seals and Drains

7.8.1 The possibility of failure of an instrument part containing process fluid should be considered. Leakage from a diaphragm, bourdon tube, bellows, Sealing tube, torque tube, thermowell, and other parts containing fluids may damage the electrical components of the instrument if they are in the same housing as the measuring element. Likewise, failure of the electrical components of other instruments caused by leaks flowing through common piped raceway interconnections is possible. Such failure can be minimized by use of seals and drains.

7.8.2 Drains and seals should be considered in order to prevent moisture in a conduit system from flowing into and accumulating in an instrument or its terminal box.

7.8.3 When moisture is a problem, corrective measures include the use of protective coatings, desiccant bags, heating or dry air or nitrogen purge.

7.8.4 Instruments and connecting wiring must be suitably designed and located to withstand abnormal temperatures.

7.8.5 AC heaters when used in junction boxes for eliminating the moisture problem, should not introduce noise in to signal circuits in the box.

7.9 Junction Boxes

7.9.1 Junction boxes are used to provide a convenient location in which to connect instrument wiring. Junction boxes are a suitable place to identify wires, to join wires in a neat 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 tasks associated with instrument circuits and wiring. (See Fig. 7.)

7.9.2 Junction boxes for instrument wiring should be suitable for the service required.

7.9.3 Terminal strips should be mounted on plastic standoffs to provide thermal insulation between the metal of the box and the terminal strips.

7.9.4 A terminal point should be used to carry each shield through the terminal box. Accidental shorting or grounding of shield within a terminal box must be avoided, by insulating both the shield end and the shield drain wire between the end of the cable jacket and the terminal strip.

7.10 Control Room Wiring

7.10.1 Wire routing in the control room should be done while keeping in mind guides on reducing electrical interference, by taking into account the separation considerations.

7.10.2 The termination of field wiring in the control room may be done by three methods:

1) At the connections in a panel instrument.
2) At terminal strips mounted on the panel board.
3) At terminal strips mounted in separate junction boxes.

7.10.3 On large job, the use of both approaches, overhead and under the floor, can minimize congestion and aid in system segregation. One system is to use elevated flooring or "computer floors" to provide wire way space.

7.10.4 Wiring in the back of panel board may be open (normally in laced bundles), in conduit, or in ducts. Panels can be enclosed or open. In addition to intrinsically safe and non-intrinsically safe signal transmission wiring, wiring for power, alarms, and motor control circuits are also present. Good wiring practices require these groups be separated in accordance with the signal type and intrinsic safety requirements.

7.10.5 Open wiring is used in totally enclosed panel boards, but extreme care in distances between wires and routing of wires and cables to avoid stray electrical pickup is necessary.

7.10.6 Panel boards contain devices other than instruments that require electrical power. Wiring for AC or DC power should be separated from signal wiring to reduce electrical interference. The interference can also be picked up by DC power supply wires and fed back through the power supply to other instruments. This interference can be minimized by completely enclosing the power supply wiring in a steel wireway entirely up to the instrument case, by using short lengths of twisted pair cord where plug-in concepts are used, and by instrument case design which provides signal wire entry at a point some distance from the power entry point.

7.10.7 High density instruments are too close together to allow the standard separation distances. However, interference is not usually a problem since only short lengths of wire are involved and currents are low. Power cords are typically about 50 cm in length and plug-in connections are usually used where area classification will permit. Power supplies to individual instruments usually draw less than one ampere of current.

7.10.8 A cable containing only analog signals, which run from groups of high density instruments to a terminal block should not contain power supply wires under any circumstamnces.

7.11 Grounding

7.11.1 Most details on grounding practices have been developed by the power aspects of electrical work. protection of personel and equipment from lightning and fault currents have been prime considerations in such development. However, signal transmission circuits are sensitive to electrical interference that is induced along the wiring.

One of the methods for minimizing interference is the judicious use of grounds. The previous power industry practice of grounding various circuits to any convenient earth ground is not recommended for electric signal transmission circuits. The chief reason for not using more than one earth ground is that potential differences do exist between earth grounds at different points within a given area. These differences result from:

1) Ground return paths of electrical equipment.

2) Natural soil differences and "battery" action of the soil varying in voltage. Voltage differences in this case are usually less than a few tenths of a volt.

3) Cathodic protection currents impressed on steel in contact with the soil.

4) Induced currents caused by artificially induced magnetic fields, from electrical machinery and distribution systems, from electromagnetic activity such as radio station, radar (commercial and military, naval, and air craft), and from other sources of interference.

5) Ground faults of electrical systems.

6) Lightning and other atmospherically induced static charge phenomena.

Such potential differences can cause false signals, or "noise" in instrument circuits and often cause current flow in wireways, trays, and shields. These false signals can in turn induce noise in circuits within such enclosures. To avoid these problems, all signal systems should have only one high quality earth ground.

7.11.2 The consensus regarding instrument circuit grounds is that they should be as good as or better than power grounds in any given area. Power grounds are typically specified as a maximum of three to five ohms resistance to true earth ground for most plant applications.

7.11.3 The earth ground system separate from the power ground should be used, Unless otherwise specified. With this approach, care is necessary to avoid the accidental joining of the two ground systems. Electrical isolation of the instrument panel from incoming conduit, trays, building steel, AC power supply (normally 115 VAC), and the floor is accomplished in order to ensure separation of the two ground systems.

7.11.4 Upon completion a ground system should be tested to verify that an adequate system is availble. Periodically thereafter, testing should be repeated to verify that the ground system is still adequate.

7.11.5 The need for grounded transmission circuit and the location of the intentional ground is related to the type of instrument or sensor in the circuit. (For details refer to API-RP 550, Part I Section 7).

7.11.6 Shields on signal wires should never be left unconnected, grounded indiscriminately, connected to their signal pair, or tied to other signal leads.

7.11.7 The panel board is usually grounded through attachment to a ground bus which is attached to the panel.

7.11.8 The cases of instruments supplied with electric power should be grounded to protect personnel from electric shock.

7.11.9 On some installations, the instrument ground system must be isolated from other system grounds.

7.11.10 The panel board should have at least one ground bus.

7.11.11 Two buses may be used also, one for AC instruments, and the other for DC grounds.

7.11.12 Buses are typically 6 mm thick and 25 mm to 40 mm wide and constructed of copper material.

7.11.13 Each panel section should have its own bus, with the center of the bus connected to a ground point which is common to all panel section grounds and from which an adequately sized conductor leads to earth connection. (See Fig. 6.)

7.11.14 The grounding of cases should not be confused with circuit ground, which usually require other grounding procedures.

7.11.15 Conduit grounding, should be taken into account, if the presence of severe interference is indicated.

7.11.16 All exposed non-current-carrying metallic parts that could become energized with hazardous potentials must be reliably connected to the equipment grounding circuit.

Equipment grounding assures that hazardous potential differences do not exist between individual instrument frames or between an instrument frame and ground. Grounding circuits must have a resistance low enough to operate overcurrent devices should a ground fault occur within the instrument (see Fig. 6).

7.11.17 Single point grounding of low level instrumentation signal circuit should not be confused with the multiple grounding requirement of high energy power cable.

7.11.18 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 nearby lightning strikes occur.

APPENDICES

APPENDIX A
ELECTRONIC INSTRUMENTATION WIRING TECHNIQUES

1. Electronic instruments use medium and low level signals. These signals should involve small values of voltage or current. These signals should not be altered by any external means during their transmission from the transmitter to the receiver for if some of the signal is lost or otherwise modified, the receiver will give an erroneous reading. Therefore, signal transmission for electronic instrumentation requires careful wiring techniques. Many problems encountered with electronic instrumentation are the result of poor practice or arrangement in the design of signal wiring.

2. Good circuit continuity and good wiring and terminal block insulation are required if the full signal is going to reach the receiver, In order to maintain good continuity, all wiring connections must be well made, low resistance connections. Poor connections are usually high resistance and allow an unexpected voltage drop to develop in the circuit resulting in an erroneous reading. A connection of this type may change resistance with temperature, vibration, etc., and cause an erratic reading.

3. Good insulation (high resistance insulation) between individual conductors, between conductors and the conduit wall, between terminals, and between the terminals and the terminal box is provided by careful material selection and application. Most insulating materials lose efficiency when they are exposed to chemicals and moisture becoming, in effect, high resistance conductors. It is important that insulation be suitable for moist and/or chemical atmospheres. Moisture usually finds its way into outdoor installations of conduit and junction boxes. The most common way is for air and chemicals to be drawn in as the conduit and boxes cool. The moisture condenses and along with the chemicals remains at the low points in the conduit and boxes causing deterioration of the insulation and/or connections.

The signal may also be modified by additional voltages and currents (called "noise") that are unintentionally introduced into the signal transmission circuit. This noise is usually coupled into the transmission circuit from other wires running nearly and parallel to the signal wires or from currents flowing in one of the signal wires that is used as a common wire for several different circuits.

Noise introduced from nearby wires is coupled into the signal circuit through mutual inductance or capacitance between the nearby wires and the signal wiring. These effects are often experienced when power wires are run along side of instrument signal wires.

4. Mutual inductance is a type of coupling between conductors, such as that existing between the primary and secondary windings of a transformer. When a wire is carrying alternating current, a magnetic field is generated around the wire. If a signal wire is running along side of a wire carrying alternating current, it will be in the alternating magnetic field and as the changing magnetic field cuts through the signal wire, alternating current will be generated in it. This effect is directly proportional to the current flowing through the source line and to the distance that the lines are running parallel. It is inversely proportional to the square of the distance between the wires.

The noise produced in signal lines through mutual inductance can be greatly reduced by running the instrument signal lines the maximum distance away from lines carrying power or other high-level alternating and pulsating currents; running signal lines in a magnetic shield such as steel conduit, using twisted wires to cancel inducted currents; providing common mode rejection in the receiver instrument. Noise is not inductively coupled to signal lines that are running at right angles to the AC wiring.

5. NOISE REDUCTION BY TWISTED PAIR

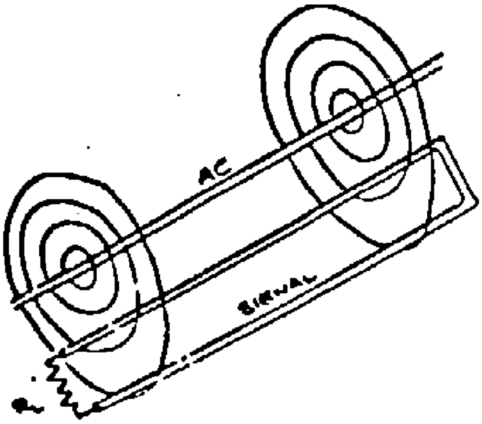


Fig. A

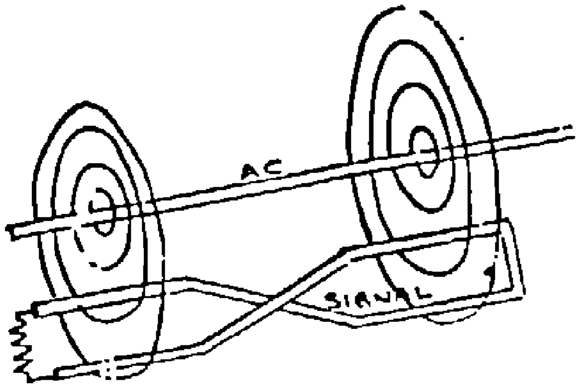


Fig. B

The advantages of a symmetrically twisted pair transmission line over a parallel pair of wires are based on the fact that much of the induced noise will be canceled out.

When a parallel pair of wires are run along side of a wire carrying an alternating current as in Figure A, the resultant alternating magnetic field generates an alternating current in each of the parallel signal wires. The signal wire nearest to the source of the alternating magnetic field will be in a denser portion of the field and will therefore have a greater current induced into it than the current induced into the more distant wire. This produces a difference in the induced AC voltage (noise) appearing between the ends of one wire and the ends of the other wire. When the two wires are connected into an instrument signal circuit, the difference between the two induced voltages is an AC noise voltage that is in series with the signal circuit. If the wires are twisted, most of this voltage can be cancelled out. The idea is illustrated in Fig. B. It can be seen that, as the relative positions of the two wires reverse with respect to the noise source, each wire is in the strongest part of the field for the same amount of its length as the other wire is. This way, the average current induced is nearly equal in each wire. The voltage measured from one end to the other of each wire of a twisted pair will, therefore, be nearly equal; and little noise voltage will be induced in series with the instrument signal circuit.

6. NOISE REDUCTION BY COMMON MODE REJECTION

If the signal circuits of both the transmitter and receiver are referenced to some common conductor, such as the plant grounding system, another type of noise problem will result from mutual inductance. Although the twisted pair prevents noise from being induced in series with the signal circuit, the noise voltage that is common to both conductors is still present.

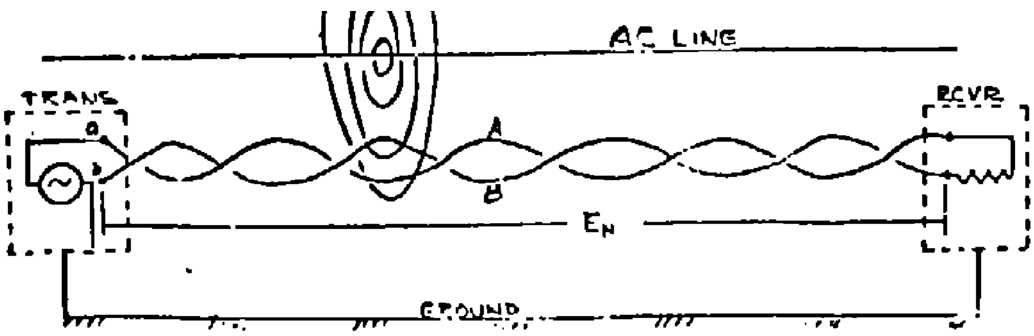


Fig. C

In the system shown in figure C, the transmitter terminal "b" is internally connected to the transmitter case which in turn is connected to ground. The induced noise in wires A and B is nearly equal so that noise current does not flow in the circuit consisting of the transmitter signal source, transmission lines, and the receiver input impedance (R_L). The induced noise voltage (E_N) is returned through the transmitter signal circuit to its case and through the ground path to the receiver case. This common mode noise voltage now appears between the receiver input system and the receiver case. If any part of the receiver input system is grounded, unbalanced noise current will flow in the transmission lines and noise voltage will be developed across R_L. This effect can be trouble some even if the receiver input is grounded through resistance or a reactance.

A Capacitance exists between all conductors that are near to each other. Even if the input circuit is well insulated from all circuits returning to the case or ground, electrical capacitance will exist between the wiring and components of the input circuit and ground. This capacitance has the property of permitting alternating current to follow through it.

(The opposition to current flow in a capacitance is known as reactance.) If enough stray capacitance exists in the receiver input system, the reactance will be quite low (permitting high AC currents to flow) and unbalanced noise currents will flow in the signal transmission system.

It can be seen that the sensitivity of an instrument to common mode noise is a function of the instrument design. When any instrument system with poor common mode rejection and low level signals is to be used, it is important to protect the signal lines from AC magnetic fields. Twisted pair lines are of no help in reducing common mode noise.

7. The capacitive reactance present between instrument signal lines and nearby wiring carrying an AC or pulsating voltage can also produce a noisy signal.

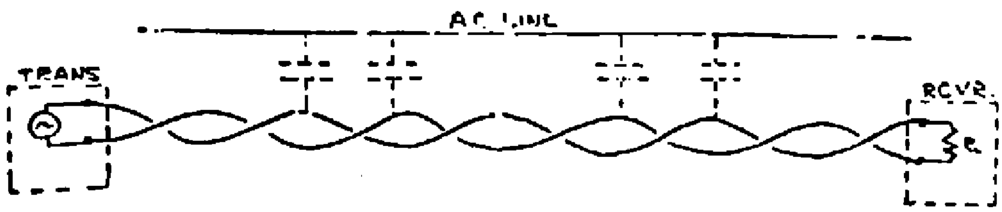


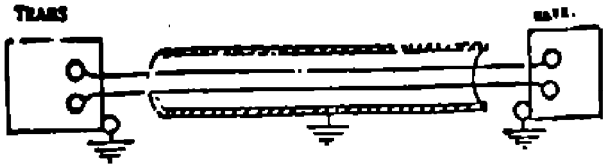
Fig. D

This distributed capacity can be looked at as a group of connected capacitances between the parallel line and the signal lines, as in Figure D. The AC voltage on the parallel line will cause current to flow through the distributed capacitance to the signal lines and couple AC noise voltage into the signal wiring. It is important to note that twisted wiring tends to provide an equal amount of distributed capacity between each signal wire and the noise source causing an equal amount of noise voltage to be coupled into each signal wire and as noted before, will cancel. The common mode noise will still be present. The effects of capacitive coupling can be greatly reduced by the use of shielded wire. However,ordinary shielded wire has very little effect on reducing noise that is induced through magnetic coupling. When shielded wiring is used, most of the noise is coupled to the shield, which is returned to ground at the ground end.

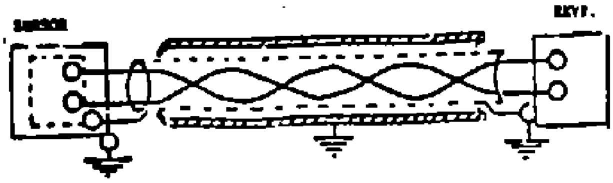
If a shielded signal line is grounded on both ends, a ground loop noise problem may be generated. A voltage difference will usually be found between various ground points in a plant. This is due to the ground currents caused by motors and other electrical equipment. A ground system of heavy copper wires does not eliminate this voltage difference between ground points. When the ends of shielded signal wires are connected to different ground points, voltage existing between the grounds will cause current to flow through the shield. If the voltage between ground points is AC or pulsating, an alternating magnetic field will develop around the shield. The magnetic fields will induce noise into the signal wires inside of the shield. In a practical installation, an insulating jacket should be provided over the shield to prevent contact to any but the selected point. If any part of the measuring circuit in the receiver is grounded to the case, the shield should also be grounded to the receiver case. If either the transmitter or the receiver has an ungrounded signal circuit, and the other unit has a grounded signal circuit, the shield should be grounded at the unit that has the grounded signal circuit. Some instruments have a shield terminal that is isolated from the case and ground both ends of the shield should be connected when this type of terminations provided. Although steel conduit provides some shielding, it is often necessary to use shielded cable inside of conduit to provide a low noise signal transmission circuit.

The typical installations shown in Figure E provide a general guide for industrial instrumentation. Lines carrying similar types of lowlevel signals can usually be grouped with each other in the same conduit without interference. High-level AC pulsed, or on-off signals should not be run in the same conduit and/or pull-boxes with low and medium level signals.

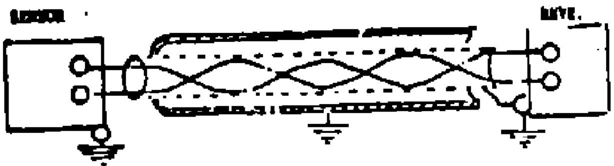
AC power should not be run in the same conduit with any type of instrument signal leads unless the instrument manufacturer specifically recommends this procedure. If the instrument manufacturer recommends the installation of power wiring in the conduit with signal wiring, it is important that he is informed of the length of the signal line and that he recommends the type of wiring or cable to be used. The typical installations are shown for moderate noise levels, Several inches should be maintained between instrument signal conduit and conduit carrying power to motors and other equipment. If conduit is not used, instrument leads should be several feet away from power wiring.



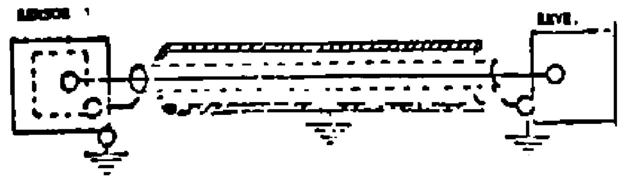
4-20 mA DC.



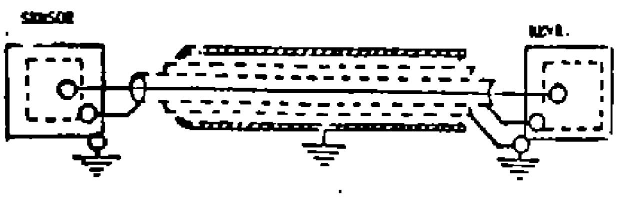
Differential Transformer, AC Strain Gage, & other low-level AC signals.



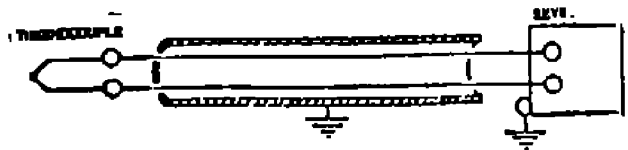
1-5 mA DC, balanced DC millivolts (where receiver lacks AC noise rejection filter) & balanced AC millivolts signals.



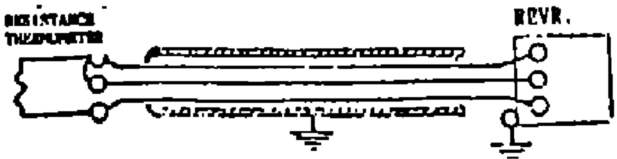
Unbalanced DC millivolts signals (where receiver lacks AC noise rejection filter) & unbalanced AC millivolts signals.



Very low level signals such as ionization chambers, ph, and other analytical instruments (use where recommended by manufacturer.)

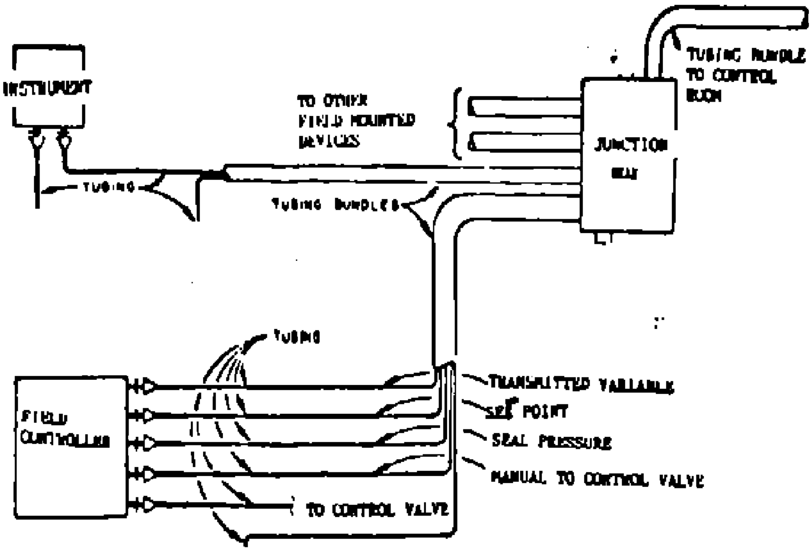


Thermocouple (where receiver is provided with AC noise rejection filterer.)



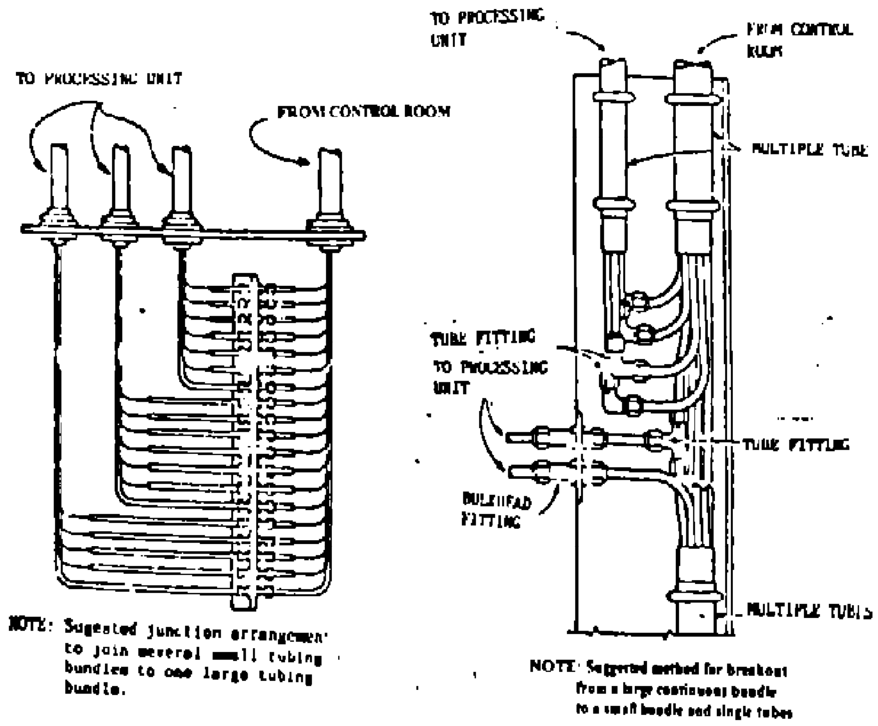
DC actuated resistance thermometer (Where receiver is provided with AC noise rejection filter.)

Fig. E



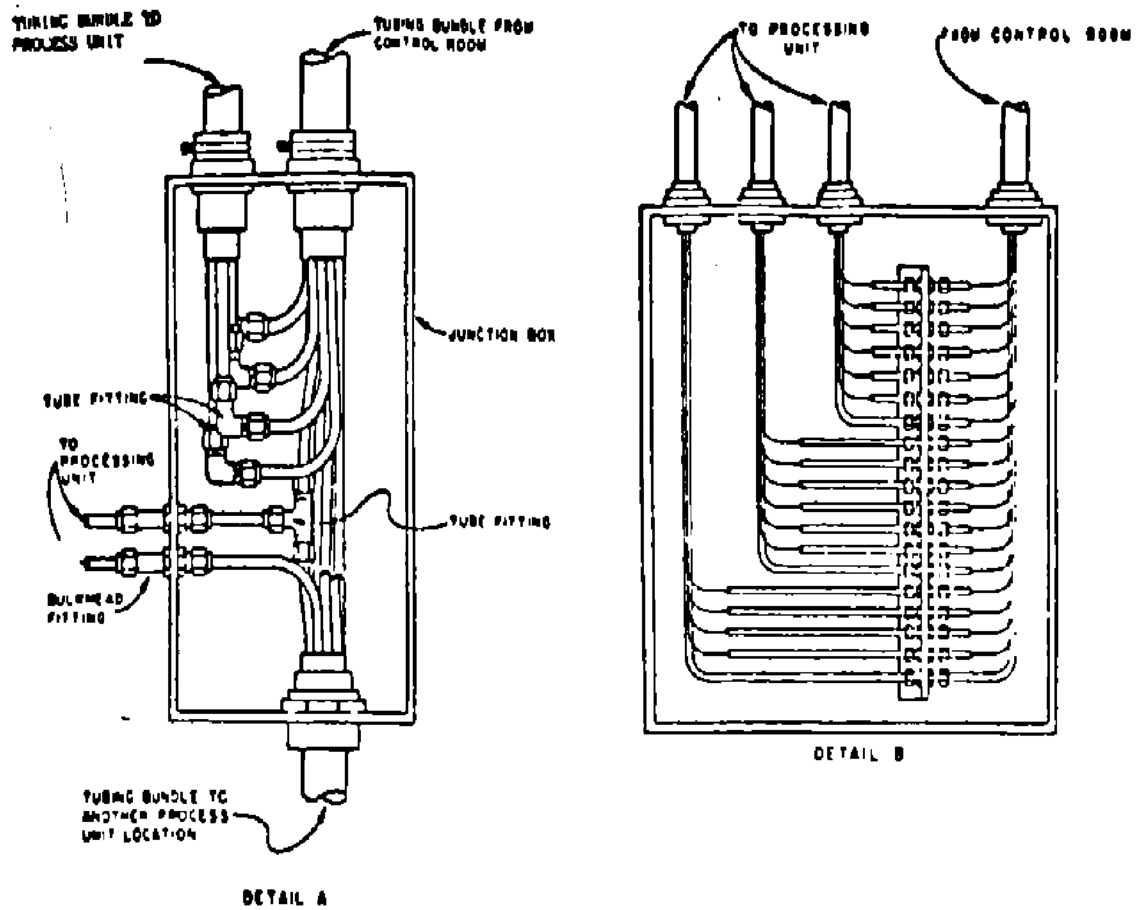
BUNDLED TUBING USAGE AT PROCESS UNIT

Fig. 1



TYPICAL UNENCLOSED JUNCTION FOR USE IN COLLECTION AREA WHERE ENCLOSURE IS NOT REQUIRED

Fig. 2

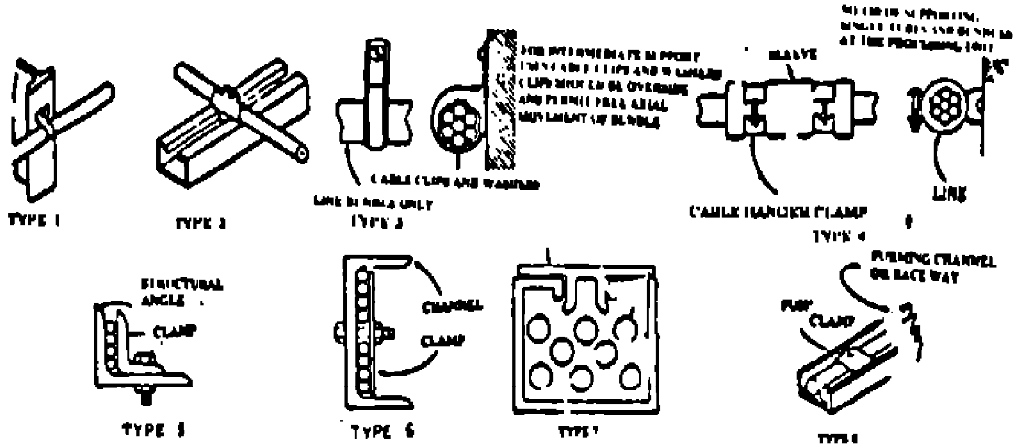


DETAIL A
NOTE: Junction box utilized for breakout from a large continuous bundle to a small bundle and single tubes.

DATAIL B
NOTE: Junction box used to join several small tubing bundles to one large tubing bundle utilizing a terminal plate and bulk-head fitting.

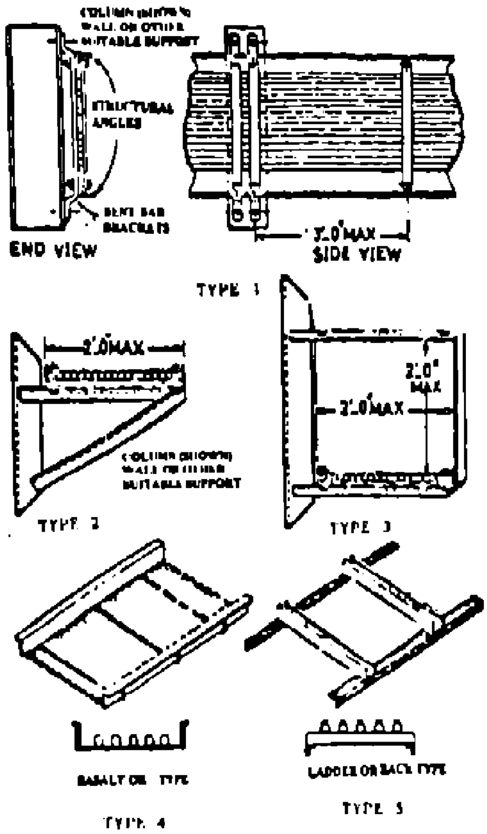
ENCLOSED JUNCTION BOX CONFIGURATIONS

Fig. 3



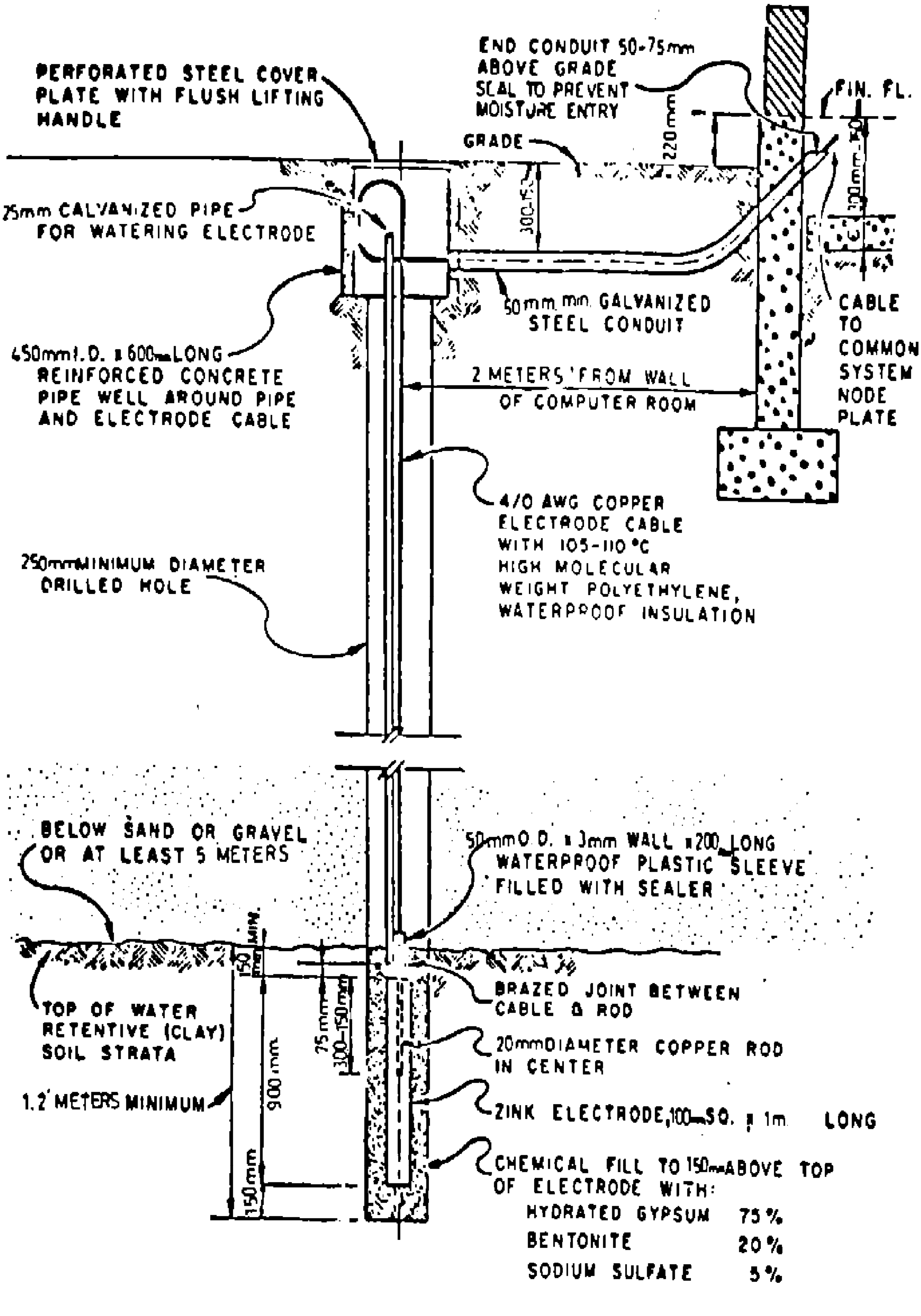
METHODS OF SUPPORTING SINGLE TUBES AND TUBING BUNDLES AT THE PROCESSING UNIT

Fig. 4



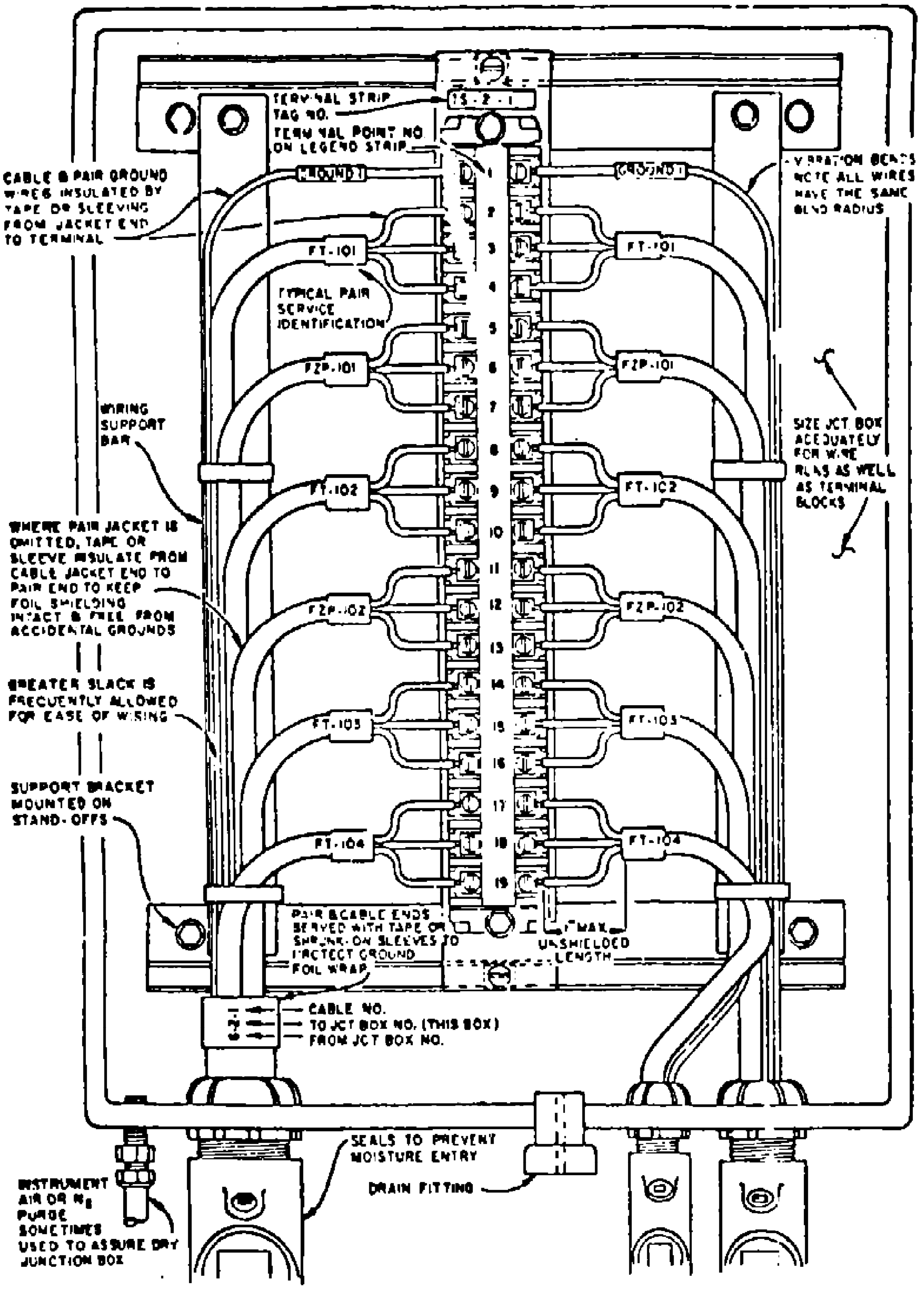
TRAY DESIGNS

Fig. 5



GROUND ELECTRODE FOR ONE LOW-CONDUCTIVITY SOIL CONDITION

Fig. 6



TYPICAL JUNCTION BOX

Fig. 7

TABLE 1 - SPECIFIC APPLICATIONS AND THEIR WIRING REQUIREMENTS, WIRE TYPE, AND ENVIRONMENT

APPLICATION IP CONTROLS D-C SIGNAL	NORMAL I	STRONG MAGNETIC FIELD II	STRONG ELECTRO-STATIC III	REDUCE NOTES OVER 10 HERTZ NO NEED	REMARKS A CONSTANT CURRENT SOURCE
IP CONTROLS VOLTAGE SIGNAL	I	II	III	NO NEED	A CONSTANT VOLTAGE SOURCE, RECEIVER'S IMPEDANCE SHOULD BE AT LEAST 100 TIMES SOURCE'S IMPEDANCE.
IP CONTROLS AND A COMPUTER	II	II	III	YES	FOLLOW COMPUTER MANUFACTURER'S INST-RUTIONS ON GROUNDING POWER TRANSFOR-MFR AND LIGHTNING PROTECTION.
THERMOCOUPLE TO IP CONTROLS	MODIFY I WITH I SA RP 1.1-7	MODIFY I WITH I SA RP 1.1-7	MODIFY I WITH I SA RP 1.1-7		DO NOT PUT A SECOND GROUND ON A TC CIRCUIT WITH A GROUNDED SENSING JUNC-TION. LEAD WIRE MUST NOT BE IN SAME CONDUIT OR RACEWAY AS HIGHER VOLTAGE WIRING.
RESISTANCE BULBS TO IP CONTROLS	I	I	I	NO NEED	WIRING TO STRAIN GAGES MUST NOT BE IN SAME CONDUIT OR RACEWAY AS HIGHER VOLTAGE WIRING.
ORP ELECTRODES TO IP CONTROLS	I	II	III	NO NEED	DO NOT GROUND CIRCUIT, WIRE MUST NOT BE IN SAME CONDUIT OR RACEWAY AS HIGHER VOLTAGE WIRING.
THERMOCOUPLE TO CONTROLS	MODIFY III WITH ANSI C 96.1	MODIFY III WITH ANSI C 96.1	MODIFY III WITH ANSI C 96.1	YES	DO NOT PUT A SECOND GROUND ON A TC CIRCUIT WITH A GROUNDED SENSING JUNC-TION. LEAD WIRE MUST NOT BE IN SAME CONDUIT OR RACEWAY AS HIGHER VOLTAGE WIRING.
RESISTANCE BULBS TO COMPLEX	III	III	III	YES	WIRING TO STRAIN GAGES MUST NOT BE IN SAME CONDUIT OR RACEWAY AS HIGHER VOLTAGE WIRING.
ORP ELECTRODE AND STRAIN GAGES TO COMPUTER	III	III	III	YES	SEE ABOVE
PII GLASS ELECTRODE TO IP CONTROL	SPECIAL	SPECIAL	SPECIAL	NO NEED	SPECIAL COAXIAL CABLE LEAD'S LENGTH SHOULD BE <200 ft. DO NOT PUT CABLE WITH WIRES BEARING OTHER SIGNALS.
TURNIN METERS	III	III	III	YES	USE SEPARATE CONDUIT. LEAD LENGTH SHOULD BE <200 ft.
MAGNATE IC FLOW	SPECIAL	SPECIAL	SPECIAL	YES	SPECIAL TYPE III SOLD WITH TRANSMIT-TER.

Note:

See Table 2 for wire type description.

TABLE 2 - 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" for wiring certain items such as some resistance bulb sensors, strain gages, and the like.

TABLE 3 - MINIMUM SEPARATION BETWEEN PARALLEL RUNS OF POWER AND SIGNAL WIRING

NONCRITICAL CONTROL AND POWER CRITERIA		MINIMUM REQUIRED SPACING FROM CRITICAL CONTROL CIRCUITS	
MAXIMUM CIRCUIT VOLTAGE (Volts)	MAXIMUM CIRCUIT (Amperes)	2 and 3 CONDUCTOR CABLES mm (inches)	SINGLE-CONDUCTOR CABLES mm (inches)
125	10	150 (6)	300 (12)
250	50	250 (10)	375 (15)
440	200	300 (12)	450 (18)
5000	800	500 (20)	600 (24)

Adapted from Iron and Steel Engineer, July 1964.

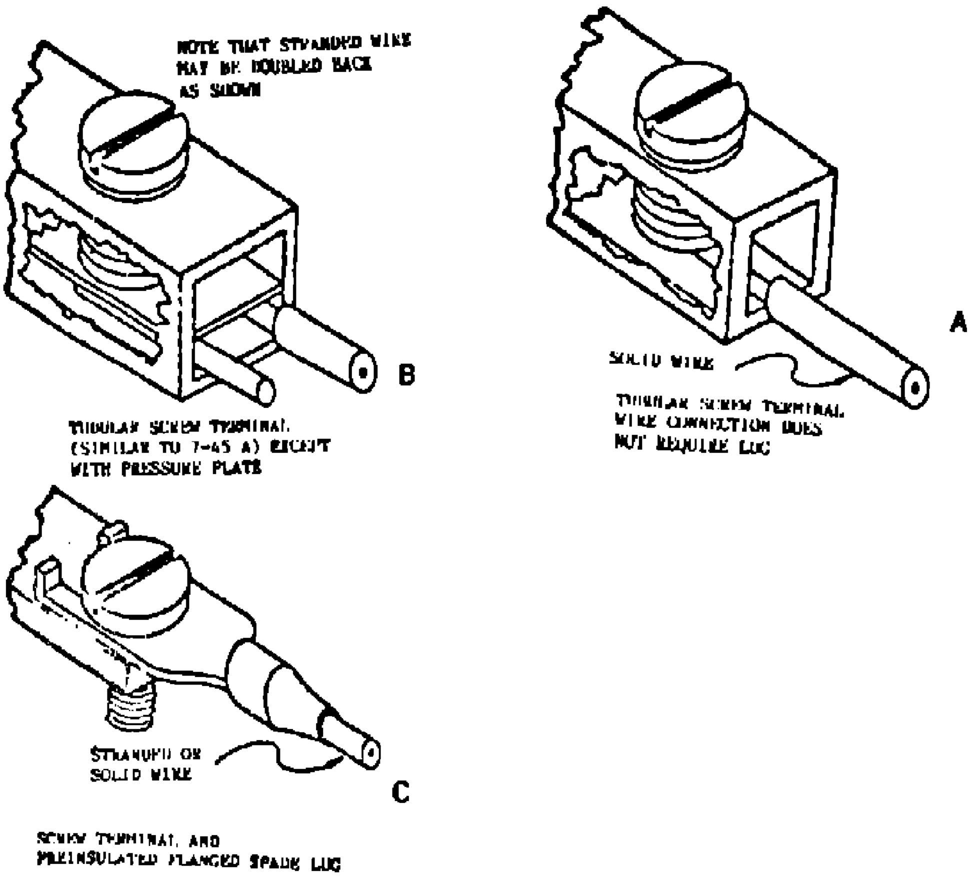
Notes:

1. for very critical control leads requiring an overall accuracy of below 0.25 percent of full scale, the maximum parallel run length with non-critical circuits is approximately 6 meters. For each additional 6 meters of parallel run, increase the tray separation 300 mm. Critical leads may be run in the same tray barriers are used.

2. For critical control leads requiring the maintaining of normal mode noise below 100 millivolts, the maximum parallel run length with non-critical circuits is approximately 120 meters.

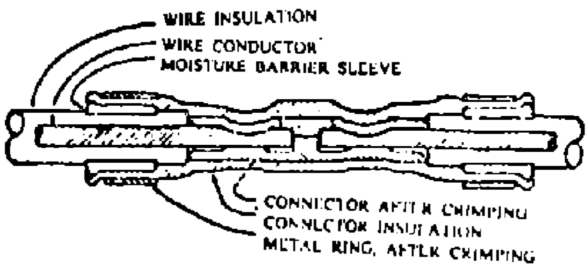
3. The above guidelines on separation have been used with good results by many designers, although no complete agreement exists among them.

4. Typical steel cable tray arrangement is at least 85% coverage. trays solidly grounded, untwisted power conductors, and recommended signal wiring.



TYPICAL TERMINAL BLOCK CONNECTIONS

Fig. 8



MOISTURE-RESISTANT, MECHANICALLY CRIMPED WIRE SPLICE

Fig. 9