

Engineering Standard

SAES-J-902

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Electrical Systems for Instrumentation

Instrumentation Standards Committee Members

Al-Awami, L.H., Chairman

Tuin, R.R., Vice Chairman

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Gawargy, N.E.

Grainger, J.F.

Jumah, Y.A.

Mahmood, B.

Qarni, M.A.

Trembley, R.J.

Saudi Aramco DeskTop Standards

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1 Scope

This Standard establishes the design criteria for the installation of power and wiring systems for electrical instrumentation.

2 Conflicts and Deviations

- 2.1 Any conflicts between this Standard and other applicable Saudi Aramco Engineering Standards (SAESs), Materials System Specifications (SAMSSs) Standard Drawings (SASDs), or industry standards, codes, and forms shall be resolved in writing by the Company or Buyer Representative through the Manager, Process & Control Systems Department of Saudi Aramco, Dhahran.
- 2.2 Direct all requests to deviate from this standard in writing to the Company or Buyer Representative, who shall follow internal company procedure [SAEP-302](#) and forward such requests to the Manager, Process & Control Systems Department of Saudi Aramco, Dhahran.

3 References

The selection of material and equipment, and the design, construction, maintenance, and repair of equipment and facilities covered by this standard shall comply with the latest edition of the references listed below, unless otherwise noted.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

[SAEP-302](#)

*Instructions for Obtaining a Waiver of a
Mandatory Saudi Aramco Engineering
Requirement*

Saudi Aramco Engineering Standards

[SAES-B-006](#)

Fireproofing in Onshore Facilities

<u>SAES-J-903</u>	<i>Intrinsically Safe Systems</i>
<u>SAES-J-904</u>	<i>Foundation Fieldbus (FF) Systems</i>
<u>SAES-P-100</u>	<i>Basic Power System Design Criteria</i>
<u>SAES-P-103</u>	<i>Batteries and UPS Systems</i>
<u>SAES-P-104</u>	<i>Wiring Methods and Materials</i>
<u>SAES-P-111</u>	<i>Grounding</i>

Saudi Aramco Materials System Specifications

<u>17-SAMSS-516</u>	<i>Uninterruptible Power Supply System</i>
<u>23-SAMSS-010</u>	<i>Distributed Control Systems</i>
<u>34-SAMSS-820</u>	<i>Instrument Control Cabinets - Indoors</i>
<u>34-SAMSS-913</u>	<i>Instrument and Thermocouple Cable</i>

Saudi Aramco Library Drawing

<u>DC-950043</u>	<i>Electrical Connections for Field Mounted Instruments</i>
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3.2 Industry Codes and Standards

American National Standards Institute

<i>ANSI MC96.1</i>	<i>Temperature Measurement Thermocouple</i>
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Institute of Electrical and Electronics Engineers

<i>IEEE 518</i>	<i>IEEE Guide for the Installation of Electrical Equipment to Minimize Electrical Noise Inputs to Controllers from External Sources</i>
<i>IEEE 1100</i>	<i>Recommended Practice for Powering & Grounding Sensitive Electronic Equipment, The Emerald Book</i>

International Electrotechnical Commission

<i>IEC 60529</i>	<i>Degrees of Protection Provided by Enclosures</i>
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National Electrical Manufacturers Association

<i>NEMA ICS 6</i>	<i>Enclosures for Industrial Controls and Systems</i>
<i>NEMA 250</i>	<i>Enclosures for Electrical Equipment (1000 Volts Maximum)</i>

NEMA VE 1 - 2002 *Metal Cable Tray Systems*
NEMA VE 2 - 2001 *Cable Tray Installation Guidelines*

National Fire Protection Association

NFPA 70 - 2002 *National Electrical Code (NEC)*
NFPA 72 - 2002 *National Fire Alarm Code*

Underwriters Laboratories, Inc.

UL 94 *UL Standard for Safety Test for Flammability of
Plastic Materials for Parts in Devices and
Appliances*

4 Definitions

The following list of definitions shall apply to this Standard.

Class 1 Circuit: A circuit complying with National Electrical Code (NEC) Article 725, Part II.

Class 2 Circuit: A circuit that complies with National Electrical Code (NEC) Article 725, Part III.

Class 3 Circuit: A circuit that complies with National Electrical Code (NEC) Article 725, Part III.

Data Link: Any information channel used for connecting data processing equipment to any input, output, display device, or other data processing equipment.

Drain Wire: In a cable, the non-insulated wire in intimate contact with a shield to provide for termination of the shield to a ground point.

Home-Run Cable: A cable, typically multi-pair/triad, extending between the field junction boxes and marshaling cabinets in control or PIB buildings.

Severe Corrosive Environments: For the purposes of this standard only, severe corrosive environments include:

- a. Outdoor offshore locations, and
- b. Outdoor onshore locations within one kilometer from the shoreline of the Arabian Gulf; all of the Ras Tanura Refinery and Terminal; all of the Yanbu Refinery and Terminal; and within three kilometers from the shoreline of the Red Sea.

5 General

- 5.1 Design and installation of power and wiring systems for instrumentation shall be in accordance with NFPA 70 National Electrical Code (NEC), unless otherwise supplemented by this standard.
- 5.2 Foundation Fieldbus wiring systems shall be installed in compliance with [SAES-J-904](#) Foundation Fieldbus (FF) Systems.
- 5.3 Electrical and electronic equipment in hazardous areas shall meet listing/certification requirements specified in [SAES-P-100](#) and the NEC.
- 5.4 Intrinsically Safe Systems
 - 5.4.1 Intrinsically safe systems shall only be used in Zone 0 hazardous areas or when the vendor's standard product offering is supplied as intrinsically safe.
 - 5.4.2 Intrinsically safe systems shall be installed in compliance with [SAES-J-903](#), Intrinsically Safe Systems.
- 5.5 Fireproofing of cables in fire hazardous areas shall be in accordance with [SAES-B-006](#).
- 5.6 Fire Alarm systems shall be installed in accordance with this standard, NEC Article 760 and NFPA 72.
- 5.7 Cable Ties
 - 5.7.1 All cable ties used in the field shall be 'nylon coated 316 stainless steel,' e.g., Panduit MLTC Series.
 - 5.7.2 All cable ties used inside of enclosures and buildings (i.e., field junction boxes, marshaling cabinets, control rooms, and PIBS) shall be weather resistant nylon cable ties with a stainless steel barb. The cable tie shall have a maximum continuous use temperature rating of 85°C or higher, e.g., Panduit Dome-Top Barb Ty Cable Ties – Weather Resistant.

Commentary Note:

Cable tray with covers shall not be considered as 'inside of an enclosure'; therefore nylon coated 316 stainless steel ties shall be used.

6 Conduit and Cable Sealing

6.1 Conduit and cable sealing shall be installed in accordance with NEC Article 505.16, except as specified in section 6.2 and 6.3.

6.2 Armored Cable Sealing

Certified flameproof (Type 'd') cable glands using a compound barrier seal (e.g., CMP Protex 2000 - PX2K) shall be used on all instruments and field junction boxes located in Class I, Zone 2 areas and on all instruments and field junction boxes located in non-hazardous areas.

6.3 Conduit Sealing for Individually Shielded Twisted Pair/Triad Cable

When individually shielded twisted pair cable passes through a conduit seal, it shall be treated as a single conductor and shall be sealed with the outer jacket intact. In addition, the cable end within the enclosure shall be sealed by an approved means.

7 Enclosures

7.1 Enclosures for instruments in outdoor plant areas shall be NEMA Type 4 in accordance with NEMA ICS 6 and NEMA 250 or IEC 60529 Type IP 65. Enclosures in severe corrosive environments shall be NEMA Type 4X or IEC 60529 Type IP 66.

7.2 The field junction box, in a Class I, Zone 2 location and in non-hazardous areas, shall be a single door NEMA Type 4X or IEC 60529 Type IP 66 box. The box construction shall meet the following requirements:

7.2.1 Type 316 stainless steel body, door and hardware.

7.2.2 Continuously welded seams, finished smooth.

7.2.3 Continuous stainless steel hinge with removable pin.

7.2.4 Stainless steel captive clamps.

7.2.5 Data/Print pocket on inside of door.

7.2.6 External mounting brackets.

7.2.7 Collar studs for mounting inside panel.

7.2.8 Ground stud for terminating A/C safety ground wire.

- 7.2.9 Painted steel panel (back-pan); in 'severe corrosive environments' a stainless-steel panel shall be used.
- 7.3 All field junction boxes shall be mounted vertically i.e., the door shall open from left-to-right or from right-to-left.
- 7.4 Instrument enclosures and junction boxes having an internal volume exceeding 2,000 cm³ shall be provided with Type 300 Series stainless steel breather and drain fittings, or a combination breather and drain fitting.

8 Conduit, Conduit Fittings and Supports

- 8.1 Conduit installation, fittings and supports shall comply with [SAES-P-104](#) Wiring Methods and Materials, Section 8, Conduit, Conduit Fittings and Supports.
- 8.2 In outdoor installations, conduit bodies and fittings shall have threaded cover openings.
- 8.3 A conduit outlet box (e.g., GUAT) shall be installed within eighteen (18) inches of the field device. The cable to the instrument shall be looped one or more times within this fitting; the sizing of the conduit outlet box shall take into account the bending radius of the cable.

Commentary Note:

The new transmitters and digital valve controllers have very small connection heads compared to previous models. Therefore, a conduit outlet box is being mandated within 18" of the device to allow for a spare loop of cable. This can potentially prevent maintenance from having to re-pull cable if the cable end has been damaged.

- 8.4 Flexible conduit shall be used at the instrument end of the conduit to provide isolation from vibration, protection against thermal expansion of the rigid conduit systems and for ease of maintenance.
 - 8.4.1 For Class I, Zone 1 locations, flexible fittings listed for the area shall be used e.g., Crouse-Hinds ECLK.
 - 8.4.2 For Class I, Zone 2 locations and unclassified areas, the flexible conduit shall be Liquidtight Flexible Metal Conduit (LFMC) e.g., Anaconda Sealtite Type HTUA. The LFMC shall have a sunlight resistant cover which resists oil and chemical breakdown and shall be rated for temperatures $\geq 90^{\circ}\text{C}$.

9 Cable Trays

- 9.1 Cable tray specification shall be per NEMA VE 1. The tray installation shall be per NEMA VE 2 and [SAES-P-104](#), Section 9, Cable Tray.
 - 9.2 Cable trays shall be of the ladder type i.e., two longitudinal side rails connected by individual transverse members (rungs). The distance between consecutive rungs shall not exceed 229 mm (9 inches).
 - 9.3 The cable tray system shall be installed with the manufacturers standard fittings, clamps, hangers, brackets, splice plates, reducer plates, blind ends, connectors, and grounding straps.
 - 9.4 All fasteners (i.e., nuts, bolts, washers, etc.) used to connect and assemble the cable tray system shall be 316 SS.
 - 9.5 Cable Trays shall be grounded as required in [SAES-P-111](#).
 - 9.6 In new grass root projects, cable trays extending between the process area and the control room or process interface building, or trays installed beneath raised computer floors, in control rooms or PIB shall be sized for a minimum of 20% spare space for future expansions. This spare capacity is in addition to the installed 20% spare cabling.
 - 9.7 Cable tray fill shall comply with NEC Article 392.
 - 9.8 Cable tray supporting armored cables extending between field instruments and junction boxes shall be NEMA VE 1, Class C, ventilated bottom, channel cable tray. In addition to the requirements in section 9.1 and 9.5, the channel cable tray system shall meet the following:
 - 9.8.1 The channel cable tray material shall be copper-free aluminum (aluminum with a maximum of 0.4% copper).
 - 9.8.2 Channel cable tray width shall be 3, 4, or 6 inches with a minimum loading depth of 1-¼ inch.
 - 9.8.3 The channel cable tray system shall be installed with the manufacturers standard fittings, clamps, hangers, brackets, splice plates, reducer plates, blind ends, connectors, and grounding straps.
 - 9.8.4 The channel cable tray system shall be installed with flanged covers.
 - 9.8.5 The ventilated strait sections shall have slots (approximately 3/16" x ½") to facilitate the use of cable ties to secure the cable(s). The slots shall repeat every 12-18 inches.
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- 9.8.6 The ventilated strait sections shall have splice holes, repeating every 12-18 inches to simplify field modifications.
- 9.8.7 All fasteners (i.e., nuts, bolts, washers, etc.) used to connect and assemble the channel cable tray system shall be 316 SS.
- 9.8.8 The channel cable tray system shall be free from burrs or other sharp projections that could cause damage to the cable jacket during installation.

10 Connections at Field Instruments and Junction Boxes

10.1 Connections at Field Instruments

- 10.1.1 All connections at the field instrument shall be made on screw type terminal blocks. Wire nuts and spring type terminals shall not be used. Instruments with integral terminal blocks shall be connected directly to the field cable.
- 10.1.2 If the instrument is fitted with factory sealed fly leads then they shall be connected to a screw type terminal block installed in a GUA conduit fitting. A typical installation arrangement is shown in Library Drawing [DC-950043](#), Electrical Connections for Field Mounted Instruments. For armored cable installation, refer to section 13.1.1.2.
- 10.1.3 The outer jacket of shielded twisted single pair/triad cables shall be left intact up to the point of termination. Drain wires and mylar shields on shielded cables shall be cut and insulated with heat shrink sleeve at the field instrument unless otherwise specified by the instrument manufacturer.

10.2 Connections at Field Junction Boxes

- 10.2.1 Conduit and cable entries to field junction boxes shall be through the bottom. Top entry is allowable provided a drain seal is installed on the conduit within 18" of the enclosure. Side entry (within six inches of the bottom) shall be permitted only when space limitations dictate. The number of conduit entries shall be kept to a minimum. All unused entry ports shall be fitted with approved plugs.
- 10.2.2 Conduit entries shall be through gasketed hubs, except in explosion-proof installations where the connection shall be through threaded connections.

- 10.2.3 In severe corrosive environments, cable glands shall be protected against corrosion, either by a heat shrink sleeve, anti corrosion tape or PVC shroud with anti-corrosion compound. Gasket materials shall be oil resistant.
- 10.2.4 All connections and entries shall comply with the electrical area classification.
- 10.2.5 Low point conduit drains shall be provided as needed.
- 10.2.6 Twisted, multi-pair/triad cables shall be cut to the appropriate length to minimize looping and flexing of the cable within the junction box.
- 10.2.7 For twisted shielded single pair/triad cables the outer jacket shall be left intact up to the point-of-termination (approximately three to four inches from terminal blocks). The shield drain wire shall be insulated from jacket end to terminal. Approximately, one inch of heat shrink tubing shall be applied over the jacket end.
- 10.2.8 For individually shielded twisted multi-pair/triad cables each pair/triad shall be heat shrink sleeve insulated from the cable-jacket-end up to the point-of-termination to keep the foil shielding intact and free from accidental grounds. The shield drain wire shall be insulated from foil end to terminal. Approximately, two inches of heat shrink tubing shall be applied over the jacket end.
- 10.2.9 Terminal blocks used in junction boxes shall be per Paragraph 15.2.
- 10.2.10 The terminals shall be mounted on vertical DIN rails (i.e., horizontal DIN rails are not allowed).

Commentary Note:

This section is specifying vertical DIN rails in 'field junction boxes'. This section is not intended to apply to ancillary termination boxes, e.g., smart ZV control stations, GUA fittings, etc.

- 10.2.11 The DIN rail shall only be mounted on the inside panel (back-pan) of the junction box.
- 10.2.12 Twenty percent (20%) unused DIN rail length shall be provided in field junction boxes.

11 Power Supply

11.1 Supply Voltages

- 11.1.1 Where instrument-circuit power distribution panels are used, each panel shall be dedicated to a single voltage level. These panels shall not provide power to non-instrumentation circuits. Distribution panels shall be furnished with a minimum of 20% spare circuit breakers.
- 11.1.2 Power wiring for field instruments, two-wire analog transmission loops, field switch contacts, etc., shall be individually fused and provided with a means of disconnecting the power without disturbing terminated wiring (e.g., knife-switch-type terminal blocks). Visual indication of a blown fuse condition shall be provided.

Exceptions:

- 1) *Wiring connected to I/O modules or to interfaces containing individual current-limiting circuit protection does not require fuses.*
- 2) *Low level signal wiring connected directly to I/O does not require fuses. Low level signals are defined as Millivolt, Microamp, Pulse and Frequency Signals under 1 Volt.*

Commentary Note:

Fuse application, location, and amperage ratings must be properly sized and coordinated, taking into account the maximum expected load at the maximum operating temperature of the indoor cabinet (50°C).

- 11.1.3 Equipment shall be suitable for the supply voltages shown in Table 1.

Table 1 – Supply Voltages

System/Device	Nominal	Supply Voltage Tolerance	NEC Class
Annunciator Power	24 VDC	21 - 28 VDC	1 or 2
	125 VDC	113 - 137 VDC	1 or 3
	120 VAC, 60 ±2 Hz	110 - 126 VAC	1 or 3
Shutdown and isolation system power	24 VDC	21 - 28 VDC	1 or 2
	125 VDC	113 - 137 VDC	1 or 3
	120 VAC, 60 ±2 Hz	110 -126 VAC	1 or 3
Field switch contacts	24 VDC	21 - 28 VDC	1 or 2
	125 VDC	113 - 137 VDC	1 or 3
	120 VAC, 60 ±2 Hz	110 - 126 VAC	1 or 3
Analog signal (loop power)	24 VDC (4-20 mA)	21 - 28 VDC	1 or 2
Instrumentation power	24 VDC	21 - 28 VDC	1 or 2
	120 VAC, 60 ±2 Hz	110 - 126 VAC	1 or 3

- 11.1.4 Where multiple online DC power supplies are connected to a single power bus, diode auctioneering shall be used to ensure bump less transfer in the event of a single power supply failure. Where multiple DC power supplies are an integral part of a manufacturer's standard

product, the manufacturer's standard method of load sharing shall apply.

- 11.1.5 For supplies to DC instrument loads, voltage stabilization shall be provided to maintain the output voltage within tolerable limits of the loads served.

11.2 Backup Supply Systems

11.2.1 UPS Systems and Battery Backup

- 11.2.1.1 All process control instrumentation, gas chromatographs, analyzers, emission monitoring devices, PLCs, burner management systems, distributed control systems, metering systems, stand-alone controllers, computational devices, annunciators, fire and gas detection/safety systems, SCADA systems, and emergency shutdown (ESD) systems shall be powered by UPS system.

- 11.2.1.2 Uninterruptible power supply (UPS) systems shall be designed and installed in accordance with [SAES-P-103](#) and [17-SAMSS-516](#).

- 11.2.1.3 UPS power and utility power shall not share the same cable or be routed in the same conduit.

11.2.2 Redundant UPS System

UPS systems powering critical instrumentation shall consist of redundant UPS units. Critical instrument systems are defined as systems which, upon loss of their supply power, would cause: 1) process failure in a non-failsafe mode, 2) area or plant shutdowns, 3) loss of custody transfer metering or accounting systems, or 4) other adverse facility operating scenarios. Such systems shall include, but not be limited to: ESD control; compressor control; safety monitoring systems; boiler burner management and safety; process monitoring and control; and custody transfer metering systems.

Exception:

Simplex UPS systems may be used on non-critical process and service facilities such as Bulk Plants and GOSPs with the prior approval of the operating facility Manager.

11.2.3 UPS Batteries

UPS battery requirements, such as capacity determination, installation and charging systems, are detailed in [SAES-P-103](#). The time during which the battery bank shall supply power to the instrumentation system shall depend on the application, but not be less than 30 minutes.

11.2.4 Backup Supply for Instruments with Volatile Memory

Backup power supply shall be required for instrumentation systems containing volatile memory. For all such systems, the manufacturers' recommendations shall be followed.

11.2.5 Remote Terminal Unit (RTU)

11.2.5.1 Remote Terminal Unit's shall be provided with battery backup power supply systems. These may be an Uninterruptible Power Supply (UPS) System or DC Power System for sites supplied with AC utility power or a Solar Photovoltaic (PV) Power System where AC utility power is not available and as defined in [SAES-P-103](#). These systems shall be designed and installed in accordance with the requirements set out in [SAES-P-103](#). The required back up time for these systems shall be determined in consultation with the Proponent Department Manager and shall consider the remoteness of the location, ease of access, and reasonable maintenance personnel response time.

Commentary Note:

A UPS system shall be used to provide power to an RTU where the RTU is associated with critical instrumentation, as defined in section 11.2.2.

11.2.5.2 Where bulk DC power is provided to the RTU and associated instruments loads from positively grounded DC systems designed per SEAS-T-151 these systems shall be isolated from each other by means of a suitable sized DC/DC converter that provides complete input to output electrical isolation between communication and instrumentation type loads. The instrument load DC supply system shall be designed to be a floating system and suitable ground fault detection shall be provided as detailed in section 17.6.

12 Signal/Control Wiring

12.1 General

- 12.1.1 Splices are not permitted in wiring. When wiring must be extended, connections shall be made via terminal blocks in a junction box installed aboveground.
- 12.1.2 Twist-on wire nut connectors shall not be used for making any electrical instrumentation terminations or wiring connections.

12.2 Cable Types

Cables used for instrumentation signals shall be selected per Table 2. For detailed cable construction, refer to [34-SAMSS-913](#).

Table 2 – Wire and Cable Minimum Requirements for Instrument Circuits

A. NEC Article 725 Class 1 Circuits (Note 1, 2, 4, 8, 9, 10)			
Instrument Circuit Type	Circuit Example	Field Instrument To Junction Box	Field Junction Box To Marshaling Cabinet
120 VAC or 125 VDC	Switches, Solenoids, Relays, Limit switches	16 AWG, 600 V, single twisted pair, Type TC cable (Note-7) ARMORED: 16 AWG, 600 V, single twisted pair, TYPE MC or equivalent	18 AWG, 600 V, twisted multi-pair cable, type TC
B. NEC Article 725 Class-2 & 3 Circuits, Conduits and Cable Tray Installations (Note 1, 2, 3, 4, 8, 10)			
Instrument Circuit Type	Circuit Example	Field Instrument To Junction Box	Field Junction Box To Marshaling Cabinet
24 VDC or less Discrete signals	Solenoids, Alarms, Switches, Relays, limit switched, Secondary Motor Control	16 AWG, 300 V PLTC/ITC, single twisted pair or triad cable ARMORED: 16 AWG, 300 V SWA, PLTC/ITC, twisted single pair or triad cable	18 AWG, 300 V PLTC/ITC Twisted, Multi-Pairs or Triads, Overall Shield
Analog Signals Frequency, Pulse, or Transmitter Digital Communication	4-20 mA DC, RTDs, Weigh Cells Speed, Vibration, Turbine Meter, Smart digital Transmitter	16 AWG, 300 V PLTC/ITC, single twisted, shielded pair or triad cable ARMORED: 16 AWG, 300 V SWA, PLTC/ITC single twisted, shielded pair or triad cable	18 AWG, 300 V PLTC/ITC Twisted, Individually Shielded Multi-Pairs or Triads
Thermocouple Measurement	Thermocouples	16 AWG, 300 V PLTC/ITC, single twisted, shielded, thermocouple extension pair cable ARMORED: 16 AWG, 300 V PLTC/ITC, SWA, single twisted,	18 AWG, 300 V PLTC/ITC, Twisted, Individually Shielded, thermocouple extension multi-pair cable

		shielded, thermocouple extension pair cable	
Data Links	EIA-422A Data Links, High Speed Communication networks	Follow System Manufacturer's Recommendation (<i>Note-6</i>)	Follow System Manufacturer's Recommendation

Notes on Table-2:

1. Cables installed in Zone 1 (Class -1, Div.-1) shall be listed as suitable for that classified area. In addition, cables used in other classified areas shall meet the requirements outlined in NFPA 70 (NEC), articles 501-505.
2. The minimum size for multi-pair/triad cable should be 18 AWG. The minimum wire size for single pair cable shall be 16 AWG. A larger wire size shall be considered to overcome potential voltage drops. The maximum voltage drop shall not exceed 5%.
3. Type ITC cable shall not be installed on either non-power limited circuits or powered limited circuits operating at more than 150 volts or more than 5 amperes.
4. Differences in the manufacturer recommended cable and these requirements shall be resolved with Instrumentation Unit/PID/P&CSD.
5. For control and marshaling cabinet wiring, refer to [34-SAMSS-820](#).
6. Maximum separation between redundant data links must be obtained within the operating plant. The use of a single cable tray or conduit for primary and backup data links is not acceptable. Refer to Section 12.3.2.
7. 14 AWG, 600 V THHW (or equivalent), Insulated conductors, with fire retardant insulation may be used instead of Type TC twisted pair cable if routed in dedicated conduit.
8. Protection against reverse EMF shall be provided for inductive loads such as relays, solenoids, etc. This may be accomplished by installing a diode across the coil for DC loads, or a metal oxide varistor (MOV) across the coil for AC inductive loads.
9. Long AC signal run is not recommended due to potential distributed capacitance. If the loop length exceeds 1000 feet, DC voltage shall be considered.
10. Cables used in Class 1, Class 2 and Class 3 circuits shall meet the requirements of Article 725 of the National Electrical Code (NEC). Class 1 circuit wiring is preferred when the circuit class is not identified.

12.3 Special Cables

12.3.1 Thermocouple Extension Cable

Thermocouple extension cable types are detailed in [34-SAMSS-913](#).

12.3.2 Data Links

Data links, including fiber optic cables, shall be specified and installed per system manufacturers' recommendations.

When redundant data links are provided, the primary cable shall follow a different route from the back up cable. Primary and backup data link cables shall preferentially enter cabinets or consoles from opposite sides. Data link cables shall not be routed in the same conduit, duct, or tray with other instrument cables.

Exception:

Fiber Optics data link Cables may be routed with other cables on existing trays or ducts with prior approval of the Supervisor, Instrumentation Unit/PID/P&CSD.

12.4 Color Coding

Power and signal wiring shall be color coded as follows:

AC Supply	Phase Neutral Ground	Black White Green or green with yellow tracer
DC Supply	Positive Negative	Red or red sleeve over any color except green Black or black sleeve over any color except green
Signal Pair	Positive Negative	Black White
Signal Triad	Positive Negative Third Wire	Black White Red
Thermocouple	Positive Negative	Per ANSI MC96.1 Per ANSI MC96.1

13 Routing

Instrumentation and control cables and data highways in the field may be routed either aboveground, underground or a combination of both as detailed in this standard.

13.1 Aboveground Routing

Above ground instrumentation cables may be run on a cable tray or in a conduit as detailed below. Aboveground is the preferred routing method within a process facility.

13.1.1 Instrument to Field Junction Box

Cable between field instruments and junction box shall be routed utilizing one of the following options:

13.1.1.1 Cable and Conduit

Single twisted pair/triad cables, per Table-2, shall be installed in steel conduits from the field instruments to the field junction boxes. Low-point drains and breathers shall be provided as required on all conduits. Conduit installation shall be per Section 8.

13.1.1.2 Armored Cable and Tray

- a) Armored instrumentation cable shall be routed on a cable tray per Section 9.8.

Exception:

With prior written concurrence from the Supervisor, Instrumentation Unit/PID/P&CSD, open-ended conduit "drop-outs" may be used to provide support for the armored cables between the tray system and the field instruments or between the tray system and the junction boxes .

- b) The armored cable shall be routed independently of existing overhead tray systems used for "home-run" cables.
- c) The unsupported end of the cable at the instrument shall be looped; this loop shall take into account the bending radius of the cable. The unsupported length of cable at the instrument shall be the minimum length required to provide the service loop.

Commentary Note:

This unsupported loop in the armored cable is required to provide sufficient slack for cable gland make-up and for easy removal of the cable from the device for future instrument change-out.

- d) The cable shall be either galvanized steel wire armor or galvanized steel interlocking armor, per [34-SAMSS-913](#).

13.1.2 Field Junction Box to Control Room Marshaling Cabinets

- 13.1.2.1 Cables between field junction boxes and marshaling cabinets may be routed in conduits, on trays, or direct buried. Twisted, multi-pair/triad cables per Table-2 shall be used.
- 13.1.2.2 All signal wiring from field cables shall terminate in dedicated 'marshaling cabinets'. Marshaling cabinets shall comply with [34-SAMSS-820](#), Instrument Control Cabinets - Indoors.

Commentary Note:

A marshaling cabinet contains mainly terminal strips and wire terminations.

Exception:

Wiring for millivolt, microamp, pulse, and frequency signals under one Volt such as thermocouples, vibration elements, load cells, thermistor elements and transmitters with pulse outputs may be directly connected to the I/O unless otherwise specified.

- 13.1.2.3 Each cable or group of cables carrying similar signals shall contain a minimum of 20% spare pairs or triads. The number of pairs/triads in a given cable shall be dictated by usage and spare requirements and the manufacturers' standard offerings.
- 13.1.2.4 All spare pairs/triads of a multi-pair/triad cable shall be terminated at both the field junction box and the marshaling cabinet. Drain wires for spare shielded pairs/triads shall also be individually terminated at these locations.
- 13.1.2.5 Cables entering the marshaling cabinet shall be cut to the appropriate lengths. Coiling extra cable length or spare pairs/triads beneath the marshaling cabinet is not acceptable.

Exception:

For wiring directly connected to the I/O, per the exception item in section 13.1.2.2, the spare pairs/triads may be neatly coiled & taped beneath the cabinet.

- 13.1.2.6 All conductors/pairs, from each field cable, shall be terminated adjacent to each other on the same terminal strip in the marshaling cabinet.

Commentary Note:

The intent of this section is to prohibit the splitting out of individual conductors/pairs from one field cable and having them terminated on different terminal strips in the same marshaling cabinet or terminated in separate marshaling cabinets.

- 13.1.2.7 Cable entry into control buildings and similar buildings in hydrocarbon processing plants shall be in accordance with [SAES-P-104](#), Section 15.4.
 - 13.1.2.8 Emergency shutdown system (ESD) wiring shall have dedicated cabling, junction boxes and marshaling cabinets.
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Exception:

For offshore platforms only, ESD system wiring may be terminated in the same junction box as general instrumentation wiring. Terminals shall be segregated and clearly labeled.

13.1.2.9 Wiring for intrinsically safe (IS) systems shall be segregated and installed in dedicated conduit or cable tray and terminated in dedicated junction boxes. For additional details on IS wiring, refer to [SAES-J-903](#).

13.1.3 Marshaling Cabinet to Control Room Instrumentation and Control Systems

13.1.3.1 Cables connecting marshaling cabinet terminals to control room instrumentation and control systems shall conform to the requirements of Section 13.1.2, above. Where possible and practical, pre-assembled cables with plug-in type connectors shall be used for interconnections. Wiring lists identifying pin connections shall be required for each pre-assembled cable.

13.1.3.2 Control room cabling/wiring must conform to NEC Articles 725-61 and 71 (2002 edition). Wiring requirements for distributed control systems (DCS) are detailed in [23-SAMSS-010](#).

13.2 Underground

If requirements exist to protect against fire damage or to avoid overhead obstructions, underground routing shall be considered. Direct buried instrument cables shall be installed in accordance with [SAES-P-104](#), Wiring Methods and Materials, Section 10 Underground Cable Systems and according to Section 14 of this standard.

13.3 Under Computer Floors

13.3.1 Instrumentation cables installed beneath raised computer-type floors in control rooms shall be placed in ladder, trough or solid bottom cable tray. Segregation and separation of the cabling shall be in accordance with Section 14.

Exception:

Alternative installation methods may be used with the approval of the operating facility Manager.

- 13.3.2 Where cable tray is used beneath raised computer-type floors in control rooms, it shall be sized per Section 9.
- 13.3.3 Cable trays beneath raised floor shall be adequately identified using suitable permanent tag plates. These tag plates shall be installed at each end, Tee connection and at three meter intervals. The tag plates shall be located so that it is clearly visible. The tag plates shall contain, as a minimum, the noise susceptibility level of the circuits enclosed (per section 14.1) source, and the destination.

14 Signal Segregation, Separation and Noise Reduction

14.1 Signal Segregation

- 14.1.1 Signal wiring (instrumentation cable) shall be categorized with noise susceptibility levels (NSL) of '1' or '2'.

Commentary Note:

Noise susceptibility level ratings and separation tables are derived from IEEE 518 Guide for the Installation of Electrical Equipment to Minimize Electrical Noise Inputs to Controllers from External Sources. The IEEE 518 standard defines three (3) noise susceptibility levels for instrumentation signals, however due to the signal levels commonly used in Saudi Aramco's facilities it was deemed that two (2) noise susceptibility levels were adequate.

- 14.1.1.1 Level 1 – High to Medium Susceptibility: Analog signals of less than 50 V and discrete instrument signals of less than 30 V.

Signal Types

- (a) Foundation Fieldbus
 - (b) 4-20 mA and 4-20 mA with HART
 - (c) RTD
 - (d) Thermocouple
 - (e) Millivolt / Pulse
 - (f) Discrete input & output signals e.g., pressure switches, valve position limit switches, indicating lights, relays, solenoids, etc.
 - (g) All wiring connected to components associated with sensitive analog hardware (e.g., strain gauge)
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- 14.1.1.2 Level 2 – Low Susceptibility: Switching signals greater than 30 V, analog signals greater than 50 V, and 120-240 AC feeders less than 20 amps.

Signal Types

- (a) Discrete input & output DC signals, e.g., pressure switches, valve position limit switches, indicating lights, relays, solenoids, etc.
 - (b) Discrete input & output AC signals, e.g., pressure switches, valve position limit switches, indicating lights, relays, solenoids, etc.
 - (c) 120-240 ac feeders of less than 20 amps.
- 14.1.1.3 Level 3 – Power: ac and dc buses of 0-1000 V with currents of 20-800 amps.

Commentary Note:

Level 3 – Power: is shown for the spacing requirements between 'instrumentation cable' and 'electrical cable'.

- 14.1.2 A multi-pair/triad cable shall not be used to route more than one signal type. |||
- 14.1.3 Cables with the same noise susceptibility level may be grouped in trays and conduit (e.g., all level-1 cables may be routed in one cable tray).

14.2 Signal Separation

- 14.2.1 Tray Spacing: Table 3 indicates the minimum distance in millimeters between the top of one tray and the bottom of the tray above, or between the sides of adjacent trays. This also applies to the distance between trays and power equipment of less than 100 kVA.
- 14.2.2 Tray-Conduit Spacing: Table 4 indicates the minimum distance in millimeters between trays and conduits. This also applies to the distance between trays or conduits and power equipment of less than 100 kVA.
- 14.2.3 Conduit Spacing: Table 5 indicates the minimum distance in millimeters between the outside surfaces of conduits being run in banks. This also applies to the distance between conduits and power equipment of less than 100 kVA.
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- 14.2.5 When routing instrumentation and control signal cabling (level 1 or 2) near sources of strong electromagnetic fields, such as large transformers, motors and generators, defined for purposes of this standard as greater than 100 kVA, a minimum spacing of 2 meters shall be maintained between the cables and the devices.
- 14.2.6 For direct buried cable, cable spacing shall be as shown in Table 3.
- 14.2.7 When entering terminal equipment (e.g., motor control center) and the spacing listed in tables 3, 4, or 5 cannot be maintained, parallel runs shall not exceed 5 ft in the overall run.
- 14.2.8 Minimum separation requirements between various instrumentation cables and data link cables (copper or fiber optic) shall be per the manufacturer's recommendation.

Table 3 – Tray Spacing, millimeters (inches)

NSL *	1	2	3
1	0 (0)	150 (6)	650 (26)
2	150 (6)	0 (0)	200 (8)
3	650 (26)	200 (8)	0 (0)

Table 4 – Tray-Conduit Spacing, millimeters (inches)

NSL *	1	2	3
1	0 (0)	100 (4)	450 (18)
2	100 (4)	0 (0)	150 (6)
3	450 (18)	150 (6)	0 (0)

Table 5 – Conduit Spacing, millimeters (inches)

NSL *	1	2	3
1	0 (0)	75 (3)	300 (12)
2	75 (3)	0 (0)	150 (6)
3	300 (12)	150 (6)	0 (0)

* NSL = Noise Susceptibility Level

14.3 Noise and Signal Interference Reduction

14.3.1 Noise

Signal wiring shall be installed in a manner that will minimize

unwanted and unnecessary distortion of the signal. Unwanted voltages are imposed on an electric signal transmission system by inductive, capacitive or direct coupling with other circuits by leakage current paths, ground current loops, or a common return lead for more than one circuit. The following wiring techniques shall be used for all instrument wiring.

14.3.2 Shielding

14.3.2.1 Shielded cables shall be used as required in Table-2 to reduce electrostatic noise. The shield shall be grounded at one point only, typically at the marshaling cabinet in the control room or process interface building.

Exception:

Shield for grounded thermocouple shall be grounded in the field, at the thermocouple end.

14.3.2.2 Cable shields must have a single, continuous path to ground. Special grounding terminals in intimate contact with the DIN Rail, jumper bars or preformed jumper combs designed for the selected terminal blocks shall be used to consolidate shield drain wires for connection to ground. Ground loops and floating shields shall be avoided. Shield drain wires shall not be daisy-chained to the ground connection.

14.3.2.3 For twisted shielded single pair/triad cables the outer jacket shall be left intact up to the point-of-termination (approximately three to four inches from terminal blocks). The shield drain wire shall be insulated from jacket end to terminal. Approximately, one inch of heat shrink tubing shall be applied over the jacket end.

14.3.2.4 For individually shielded twisted multi-pair/triad cables each pair/triad shall be heat shrink sleeve insulated from the cable-jacket-end up to the point-of-termination to keep the foil shielding intact and free from accidental grounds. The shield drain wire shall be insulated from foil end to terminal. Approximately, two inches of heat shrink tubing shall be applied over the jacket end.

14.3.2.5 In installations where there is a transition from multi-pair or multi-triad cables to individual pairs/triads for field device connection in a junction box, the respective shield drain

wires shall be joined via terminal strip and shall not make electrical contact with the junction box or any other circuit. Using push-on type connectors or sandwiched shield bars for shield drain wire connection is not acceptable.

14.3.2.6 The shield drain wire on the ungrounded end of the cable shall be cut and insulated with a heat shrink sleeve to prevent unintentional grounding.

14.3.2.7 Except for coaxial cables, instrument cable shields shall never be used or considered as signal conductors.

14.3.3 Twisting

Twisted pairs/triads shall be used as required in Table-2 to reduce electromagnetic noise.

15 Termination

15.1 Methods

15.1.1 The termination shall be channel (rail) mounted, strip-type terminal blocks, with tubular box clamp connector and compression bar or yoke, as detailed in Paragraph 15.2.

15.1.2 When screw-type terminals are provided on field instruments or other electrical devices, solderless crimp/compression connectors shall be used for connecting stranded copper conductors. Screw-type terminals are defined as those in which the termination method involves the direct compression of the conductor by the underside of the screw head, and which do not contain the conductor within a clamp or yoke. Insulated ring lugs or locking fork connectors, specifically designed to hold the connector on the terminal in the event of loosening of the terminal screw, shall be used on all such connections. Exposed electrical connections at signal lamps and pushbuttons shall be completely shrouded by removable, insulating covers.

15.2 Terminal Blocks

15.2.1 Terminal blocks shall be channel (rail) mounted, strip type, with tubular box clamp connector and compression bar or yoke for wire termination. As a minimum, the thickness of the terminals shall be 5 mm or higher. Multi-deck and spring type terminal blocks are not acceptable.

- 15.2.2 Terminals and terminal block accessories (e.g., DIN rail mounting brackets for electrical insulation, busbar support blocks, end brackets, etc.) shall be made of fire retardant, halogen free, high strength material such as polyamide or equivalent in accordance with UL 94, V0. Brittle materials such as melamine shall not be used.
 - 15.2.3 Fused terminals shall be equipped with blown fuse visual indication. The disconnect levers for fused terminals and knife- switch terminals shall be hinged.
 - 15.2.4 Wires terminated on these terminal blocks shall not have the bare ends coated with or dipped in solder ("tinned"). However, termination of wiring that has individual strands of the copper conductor tinned during manufacture (typical of shield drain wires or for corrosion protection) is acceptable. Direct termination of the bare wire end is acceptable. No more than two bare wire ends shall be connected to each side of a single terminal block.
 - 15.2.5 The use of crimp-on ferrules for this type of termination shall follow manufacturer's guidelines. Ferrules shall be provided with plastic insulating collars. Two-wire ferrules are acceptable. However, the use of ferrules to daisy chain is not acceptable. Only one ferrule shall be connected to each side of a single terminal block.
- 15.3 Terminal Strip Assemblies
- 15.3.1 Terminal strip spacing shall allow ample room for plastic wire ducts and permit training and lacing of cables, and fanning of individual wires to termination points. Each terminal strip shall be labeled above or below with the terminal strip number, as shown on wiring diagrams.
 - 15.3.2 Terminals for similar (AC or DC) current service shall be grouped together and physically separated from terminals for different service by means of dividers, separate mounting rails or separate enclosures.
 - 15.3.3 Terminals for 120 VDC and 120 VAC power for field contacts shall be segregated from other systems.
 - 15.3.4 Terminal strips for ESD wiring shall be completely separate from all other wiring including power, control and instrumentation.
- 15.4 Wire Ducts and Gutters
- 15.4.1 Plastic wire ducts with removable covers shall be installed in control panels and marshaling cabinets as required to provide a means of routing and organizing wiring between terminal blocks and instrument
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racks or panels. A minimum of 50 mm (two inches) shall be maintained between the duct and terminal strips to permit wire markers to be completely presented without being obscured by the duct. Where space limitations preclude the use of plastic wire ducts, wiring shall be neatly loomed and secured with plastic spiral wrapping or tie-wraps and anchors.

15.4.2 Wire ducts for ESD wiring shall not contain any other types of wiring.

16 Identification

16.1 Wire Tagging

16.1.1 All wiring shall be tagged at each end. Each wire tag shall have two labels. The first label (closest to the end of the wire) shall identify the terminal number to which the wire is physically connected. The other label shall be the terminal number of the connection of the opposite end of the wire.

Commentary Note:

This section is specifying the source and destination information to be imprinted on one (1) heat shrink sleeve. Sometimes, the term 'label' is interpreted as requiring two separate wire tags, one containing the source information and the other containing the destination information, which is incorrect.

16.1.2 Where wires terminate on instrument or device terminals, the instrument tag number and terminal designation (+) or (-), shall be used in lieu of terminal strip identification.

16.1.3 Wire tag information shall be permanently marked in block alpha numeric or typed on tubular, heat-shrinkable, slip-on sleeves. Wrap-around, snap-on or self-adhesive wire markers shall not be used. Handwritten wire tags are not acceptable.

Exceptions:

- 1) *Alternate wire tagging schemes, which conform to established local practice, may be used for extensions to existing facilities with the prior approval of the operating facility Manager.*
- 2) *Plastic sleeves that are specifically designed to fit on a specific wire gauge and come with pre-printed alpha/numeric inserts (such as Grafoplast Trasp System) may be used for wire tags with prior approval of the operating facility Manager.*

- 16.1.4 A clear heat shrink sleeve shall be installed over the wire tag for all instruments that use rust preventive grease on its threaded wiring access cover.
- 16.1.5 Spare pairs/triads in multi-pair/triad cables shall be labeled "Spare" in addition to the destination and source terminal numbers. The "Spare" designation shall be on a separate wire tag installed on the twisted pair and not part of the source/destination tag.

Commentary Note:

We do not allow the "Spare" designation to be printed on each source/destination wire tag because this would require new tags to be made when the conductors are utilized. This is inefficient since the source/destination designations do not change.

16.2 Cable Tagging

- 16.2.1 All cables shall be tagged, at each end, with a cable-tag.
 - 16.2.1.1 Homerun cables shall be tagged with the assigned "IC" cable number.
 - 16.2.1.2 The cable tagging philosophy for cables routed from junction boxes to field instruments shall be defined by the Proponent Representative.

Commentary Note:

Some Proponent facilities prefer to tag the instrument cables with the instrument cable number (e.g., IC-1249) where other facilities prefer to tag the cables with the instrument tag number (e.g., TT-1249).

- 16.2.2 Cable-tags shall be 316 SS with permanently marked alphanumeric characters i.e., raised or stamped characters. The cable-tag shall be securely attached to the cable with stainless-steel cable ties.

16.3 Terminal Reference

- 16.3.1 Each row of terminals shall be uniquely identified alphanumerically, e.g., TS-101, TS-102, etc.
- 16.3.2 The terminals in each row shall be sequentially numbered starting at number one (1).

17 Grounding

17.1 General

- 17.1.1 Electrical systems must be connected to ground for the protection of personnel and equipment from fault currents (AC safety ground) and to minimize electrical interference in signal transmission circuits (Instrument circuit ground).
- 17.1.2 Two grounding systems are required for instrumentation systems:
 - a) Safety Ground for personnel safety.
 - b) Instrumentation Circuit Ground.
- 17.1.3 Both safety ground and instrumentation circuit ground must conform to NEC, Article 250. Grounding system recommendations and requirements provided by manufacturers of instrumentation and control systems (e.g., distributed control systems and ESD Systems) shall also be taken into consideration.

17.2 Safety Ground

- 17.2.1 All exposed non-current-carrying metallic parts that could become energized with hazardous potentials must be reliably connected to the equipment grounding circuits. This assures that hazardous potential differences do not exist between individual instrument cases or between an instrument case and ground. Therefore, all metal equipment and enclosures within a panel or series of panels (i.e., instrument cases, hinged doors, racks, etc.) shall be bonded with bonding jumpers and connected to a safety ground bus with a minimum copper wire size of 4 mm² cross-sectional area. Two copper conductors, 25 mm² minimum, shall be connected from the safety ground bus to a single tie point on the safety ground grid in a closed loop configuration. Safety ground connections must be made such that when a case-grounded instrument is removed, the integrity of the rest of the safety ground system is maintained.
 - 17.2.2 Enclosures for field instruments shall be grounded as follows:
 - 17.2.2.1 Instruments Operating at Greater Than 50 Volts

The enclosures for instrument devices operating at 120 V AC or 125 VDC shall be grounded per [SAES-P-111](#).
 - 17.2.2.2 Instruments Operating at Less Than 50 VDC
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The enclosures of instrument devices operating at 50 V DC or less may be grounded using one of the following options:

- a. Connecting the enclosure directly to the grid using 25 mm² ground wire.
- b. Connecting the enclosure to a grounded instrument stand or other supporting structure, provided that the instrument device is properly fastened and the mounting clamp is mechanically and electrically in intimate contact with the stand.
- c. Using the conduit as a ground conductor, provided that the conduit system is continuous and properly grounded. A bonding jumper shall be used across any flexible conduit at the instrument end. All conduit fittings shall be listed as suitable for grounding.
- d. Using the cable armor (assuming armored cable is used) provided that the following criteria are met:
 - 1) The armor construction is suitable as a grounding path per the NEC.
 - 2) The cable glands, on each end of the armored cable, shall be designed to bond the armor to the gland (i.e., listed as suitable for grounding).
 - 3) The armored cable runs in one continuous length from a properly grounded junction box to the device being grounded, i.e., no splices are permitted.
 - 4) The armored cable is not in direct contact with the soil for any portion of the run.

17.3 Instrument Circuit Ground

17.3.1 The purpose of instrument circuit grounding is to reduce the effect of electrical interference upon the signal being transmitted. An instrument circuit ground bus shall be provided for consolidating instrument signal commons and cable shield drain wires. This ground bus shall be isolated from the safety ground system except at a single tie point as described below.

17.3.2 Each instrument signal common shall be connected to the isolated instrument ground bus with copper wire sized to carry the expected fault current or 1.5 mm², whichever is larger. Two insulated copper conductors, 25 mm² minimum, shall be connected from the instrument

circuit ground bus to a single tie point on the safety ground grid in a closed loop configuration. The resistance from the isolated instrument ground bus to the safety ground grid shall be less than 1 ohm.

17.4 Grounding within Control and Process Interface Buildings

17.4.1 In cases where there are many ground buses such as in control or process interface buildings, isolated instrument ground bars from all cabinets shall be consolidated into a Master Instrument Ground Bus located within that building. Similarly, safety ground bars shall be consolidated into a Master Safety Ground Bus. Bonding cabinet safety ground bus bars in a daisy-chain connection is not acceptable.

17.4.2 The Master instrument circuit ground bus and safety grounds shall be both connected to the plant overall grounding grid, as mandated by IEEE 1100. The connection to the plant grid shall be in a loop configuration as detailed in Paragraphs 17.2 and 17.3.

17.4.3 Instrument cable shields shall be connected to the instrument circuit ground bus in accordance with Paragraph 14.3.2.

17.5 Special Considerations

Some equipment (data highways, computers, distributed control systems, etc.) may require special provisions for grounding. Manufacturers' recommendations should be carefully evaluated at all times.

17.6 Ground Fault Detection

17.6.1 When critical control systems, i.e., emergency shutdown (ESD) systems, utilize fully floating DC power where both positive and negative buses are isolated from earth ground, a selective ground fault detection system shall be incorporated to detect leakage current from field I/O wiring to ground.

17.6.2 Due care must be taken to ensure that circuits from one ground fault selector switch will not be cross-connected to circuits from any other ground fault selector switch (e.g., at common annunciator points, lamp test connections).

31 July 2004
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Minor revision.