Engineering Standard

SAES-P-104 8 August 2010

Wiring Methods and Materials

Document Responsibility: Electrical Systems Designs & Automation Standards Committee

Saudi Aramco DeskTop Standards

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1 Scope

1.1 This Standard prescribes mandatory requirements for the design and installation of insulated power and control wiring and cable systems. It also prescribes minimum mandatory requirements for outdoor enclosures for electrical equipment and wiring that are not covered by another SAES or SAMSS.

1.2 For the purpose of this standard, control wiring is wiring used for the interconnection of electrical control devices, such as pushbuttons, electromechanical relays, meters, transducers, etc., associated with power systems, and also microprocessor based protection relays for power distribution and motors.

1.3 For the purpose of this standard, wiring connected on one or both sides to instruments, distributed control systems, computers, etc., (except for AC power connections) is considered instrumentation wiring and is covered by SAES-J-902. SAES-P-104 applies to instrumentation wiring only insofar as it is referenced in SAES-J-902.

1.4 Fiber optic cables dedicated to the control of power systems, such as intertrip and switchgear control including installation of composite power-fiber optic cables and composite submarine cables shall be installed as per SAES-T-624, and SAES-T-919. The use of composite power-fiber optic cables must be concurred to by the Department responsible for the maintenance of the fiber optic component of the cable.

1.5 This standard does not apply to internal wiring of manufactured equipment covered by SAMSS, or manufactured equipment labeled, listed or certified by a testing agency recognized by Saudi Aramco.

1.6 This standard does not apply to overhead distributions systems. Refer to SAES-P-107.

2 Conflicts, Deviations and Commentary

2.1 If there are any conflicts between this Standard and associated purchasing, project or engineering documents, this standard shall take precedence.

Exception:

The exception is if an approved Waiver that is to be applied in SAP has been included with the purchasing documents.

2.2 Any conflict between this Standard and other Mandatory Saudi Aramco Engineering Requirements (MSAERs*) or referenced industry standards shall be

brought to the attention of the Company or Buyer Representative who will request the Manager, Consulting Services Department of Saudi Aramco, Dhahran to resolve the conflict.

* *Examples of MSAERs are Saudi Aramco Engineering Standards (SAESs), Materials System Specifications (SAMSSs) and Standard Drawings (SASDs).*

2.3 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 a waiver request to the Manager, Consulting Services Department of Saudi Aramco, Dhahran requesting his approval.

2.4 The designation "Commentary" is used to label a sub-paragraph that contains comments that are explanatory or advisory. These comments are not mandatory, except to the extent that they explain mandatory requirements contained in this SAES.

3 References

All referenced Standards, Specifications, Codes, Forms, Drawings and similar material shall be the latest issue (including all revisions, addenda and supplements) unless stated otherwise.

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-A-112	*Meteorological and Seismic Design Data*
SAES-B-006	*Fireproofing in Onshore Facilities*
SAES-B-008	*Restrictions to Use of Cellars, Pits & Trenches*
SAES-B-009	*Fire Protection and Safety Requirements for Offshore Production Facilities*
SAES-B-064	*Onshore & Nearshore Pipeline Safety*
SAES-B-068	*Electrical Area Classification*
SAES-H-101	*Approved Protective Coating Systems*
SAES-J-902	*Electrical Systems for Instrumentation*
SAES-O-113	*Security Lighting System*

SAES-P-100	*Basic Power System Design Criteria*
SAES-P-107	*Overhead Distribution Systems*
SAES-P-111	*Grounding*
SAES-P-116	*Switchgear and Control Equipment*
SAES-Q-001	*Criteria for Design and Construction of Concrete Structures*
SAES-T-624	*Telecommunications Outside Plant - Fiber Optics*
SAES-T-911	*Telecommunication Conduit System Design*
SAES-T-919	*Submarine Fiber Optic Cable (1.4)*
SAES-T-928	*Telecommunications - OSP Buried Plant*

Saudi Aramco Materials System Specifications

09-SAMSS-097	*Ready-Mixed Portland Cement Concrete*
15-SAMSS-502	*Medium Voltage Power Cable 5 kV through 35 kV*
15-SAMSS-503	*Submarine Power Cable 5 kV through 115 kV*
16-SAMSS-520	*Cablebus*

Saudi Aramco Standard Drawings

AA-036025	*Four-Way Manhole (2 Sheets)*
AB-036273	*Surface Marker - Underground Electric Cable*
AB-036326	*Standard Sign - Underground Electric Cable*
AD-036874	*Installation - Direct Buried Electric Cable and Conduit*

Saudi Aramco General Instructions

GI-0002.705	*Performance Certification of High Voltage Cable Splicers (formerly GI-0401.082)*
GI-1021.000	*Street and Road Closure: Excavations, Reinstatement and Traffic Controls*

Saudi Aramco Form and Data Sheet

7823-ENG	*Saudi Aramco H.V. Cable Test Record*

Saudi Aramco Precommissioning Forms

Form P-040	*Low Voltage Cables*
Form P-041	*HV Cables 5-15-36 kV*

Form P-042	*HV Cables 69 – 115 kV*

3.2 Industry Codes and Standards

The following industry standards are mandatory when and to the extent referenced in other sections of this standard:

American National Standards Institute

ANSI C80.1	*Rigid Steel Conduit - Zinc Coated*
ANSI C80.3	*Electrical Metallic Tubing - Zinc Coated*

American Society for Testing and Materials

ASTM B8	*Concentric-lay-stranded Copper Conductors, Hard, Medium-hard, or Soft*
ASTM B496	*Compact Round Concentric-Lay-Stranded Copper Conductors*

American Society of Mechanical Engineers

ASME B1.20.1	*Pipe Threads, General Purpose (Inch)*

Association of Edison Illuminating Companies

AEIC CS2	*Specification for Impregnated Paper and Laminated Paper Polypropylene Insulated Cable, High Pressure Pipe Type*
AEIC CS4	*Specifications for Impregnated-Paper-Insulated Low and Medium Pressure Self-Contained Liquid Filled Cable*
AEIC CS6	*Specifications for Ethylene Propylene Rubber Insulated Shielded Power Cables Rated 5 through 69 kV*
AEIC CS9	*Specifications for Crosslinked Polyethylene Insulated Shielded Power Cables Rated 69 through 138 kV*
AEIC CS8	*Specification for Extruded Dielectric, Shielded Power Cables Rated 5 through 46 kV*

British Standards Institution

BS 6121	*Mechanical Cable Glands*
BS 50262	*Metric Cable Glands for Electrical Installations*

Institute of Electrical and Electronic Engineers

IEEE 386	*Separable Insulated Connector Systems for Power Distribution Systems above 600 Volts*
IEEE 442	*IEEE Guide for Soil Thermal Resistivity Measurements*
IEEE 835	*IEEE Standard Power Ampacity Tables*

Insulated Cable Engineers Association

ICEA S-94-649	*Concentric Neutral Cables Rated 5,000 – 46,000 Volts*
ICEA S-97-682	*Utility Shielded Power Cables Rated 5,000 – 46,000 Volts*
ICEA-S-108-720	

International Electrotechnical Commission

IEC 60227	*Polyvinyl Chloride Insulated Cables of Rated Voltages up to and including 450/750 V*
IEC 60228	*Conductors of Insulated Cables*
IEC 60332-1	*Tests on Electric Cables under Fire Conditions – Part 1: Test on a Single Vertical Insulated Wire or Cable*
IEC 60332-3	*Tests on Electric Cables under Fire Conditions – Part 3: Tests on Bunched Wires or Cables*
IEC 60502-1	*Power Cables with Extruded Insulation and their Accessories for Rated Voltages from 1 kV up to 30 kV – Part 1: Cables for Rated Voltages of 1 kV and 3 kV*
IEC 60502-2	*Power Cables with Extruded Insulation and their Accessories for Rated Voltages from 1 kV up to 30 kV – Part 2: Cables for Rated Voltages from 6 kV up to 30 kV*
IEC 60529	*Classification of Degrees of Protection Provided by Enclosures*
IEC 60840	*Power Cable Extruded Insulation 30 kV to 150 kV*
IEC 60364	*Low Voltage Cable Electrical Installation*
IEC 62067	*Power Cable w/ Extruded Insulation above 150 kV*
IEC 60287	*Electrical Cables Calculation of Current Rating*

National Electrical Manufacturers Association

NEMA 250	*Enclosures for Electrical Equipment (1000 Volts Maximum)*
NEMA FG 1	*Fiberglass Cable Tray Systems*
NEMA ICS 6	*Enclosures for Industrial Control and Systems*
NEMA RN 1	*Polyvinyl-Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit*
NEMA TC 2	*Electrical Polyvinyl Chloride (PVC) Conduit*
NEMA TC 3	*PVC Fittings for Use with Rigid PVC Conduit and Tubing*
NEMA TC 6 & 8	*PVC Plastic Utilities Duct for Underground Installations*
NEMA TC 9	*Fittings for PVC Plastic Utilities Duct for Underground Installation*
NEMA VE 1	*Metal Cable Tray Systems*
NEMA VE 2	*Cable Tray Installation Guidelines*

National Fire Protection Association

NFPA 70	*National Electrical Code (NEC)*

Underwriters Laboratories

UL 44	*Thermoset-Insulated Wires and Cables*
UL 83	*Thermoplastic-Insulated Wires and Cables*
UL 1277	*Power and Control Tray Cables with Optional Optical Fiber Members*

3.3 Other References

Saudi Standards, Metrology and Quality Organization

SASO 55	*PVC-Insulated Cables with Circular Copper Conductors*
Volume 4	*Saudi Building Code*

4 General

4.1 Design and installation of wiring and cable systems shall be in accordance with Saudi Building Code, ANSI/NFPA 70 (National Electrical Code, NEC), and IEC as supplemented by this standard.

4.2 Severe corrosive environments are locations and installations listed in Section 9.1 of SAES-P-100.

4.3 Locations where chemicals are being handled, enclosures, conduits, fittings, and wirings must be resistant to the chemicals present.

4.4 For the purpose of this standard only, outdoor locations correspond to wet or damp locations; and indoor locations correspond to dry locations. This is defined by the National Electrical Code Article 100.

Commentary Note 4.4:

A structure enclosed by walls on three sides only, and has a roof, is considered an outdoor location. A non-airconditioned building is considered an indoor location. A shop that has its doors kept open to facilitate entry of vehicles is considered an indoor location.

5 Wire and Cable

5.1 Wires and cables shall have copper conductors. Aluminum conductors are permitted to be used in community areas for sizes 25 mm² or larger.

5.2 Equipment grounding conductor shall be provided with each power circuit as mandated in Section 9.1 of SAES-P-111.

5.3 Basic Wire and Cable Specifications

5.3.1 Low voltage jacketed cables shall comply with NEC or IEC 60502-1.

5.3.1.1 NEC low voltage cables shall be rated 600 V, shall have a minimum temperature rating of 90°C dry/75°C wet, and shall conform to UL standards according to the particular type (e.g., UL 1277, including its vertical tray flame test, for type TC tray cables, etc.)

5.3.1.2 IEC 60502-1 type cables shall be rated 600/1000 V, shall have a minimum rating of 85°C, and shall meet the flame test of IEC 60332-3.

5.3.2 Low voltage unjacketed insulated wires shall comply with NEC, SASO 55, or IEC 60227.

Exception to Sections 5.3.1 and 5.3.2:

For wiring of equipment such as lighting fixtures, etc., that require higher temperature wires and cables, the above minimum temperature ratings shall be increased accordingly.

5.3.2.1 NEC low voltage wires shall be rated 600 V, shall have a minimum temperature rating of 90°C dry/75°C wet, and shall conform to UL standards according to the particular type (e.g., UL 83 for THHN/THWN and UL 44 for XHHW).

5.3.2.2 SASO 55 or IEC 60227 type low voltage wires shall be rated 450/750 V, shall have a minimum rating of 85°C, and shall meet the flame test of IEC 60332-1.

5.3.2.3 Low voltage unjacketed insulated wires shall not be used in cable trays (except when used as grounding conductors or listed and marked for use in cable trays), duct banks involving manholes, or direct burial applications.

Commentary Notes: 5.3.1.1 and 5.3.2.1

A third party type test certificate from the manufacturer acceptable to the Coordinator, CSD/ESD, and meets applicable UL standards is acceptable in lieu of formal UL listing or certification.

5.3.3 Medium voltage power cables, rated 5 kV through 35 kV, to be used on systems with nominal voltages between 2 kV and 34.5 kV, [excluding submarine, submersible pump (down hole), portable, and motor lead cables] shall comply with 15-SAMSS-502, and shall be either IEC or ICEA/AEIC type cables.

5.3.3.1 IEC type medium voltage cables shall comply with IEC 60502-2 and IEC 60332-3, and the additional requirements of 15-SAMSS-502.

5.3.3.2 ICEA/AEIC type medium voltage cables shall comply with ICEA S-94-649 or S-97-682, and AEIC CS9, and the additional requirements of 15-SAMSS-502.

5.3.4 Power cables rated 69 kV and above, with solid dielectric insulation, shall comply with either AEIC CS6 (69 kV EPR insulated cable) or AEIC CS9 (69 kV and above XLPE insulated cable). Insulation thickness shall be in accordance with the tables in these standards [e.g., 16.5 mm (650 mils) for 69 kV rated cables and 20.3 mm (800 mils) for 115 kV rated cables], not reduced thickness based on maximum stress design.

Commentary Note 5.3.3.2 and 5.3.4:

Despite its title, AEIC CS6 is currently used to specify only 69 kV EPR insulated cables. For 5 through 46 kV cables, it has been superseded by AEIC CS8.

5.3.5 Submarine power cables, 5 kV through 115 kV, shall comply with 15-SAMSS-503.

5.4 Medium-voltage cables meeting the requirements of 15-SAMSS-502 are suitable for use in Class I, Division 2 and Zone 2 locations. Cables manufactured in accordance with IEC 60502-1 and rated 600/1000 V, having similar constructions to those listed in NEC Article 501, are suitable for use in Class 1, Division 2 and Zone 2 locations.

5.5 For land cable concentric neutral wire, metallic armor, and metallic sheaths shall be protected with a PVC or equivalent jacket.

5.6 Power and control conductors shall be stranded, except solid copper conductors 6 mm² (10 AWG) and smaller may be used in non-industrial locations. Mineral insulated cables and specialty cables (e.g., downhole pump motor cables, high temperature cables, etc.) with solid conductors are also permitted. Stranded power, control and grounding conductors shall have stranding in accordance with ASTM B8 Class B or C, or ASTM B496, or IEC 60228 Class 2, except flexible cords, portable cables, battery leads and motor leads may have finer stranding in accordance with appropriate UL Standards or the manufacturers' recommendations.

5.7 Splicing of conductors shall be kept to a minimum. The maximum number of field splices permitted in any one circuit for new installations of cables rated above 1000 V (excluding submarine cables) is the number made necessary by the use of standard size reels with full length cables. In case of accidental damage of the cable during installation, one additional splice is permitted with the concurrence of the cable Proponent. Splices and terminations on cables rated above 1000 V shall be made by personnel certified in accordance with Saudi Aramco General Instruction GI-0002.705. Conductors used for grounding metallic shields or maintaining shield continuity through splices or termination shall have a current rating no less than the metallic shield.

5.8 Conductors of multi-conductor control cables shall be numbered or color-coded by colors other than green, green with yellow stripes, white or gray.

5.9 Size of Conductors

5.9.1 Minimum size of conductors shall meet the requirements of Table 1.

Table 1 – Minimum Conductor Size

Voltage	Size
600 V and below (control)*	2.5 mm² (14 AWG)
600 V and below (power)*	4 mm² (12 AWG)
5 kV	10 mm² (8 AWG)
15 kV	35 mm² (2 AWG)
35 kV	50 mm² (1/0 AWG)
69 kV	120 mm² (4/0 AWG)

Note: * Including associated grounding conductors.

Commentary Note:

The 2.5 mm² minimum size does not apply to instrument cables. See paragraph 1.3.

5.9.2 Maximum size of conductors rated below 69 kV shall be 500 mm² or 1,000 kcmils.

5.10 Cables for security lighting (perimeter and area lighting) shall be armored or metal clad, installed underground and rising inside the lighting poles. See SAES-O-113.

5.11 Armored cable (unless specifically designated as Type AC per NEC) shall be manufactured to IEC 60502-1 or IEC 60502-2, and shall have galvanized steel wire armor or galvanized double steel tape armor under the jacket. For installation and application purposes, armored cable manufactured to IEC 60502-1 or IEC 60502-2 shall be considered equivalent to type MC (metal clad) cable.

Exceptions:

A) In Class I, Division 1 and Zone 1 hazardous locations, only cables specifically permitted by NEC Article 501 are allowed without rigid steel conduit;

B) Cable terminators shall be approved for the specific type of cable used;

C) For single conductor cables, armor material shall be aluminum instead of steel.

Commentary Note 5.11:

Armored cable Type AC per NEC, referred to also as type BX, not to be confused with the above, is light duty cable, and is not permitted in hazardous locations. Metal clad cable type MC per NEC is permitted in Class I, Division 2 and Zone 2, and if listed in Class I, Division 1 and Zone 1 locations.

5.12 Type MC cable and armored cable per paragraph 5.10 shall be permitted to be installed and exposed where it is not subject to damage by vehicular traffic or similar hazards. Sections of exposed type MC or armored cable longer than 2 meters shall have continuous support. Other types of cable shall not be installed or exposed above ground, and shall be installed in cable trays, conduit, or where flexibility is required in flexible conduit.

Exception:

Equipment grounding conductors shall be permitted to be installed exposed where they are protected from physical damage; see also paragraph 10.5 Exception (B).

5.13 Type MC cable and armored cable shall be used for underground installations. Un-armored type cables shall be used for cable tray and conduit systems installations.

Exception:

If the cable run has transition from direct burial to cable tray, then the cable shall be armored for the entire length or to the nearest point where it become practical to change to unarmored cable.

5.14 The grounding of shields, sheaths, armor and other materials in cable systems shall be in accordance with SAES-P-111.

5.15 Fireproofing of cables shall be in accordance with SAES-B-006 (onshore facilities) or SAES-B-009 (offshore facilities). See also paragraph 12.6.4.

5.16 The material specifications of fiber optic components of composite cables, and fiber optic cables that fall under the scope of paragraph 1.4 shall be in accordance with SAES-T-624 and SAES-T-919.

6 Connections and Terminations

6.1 Compression (crimped) type connectors shall be used for splicing and terminating stranded conductors, except as indicated in paragraphs 6.3 to 6.5 below, and except as specified in SAES-P-111 for grounding conductors. The use of solder lugs is prohibited. Compression terminal connectors for 4/0 and larger conductors shall be two hole NEMA design. All compression connectors for 8 AWG and larger conductors shall have a manufacturer's reference compression die number and conductor size printed or stamped on the connector.

Exceptions:

1. The use of dieless compression tools is acceptable, provided that the tool is suitable for the connector, and (for 8 AWG and larger conductor connectors), the tool ram embosses the tool manufacturer's logo on the crimp.

2. Single hole compression terminal connectors for 4/0 and larger conductors are permitted for terminations on manufactured equipment that has integral provisions for single hole lugs only.

Commentary Note 6.1:

Compression in compression connectors is accomplished by means of a compression or crimping tool. Connectors in which compression is accomplished by means of bolts, set screws, etc., are mechanical, not compression connectors.

6.2 All compression connectors shall be tinned copper.

Exception:

Separable load-break or dead-break connectors (elbows) having non-copper current carrying components, are permitted, provided they are marked and approved as suitable for copper conductors.

6.3 Spring pressure type twist-on connectors, and pressure set screw connectors with insulating caps are permitted (a) for lighting and receptacle circuits in non-hazardous locations, and (b) in non-industrial applications.

6.4 Use of connectors or terminals other than compression type, except solder connectors, supplied as integral parts or components of manufactured equipment such as molded case circuit breakers, contactors, outlets, etc., is permitted.

6.5 Use of mechanical connectors or terminals supplied as integral parts of splice and termination kits (including connectors or terminals with breakout bolt heads) for 69 kV cables are permitted with the approval of the Electrical Systems Designs and Automation Standards Committee Chairman.

6.6 Insulated ring tongue, locking fork tongue, flanged fork tongue and pin type compression (crimped) terminals shall be used for control wiring.

Exception:

Only ring tongue compression (crimped) terminals shall be used for current transformer circuits.

6.7 Cable terminators relying on inwardly protruding flat springs or tines for grounding the metallic sheath or armor are prohibited.

6.8 All threaded cable fittings including terminators (glands) for metric size cables shall have tapered (NPT) threads in accordance with ANSI/ASME B1.20.1.

6.9 Cable glands shall be designed to permit disconnection without the need to rotate the cable or the equipment on which the gland is terminating (e.g., sealing glands shall have a built-in union).

6.10 Cable and Wire Identification at Terminations

6.10.1 Identification of cables shall include the cable number and destination (e.g., load equipment tag number).

6.10.2 Individual control wires shall be identified by two labels at each end. The first label (closest to the end of the wire) shall identify the number of the terminal to which the wire is connected. The other label shall identify the terminal of the opposite end of the wire.

Exception to 6.10.1 and 6.10.2:

Alternate identification schemes, which conform to established local practice, may be used for extensions to existing facilities with prior approval of the facility Proponent.

6.10.3 Individual phases of power circuits shall be identified by color coding to be synchronized as per SASO color-coding conductors or other means (e.g., marked A, B and C). Neutral (grounded) conductors shall be identified by colors white or grey, and insulated grounding conductors by colors green or green with yellow stripes.

6.10.4 Marking methods: Wires at termination points shall be identified by the use of permanently imprinted or embossed wire markers of the heat-shrinkable or slip-on type. Slip-on wire markers shall be sufficiently tight so that they will not slip unintentionally. Wrap-around, rigid snap-on, or adhesive type markers are not permitted for wire or cable identification. Cables may be identified by special plastic or non-corrosive metal labels held with cable ties, or similar methods. Colored insulating tapes may be used for phase identification of power circuit conductors.

6.11 Stress relief shall be provided at terminations of cables with insulation shields.

6.12 Creepage Distance of Terminations

Commentary Note 6.12:

Creepage distance is measured between line and ground, but is based on the line-to-line voltage; e.g., for 13.8 kV outdoor terminations, each phase shall have a creepage distance of 552 mm to ground minimum.

6.12.1 Paragraphs 6.12.2 to 6.12.5 apply only to terminations operating at 2.4 kV and above in air, except terminations with conductive or semiconductive outer surfaces [e.g., they do not apply to potheads or separable connectors (elbows)].

6.12.2 Medium and high voltage terminations (operating at 2.4 kV and above) installed outdoors shall have a minimum creepage distance to ground of 40 mm per kV line-to-line nominal system voltage.

6.12.3 Medium and high voltage terminations installed indoors shall have a minimum creepage distance to ground of 25 mm per kV line-to-line nominal system voltage.

6.12.4 Medium and high voltage terminations installed inside enclosures located outdoors shall be considered indoor terminations if the enclosures are rated NEMA ICS 6 Type 3 or 4, or IEC 60529 Type IP54. And shall be considered outdoor terminations if the enclosure a lesser degree of protection (e.g., NEMA Type 3R).

6.13 AWG connectors may be used for metric size conductors, and vice versa, provided the connector range spans the actual cross-sectional area of the conductor. For compact stranded conductors, standard connectors suitable for non-compact conductors of the same size may be used. No down-sizing of standard connectors for compact stranded conductors is allowed.

Commentary Note 6.13:

Before compression on a compact stranded conductor, a standard connector usually appears too loose, but since the cross-sectional area of copper is the same, the end result after compression is the same.

6.14 Cable glands (for hazardous and non-hazardous locations) shall be in accordance with BS 6121 or BS 50262, except threads shall be in accordance with paragraph 6.8 above. In addition, cable glands for hazardous locations must comply with all applicable requirements of the NEC, SAES-P-100, and paragraph 15.3 below. New suppliers of cable glands must submit type tests performed by a third party testing agency acceptable to the Coordinator, CSD/ESD. (For hazardous location glands acceptable testing agencies are listed in SAES-P-100).

6.15 New suppliers of compression connectors for conductors 4/0 AWG and larger must submit type tests performed by a third party testing agency acceptable to the Coordinator, CSD/ESD.

7 Enclosures

Equipment and terminal enclosures, unless otherwise specified in other Electrical SAESs or SAMSSs, shall meet the requirements of this Section. For all outdoor enclosure conduit connection shall be installed with bottom or side entries.

7.1 In outdoor plant areas, equipment and terminal enclosures shall be: (a) NEMA 250/NEMA ICS 6 Type 4; or (b) NEMA Type 3 manufactured copper free cast

aluminum (0.4 of 1% maximum), or plastic (including fiberglass); or (c) IEC 60529 Type IP54 or better.

7.2 In outdoor plant areas, outside the perimeter of process units, and other industrial areas, equipment and terminal enclosures shall be: (a) NEMA Type 3 or 4; or (b) IEC 60529 Type IP54 or better.

7.3 In outdoor plant and other industrial areas located in severe corrosive environments as defined in Paragraph 4.2, equipment and terminal enclosures shall be: (a) NEMA Type 4X (except galvanized and/or painted or coated carbon steel sheet metal enclosures are not permitted); or (b) NEMA Type 3 or 4, manufactured of copper free cast aluminum (0.4 of 1% copper maximum), or plastic (including fiberglass); or (c) IEC 60529 Type IP 54 or better, manufactured of stainless steel (Type 304 or better), copper free cast aluminum, or plastic (including fiberglass).

Commentary Note 7.3:

In outdoor plant and other industrial areas located in severe corrosive environments, paragraph 7.3 supersedes paragraphs 7.1 and 7.2.

7.4 In outdoor non-industrial areas, equipment and terminal enclosures shall be: (a) NEMA Type 3R, 3 or 4; or (b) IEC 60529 Type IP34 or better.

7.5 In outdoor locations, enclosures for small dry-type transformers shall be totally enclosed NEMA Type 3R. In severe corrosion environments, enclosure material shall be suitable for the application.

7.6 In hazardous (classified) locations, enclosures that are required to be approved for Class I locations by NEC Article 501 or 505, shall meet the hazardous area equipment application requirements of SAES-P-100 and the NEC, in addition to all applicable requirements of Paragraphs 7.1 to 7.4 above. See also Section 15.

7.7 Enclosures that are rated (a) NEMA Type 3, 4 or 4X, or (b) IEC 60529 Type IP54, or better, shall have Type 300 Series stainless steel hardware.

Exception:

Aluminum enclosures may have aluminum or aluminum alloy hinges and operating handles.

7.8 Enclosure Breathers and Drains

7.8.1 Enclosures and junction boxes having an internal volume exceeding 2,000 cm^3 shall be provided with Type 300 Series stainless steel breather and drain fittings, or a combination of breather and drain fitting. Enclosures shall be provided with tamper-resistance factory

assembled breather/drainer or (prevision for future breather/drainer) system where required.

Exceptions:

1. Thin wall (sheet metal or plastic, including fiberglass) enclosures and junction boxes may be drained by drilling a 5 mm hole in the bottom, at the discretion of the facility Proponent.

2. Factory sealed multigang, push button, and similar control stations are exempted from this requirement.

7.8.2 Unless otherwise specified, enclosures may meet water and dust tightness requirements (paragraphs 7.1 to 7.4) with openings for breathers and drains plugged.

8 Conduit, Conduit Fittings and Supports

8.1 Underground conduit

8.1.1 Direct buried conduit shall be PVC conduit Type DB-120 (minimum modulus of elasticity 500,000 psi) per NEMA TC 6 & 8 or Type EPC-40-PVC per NEMA TC 2.

Exception:

Direct buried conduit in class I division I shall be threaded, rigid steel, hot dip galvanized and PVC coated.

8.1.2 Concrete encased conduit shall be PVC conduit Type EB-35 or DB-120 (minimum modulus of elasticity 500,000 psi) per NEMA TC 6 & 8 or Type EPC-40-PVC per NEMA TC 2.

Commentary Notes 8.1:

1990 NEMA Standards TC 6 and TC 8 have been superseded NEMA TC 6 & 8 (1999). PVC conduits Type EB-35 and DB-120 (minimum modulus of elasticity 500,000 psi) per NEMA TC 6 & 8 (1999) correspond to Type EB and DB per NEMA TC 8 (1990).

Internal diameters of NEMA TC 6 & 8 conduit are larger that NEMA TC 2 conduit internal diameters; consequently, the maximum number of conductors permitted in NEMA TC 6 & 8 conduits may be slightly larger.

8.2 Conduit installed exposed (e.g., not embedded in walls) above ground in outdoor, industrial facilities shall be threaded, rigid steel per ANSI C80.1, and in addition it shall be hot-dip galvanized. See also Paragraph 10.5.

Exception:

Where flexibility is required, liquid-tight flexible metal conduit (in non-hazardous and Class I, Division 2 and Zone 2 hazardous locations) or explosion-proof flexible couplings (in Class I, Division 1 and Zone 1 hazardous locations) shall be used.

8.3 Conduit above ground in severe corrosive environments shall be as specified in Paragraph 8.2 and, in addition, shall be factory PVC coated (minimum thickness of PVC: 40 mils (1 mm) per NEMA RN 1.

Exception:

Where flexibility is required, liquid-tight flexible metal conduit (non-hazardous and Class I, Division 2 and Zone 2 locations) or explosion-proof neoprene coated or PVC coated flexible couplings (in Class I, Division 1 and Zone 1 locations) shall be used.

8.4 Electrical metallic tubing (EMT) is acceptable only in non-hazardous indoor locations. EMT shall comply with the requirements of ANSI C80.3.

8.5 Intermediate metal conduit (IMC) is prohibited.

8.6 The minimum conduit size shall be ¾ inch or equivalent in metric size, except for, instrumentation wiring, prefabricated skids, and in non industrial areas, in which case the minimum size conduit shall be ½ inch.

8.7 Conduit and threaded conduit fittings shall have tapered (NPT) threads in accordance with ANSI/ASME B1.20.1.

8.8 Field cut conduit threads shall be coated with a zinc rich protective coating.

8.9 Conduit Fittings

8.9.1 Conduit fittings for outdoor rigid steel conduit and liquid-tight flexible metal conduit shall be cast or forged steel, cast iron or malleable iron, either hot-dip galvanized (preferably), or zinc electroplated as supplied by the manufacturer. No aluminum fittings or fitting accessories such as covers, sealing fitting plugs, etc., shall be used outdoor. Gray cast iron split type (EYSR) retrofit sealing fittings may be used if required for repair purposes.

Exception:

Rigid steel conduit and liquid-tight flexible metal conduit hubs manufactured from zinc, that are UL or CSA listed (e.g., Myers Scru-Tite hubs) are also acceptable.

8.9.2 Conduit fittings for rigid steel conduit and liquid-tight flexible metal conduit used above ground in severe corrosive environments shall be

as specified in Paragraph 8.9.1 and in addition, shall be protected by one of the following methods:

a) Factory-coating with PVC (minimum thickness of PVC: 40 mils) per NEMA RN 1. Internal surfaces of PVC sleeves (boots) and other mating PVC surfaces shall be coated with PVC patching compound (1000421977). Uncoated plugs and other bare metal shall be coated with PVC patching compound, or with SAES-H-101 APCS-22 (offshore), or APCS-26 (onshore).

b) Field-coating prior to installation in accordance with SAES-H-101 APCS-22 (offshore), or APCS-26 (onshore). Light (sweep) sandblasting is required prior to coating so that the zinc is not removed. After installation, any bare metal must be touched up using either of the above coatings, without sandblasting.

c) By heat-shrinkable tubes or wrap-arounds, where the geometric configuration permits it.

Exception:

Red leaded brass or silicon bronze conduit fittings may be used as an alternative to the above in severe corrosive environments (only above ground).

8.9.3 Conduit fittings for direct buried PVC coated rigid steel conduit shall be factory PVC coated.

8.9.4 Threads of plugs, junction boxes and other fittings shall be lightly lubricated with a rust preventive grease before assembly.

8.9.5 The use of conduit unions with underground conduit should be avoided. If this is not possible, conduit unions must be protected with heat-shrinkable sleeves or wrap-arounds.

8.9.6 Fittings for NEMA TC 6 & 8 Type PVC conduit shall be in accordance with NEMA TC 9. Fittings for NEMA TC 2 Type PVC conduit shall be in accordance with NEMA TC 3. TC 9 and TC 3 fittings are generally not interchangeable.

8.10 Supports

8.10.1 Channel erector system components (Unistrut or similar) used to support conduits, cable trays, enclosures, lighting fixtures and other electrical equipment shall be made of steel or iron, either hot-dip galvanized (preferably), or zinc electroplated as supplied by the manufacturer.

8.10.2 Channel erector system components (Unistrut or similar) used to support conduits, cable trays, enclosures, lighting fixtures and other electrical equipment in severe corrosive environments shall be: (A) as specified in Paragraph 8.10.1, and, in addition, protected by the methods outlined in Paragraphs 8.9.2 (a) or (b), or (B) stainless steel; or (C) fiberglass.

8.10.3 Process piping shall not be used to support conduits, except with the Proponent's approval. If process piping is used to support conduits, adequate corrosion protection at the interface between the piping and support fittings shall be provided.

Commentary Note 8.10:

Plant structural members used as supports for conduit and other electrical equipment are outside the scope of this Section. Attachment hardware (clamps, bolts, nuts, etc.) must however, comply with the requirements of this Section.

8.11 Conduit fill shall not exceed the maximum fill specified in NEC Chapter 9.

Commentary Note 8.11:

Because conductor sizes and insulation thickness of IEC and SASO type wires and cables vary from those of NEC type wires and cables, actual dimensions (outside diameters) must be used to calculate conduit fill and maximum number of wires allowed in conduit, instead of NEC tables.

9 Cable Trays

9.1 Cable tray material shall be copper-free aluminum (aluminum with a maximum of 0.4% copper), or fiberglass. For indoor air conditioned areas galvanized carbon steel is allowed. Cable trays shall be of the ladder (two side-rail) type. Cable tray installed outdoors shall have ventilated covers. Flanged type covers shall be secured with stainless steel (grade 316 in sever corrosive areas and 304 in other areas) banding and fasteners, one band per ½ m of cover length, with a minimum of six bands per cover. Cable trays run vertically in outdoor areas shall have covers on both sides. Cable tray system could be used to support cables or raceways only.

Exceptions:

1. *Cable trays containing only instrument and communications cables may have unventilated covers.*
2. *Cable tray covers may be deleted at the direction of the facility Proponent.*
3. *Cable tray covers are not required if cable trays are installed inside switchgear buildings.*
4. *Stainless steel cable trays shall be used when required by SAES-B-006, to satisfy*

fireproofing requirements. Stainless steel cable trays shall meet all other requirements of this section.

Commentary Note 9.1:

Cable tray covers provide additional protection for cables from deterioration caused by sunlight, and provide protection from mechanical damage. If cable tray covers are not installed, cable trays should be located to minimize the potential for mechanical damage and to minimize the effects of sunlight on the cables. The ampacity of cables installed in uncovered cable trays exposed to sunlight is reduced; see paragraph 12.2.

9.2 Aluminum and galvanized carbon steel cable tray shall be designed, manufactured, rated, and tested in accordance with NEMA VE 1. Method A (Loading to Destruction) shall be used for determining the rated load capacity. Minimum individual rung load capacity shall be 90 kg. Minimum thickness of covers shall be 1 mm. Only flanged cover sheets shall be used.

9.3 Fiberglass cable tray shall be designed, manufactured, rated, and tested in accordance with NEMA FG 1. Minimum individual rung load capacity shall be 90 kg. Fiberglass cable trays shall be sunlight (ultraviolet radiation) resistant.

9.4 The working load for cable trays shall consist of the weight of the cables (or tubing, etc.) including future additions (if required), plus a concentrated static load of 90 kg at the center of the span. If the cables plus future additions do not fill the selected cable tray to its NEC capacity, the weight of additional cables of the largest size contained in the tray, filling the cable tray to its NEC capacity (or smaller and/or varying size cables if this would maximize utilization of the available space), shall be added for calculating the working load. The concentrated static load may be converted to an equivalent uniform load using the formula in NEMA VE 1 or NEMA FG 1. The working load shall not exceed the rated load capacity of the cable tray defined in NEMA VE 1 or NEMA FG 1 (destruction load divided by a safety factor of 1.5).

9.5 Location of supports for cable tray systems shall be in accordance with the recommendations of NEMA VE 2. Splice plates (joints) shall not be located over supports, and shall be located between supports and quarter points. No more than one splice shall be located between two adjacent supports.

9.6 The maximum spacing between expansion joints shall be based on a temperature differential of 55°C (100°F) and expansion gap settings shall be in accordance with the recommendations of NEMA VE 2, based on a minimum temperature of 0°C and a maximum temperature of 55°C.

Commentary Note 9.6:

***Example**: For aluminum trays, maximum spacing between expansion joints that allow a 25 mm movement is 20 meters.*

***Note**: In Table 1 of the 1996 edition of NEMA VE 2 the °C column for temperature differential is incorrect. Correct results are obtained with the °F column.*

9.7 Cable trays shall be installed as a complete system. Cable tray systems shall not have mechanically discontinuous segments of cable tray runs.

9.8 Cables may be extended from cable trays to equipment if (a) they are armored or metal clad and are properly supported in accordance with NEC requirements, or (b) they are installed in rigid or flexible conduit.

9.9 Process piping shall not be used to support cable trays.

9.10 Deflection of the cable tray system (several sections spliced together as a continuous beam), when loaded to the working load as defined in paragraph 9.4, excluding the concentrated static load, shall not exceed L/100 (L=span length). (e.g., maximum permissible deflection for a 6 m span is 60 mm).

10 Underground Cable Systems

10.1 The minimum depth of burial requirements for underground installations shall be as specified in Table 2. See also Standard Drawing AD-036874.

Table 2 – Minimum Cover Requirements (Depth of Burial)

Millimeters from Grade Level to the Top Surface of Cable, Conduit or Duct Bank			
System Voltage	**Direct Buried Cables**	**Direct Buried PVC**	**Duct Bank and Direct Buried Rigid Steel**
600 V and below	610	460 (1), (3)	460 (2), (3)
Over 600 V to 35 kV	920	610 (3)	460 (2), (3)
Over 35 kV	1070	760 (3)	460 (2), (3)

Notes:

(1) 610 mm under roads, parking lots and other areas subject to vehicular traffic.

(2) 610 mm under roads.

(3) 1015 mm under roads where GI-1021.000 applies. ***Note:*** GI-1021.000 (Supplement 2) requirement: 1015 mm under roads, unless a reinforced concrete slab is installed. Exception may be granted by the Manager of the Saudi Aramco Department responsible for the road, in which case the 610 mm or 760 mm minimum values from the table apply. Refer to the GI-for details.

Exception:

Minimum burial depth for ground grid conductors shall be in accordance with SAES-P-111; however, minimum burial depth for ground grid conductors under

roads, parking lots and other areas subject to vehicular traffic shall be not less than 610 mm.

10.2 In rocky areas where digging must be minimized, in areas where Table 2 depths would result in cables being below the water table, or to avoid underground obstructions such as other cables, conduits or piping, cables may be installed in one of the following configurations:

a) PVC coated rigid steel conduit with a total cover not less than 300 mm, which shall include a 50 mm thick (minimum) reinforced concrete slab over the conduit; or

b) PVC coated rigid steel conduit with a total cover not less than 150 mm, which shall include a 100 mm thick (minimum) reinforced concrete slab over the conduit; or

c) A reinforced concrete encased duct bank with 150 mm of total cover, measured from the top of the upper conduit, which shall include a minimum of 100 mm of concrete over the upper conduit.

Concrete tiles cannot be used in lieu of the concrete slab in (a) or (b) above. The top layer of the concrete slab or the duct bank shall be mixed with red dye. (Minimum thickness of red concrete layer: 5 mm).

Commentary Note 10.2:

GI-1021.000 (Supplement 2) lists additional requirements for cables installed under roads.

10.3 Precast 50 mm thick red concrete tiles, red plastic tiles (12 mm minimum thickness), or PVC coated steel fence fabric shall be placed 300 mm above direct buried cable or direct buried conduit, in accordance with Standard Drawing AD-036874. In addition, a yellow warning tape shall be installed over the tiles or fence fabric. This paragraph does not apply to ground grid conductors and connections to ground grids or grounding electrodes, when paragraph 10.2 configurations are used, or under elevated substations.

10.4 Duct Banks

10.4.1 Duct banks shall consist of PVC conduit, encased in concrete.

10.4.2 Concrete shall be in accordance with SAES-Q-001 and 09-SAMSS-097.

10.4.2.1 In duct banks with steel conduit, unreinforced non-structural concrete [with minimum 28 day design compressive strength of 14 Mpa (2000 psi)] shall be used.

10.4.2.2 In duct banks with PVC conduit, under areas with no traffic, or occasional traffic (including roads with occasional traffic), unreinforced non-structural concrete as in paragraph 10.4.2.1 shall be used.

10.4.2.3 In duct banks with PVC conduit, under areas with frequent traffic, such as roads and parking lots inside plants or communities, reinforced concrete [with minimum 28 day design compressive strength of 28 Mpa (4000 psi)] shall be used.

10.4.3 There shall be a minimum of 75 mm of concrete from the outside surface of the duct bank to any conduit or reinforcing steel.

10.4.4 Fabricated spacers (1000428757, 1000428800, 1000428851, 1000428857, 1000428921 or equivalent) shall be used at intervals not exceeding 2.4 meters. The spacers shall provide a minimum conduit separation of 50 mm for 2 inch conduits and larger, and 25 mm for 1½ inch conduits and smaller.

10.4.5 Conduit runs within the duct bank shall be made continuous, by the use of threaded steel couplings for rigid steel conduit, and PVC solvent cement with PVC couplings or belled ends for PVC conduit.

10.4.6 Bell end fittings or protective bushings shall be provided on each duct where it terminates.

10.4.7 The top layer (5 mm minimum thickness) of the concrete shall be mixed with red dye.

10.4.8 Duct banks shall have 20% spare ducts (minimum one), unless this number is decreased by the facility Proponent.

10.5 PVC conduits shall not be extended above grade in industrial facilities. Where above grade extensions of buried PVC conduits are required, a transition shall be made underground, using threaded PVC to rigid metal conduit adapters.

Exceptions:

A) PVC stub-ups extending up to a maximum of 150 mm above ground and not attached to equipment are permitted;

B) Where concealed (embedded) in walls, floors, and ceilings.

C) Equipment grounding conductors running separately from power conductors (e.g., connections to ground grids) may be installed above ground in PVC conduit; if installed in rigid steel conduit; both ends of the conduit shall be bonded to the conductor.

10.6 Metallic conduit entering (from below grade) switchgear, control cabinets and similar enclosures sitting on the ground shall be cut and threaded 50 mm above finished grade level and a threaded, insulated grounding bushing shall be installed. PVC conduit entering switchgear, control cabinets and similar enclosures shall be cut flush with finished grade level and shall have its inner edge filed to a smooth radius.

10.7 Cables and conduits entering buildings shall comply with paragraphs 5.2 and 5.4 of SAES-B-008. (See also Section 15.4)

10.8 The location of underground cable, conduit or duct bank shall be marked in accordance with Standard Drawings AB-036273 or AB-036326.

Exception:

No underground cable markers are necessary inside switchyards and under elevated substations.

10.9 Manholes containing cables rated 5 kV and above shall be in accordance with Standard Drawing AA-036025.

Exception:

Manholes containing cables rated 5 kV and above, having different shape and size but equivalent structural strength to Standard Drawing AA-036025 manholes (same wall thickness, etc.), are permitted with the approval of the Electrical Systems Designs and Automation Standards Committee Chairman.

10.10 Manholes and handholes shall not be located in hazardous (classified) locations, or where prohibited by SAES-B-008. Where permitted inside hydrocarbon-handling plants, all ducts inside all manholes and handholes shall be sealed with duct sealing approved by the Electrical Systems Designs and Automation Standards Committee Chairman.

10.11 Cables that cross under paved roads, concrete slabs, railroads, or other areas that would require extensive or impractical excavations to replace, shall be run in duct banks per Paragraph 10.4 or in PVC sleeves per Table 2.

Exception:

Ground grid conductors (see also Paragraph 10.1 Exception).

Commentary Note 10.11:

Asphalt-paved parking lots and plant areas paved with asphalt for soil stabilization are not within the scope of this Paragraph. No duct banks or sleeves are required in these cases.

10.12 Cables crossing pipeline corridors shall be installed in accordance with SAES-B-064.

10.13 The minimum crossing or parallel clearance between direct buried cables or conduits and underground piping, including hydrocarbon pipelines that fall outside the scope of SAES-B-064, shall be 300 mm. For conduits, the crossing clearance may be reduced to 80 mm, if underground obstructions make it difficult to meet the 300 mm requirement. For direct buried cables, the same reduction is permitted if the cable is installed in a PVC sleeve at the crossing. Direct buried cables, conduits, or duct banks shall not be installed directly above or below parallel underground piping.

10.14 Direct buried cables and conduits shall be installed in a single layer, except where rearrangement is necessary at transitions to multi-layer concrete encased duct banks or for entering buildings.

10.15 Installation of cables in outdoor concrete-walled trenches with metal or concrete slab covers is not permitted.

10.16 The end(s) of ducts and conduit terminating below grade or in open air shall be sealed with duct sealing putty or an equivalent compound.

11 Submarine Power Cable

11.1 Cable Burial

11.1.1 Route assessment of submarine cable shall be performed taking in consideration issues like water depths and area topology, tidal currents or surf action, marine habitats, and other requirements associated with the environmental impact assessment (EIA).

11.1.2 Submarine power cable shall be buried a minimum of 1 m, starting at the land disconnecting device to a water depth of 7.5 m below Lowest Astronomical Tide (LAT).

11.1.3 Submarine power cable shall be buried a minimum of 1 m, or protected with grout-filled bags, or by a split tubing protection system, or similar method approved by the Electrical Systems Designs and Automation Standards Committee Chairman in the area within 100 m of a platform structure.

11.1.4 The axial spacing of the land section shall be minimum of 4.5 m between separate circuits. The axial spacing of cable in the submarine section, excluding that portion of the cable within 200 m of the

platform, shall be equal to the mean water depth unless a reduced spacing is approved by the Proponent of the submarine cables.

11.2 Platform Transition

11.2.1 Submarine power cable shall be physically protected from the bottom of the jacket leg, to the point of cable armor termination, by a trough, tube or direct mounting to the jacket leg. Cables shall not hang unprotected.

11.2.2 The submarine cable shall be anchored below the riser section by either of the following methods:

- Preformed cable grip(s) attached to a jacket leg by means of hot-dip galvanized chains.
- Galvanized carbon steel armor clamp designed to withstand the maximum tension exerted on the cable due to dragging. Design of the armor clamp shall include safety factor of 3. The galvanized CS armor below the J-Tube entrance to the flange shall be protected by applying PVC coating on each strand or protected with corrosion protection material at the area inside the J-TUBE.

11.2.3 The cable armor shall be terminated in an armor clamp located in a vertical riser section below the cable disconnecting device. The clamp shall provide positive anchoring and grounding of the armor wires, in addition to terminating and grounding the inner flat armor tapes.

12 Cable Sizing

The sizing of power cables in the Saudi Aramco System shall be based on the following:

12.1 Load Factor – 100%

Commentary Note 12.1:

See SAES-P-100 for load calculations.

12.2 Ambient Temperatures

Outdoor Exposed To Sun (for exposed cables, cables in conduit, and cables in uncovered cable trays)	:	60°C
Outdoor Shaded (for exposed cables, cables in conduit, cables in covered trays in the sun, and cables in cable trays in the shade)	:	50°C
Indoor Non-Air-conditioned	:	50°C

Indoor air-conditioned	:	35°C
Soil Temperature	:	40°C
Sea Water Temperature	:	35°C

Exception:

The summer design dry bulb temperature at 1% per SAES-A-112 for the specific location may be used as the outdoor shaded location ambient temperature (or increased by 10°C, if exposed-to-sun ambient temperature).

12.3 Earth Thermal Resistivity (RHO)

Land	:	120°C-cm/watt
Concrete (For Duct Banks)	:	85°C-cm/watt
Sea Bottom	:	80°C-cm/watt

Exception:

Results from measurements of RHO, if available, and if higher than the above, must be used instead of the above values. Measurements must be performed during a dry period. Results shall be reviewed by the Coordinator, CSD/ESD. For large projects, performing such measurements per IEEE 442 is recommended.

12.4 Additional Conditions - Shielded Cables:

Shields Bonded and Multi-point Grounded (at both ends and possibly additional points).

12.5 Additional Conditions - Submarine Cables

Maximum Conductor Operating Temperature	:	90°C
Maximum Conductor Emergency Temperature	:	110°C
Maximum Conductor Short Circuit Temperature	:	200°C
Maximum Shield Short Circuit Temperature	:	150°C

12.6 Ampacity Sources and Calculations

12.6.1 Ampacity calculations and cable sizing shall be based on the NEC, or from the tables in IEC 60364, and IEC 60502-2.

Commentary Notes 12.6.1:

A) For low voltage insulated unjacketed conductors in conduit above ground, NEC Table 310-16 should be used. For other methods of installation of low voltage cables and wires, Appendix B tables should be used. (Minimum conductor size for most Appendix B tables is 8 AWG.

In these cases, for conductors smaller than 8 AWG, Table 310-16 should be used). For medium voltage cables, Tables 310-67 through 310-86 should be used (except Tables 310-69 and 310-81, which are based on single-grounded shields). Article 318 should be used for sizing cables installed in cable trays.

B) To obtain ampacities at 120°C-cm/watt, when not listed in the tables, ampacities at 90°C-cm/watt should be divided by the following factors:

Direct buried single core	*1.12*
Direct buried multicore	*1.11*
Duct bank cable, single core	*1.08*
Duct bank cable, multicore	*1.05*

C) The derating factor for a change in ambient temperature, when not listed in the table, may be calculated by the formula:

$$F_t = \sqrt{[(T_c - T_a')/(T_c - T_a)]}$$

where

T_c : *Conductor temperature (used in the table)*

T_a : *Table ambient temperature*

T_a' : *Actual ambient temperature*

Source of formula: IEEE 835

12.6.2 Ampacity tables in IEEE 835 are permitted to be used in lieu of the NEC tables.

12.6.3 The Cable Derating Program of the Electrical Transient Analyzer Program (ETAP) or other power simulation software is permitted to be used to calculate ampacities, as an alternative to the NEC or IEEE 835 tables.

12.6.4 A derating factor of 0.85 shall be applied to cables that are fireproofed by coating or wrapping with a compound or other material, unless the fireproofing compound or material manufacturer recommends a different derating factor value. See also Paragraph 5.14.

12.6.5 The sizing of cables rated 69 kV and above shall be per IEC 60287, and the sizing of specialty cables, such as down-hole pump motor cables, high temperature motor leads, etc., shall be in accordance with manufacturers' guidelines.

Commentary Note 12.6.5:

When connected to terminations, devices, etc., having a lower

temperature rating, conductors must be sized based on this lower temperature rating. See NEC Article 110.

12.6.6 For cable sizing adjustment for fault conditions, the fault location shall be assumed to be at the load end of the cable. For low voltage cables, fault duration time shall be a minimum of 110% of the clearing time of the protective device providing primary protection to the cable (maximum total clearing time in the case of fuses). For medium voltage cables, fault duration time shall be a minimum of 110% of the clearing time of the protective device providing backup protection to the cable.

12.6.7 MV-105 cable (e.g., EPR insulated cable rated 105°C) shall be sized as a 90°C rated cable (using 90°C ampacities and derating factors).

12.6.8 For the basis of sizing a feeder which supplies distribution equipment, the maximum operating load shall be equal to the lower of:

1) The continuous current rating of the distribution equipment main bus or

2) The site rating of the upstream transformer.

Commentary Notes 12.6.8:

Distribution equipment would generally be equipment that will distribute power to multiple devices. Examples are switchgear, panel-boards, control-gear, switchboards, switchrack, etc.).

Note that SAES-P-116 requires the equipment (including cables) connected to the primary or secondary of the transformer to be rated based upon the site rating of the transformer.

13 Cable Testing after Installation

13.1 Low voltage (600, 450/750, or 600/1000 V rated) cables, including splices to existing cables, shall be 1000 V DC megger tested after installation and prior to placing in service (during commissioning).

13.2 Medium voltage cables (5 kV through 35 kV) shall be tested as follows:

a) New installations of cable and splices shall be 5 kV megger tested before and after backfilling and then DC high-potential tested after installation and prior to placing in service (during commissioning) at voltage levels specified in 15-SAMSS-502 or 15-SAMSS-503 and listed in Table 3.

b) New cables to be spliced to existing cables shall be megger tested and DC high-potential tested prior to splicing per (a) above. After splicing, the new and existing cable combination shall be 5 kV megger tested. In

addition, if the existing cable has been in service for less than five years, the new and existing cable combination shall be high-potential tested to the voltage listed in Table 3.

c) Routine periodic testing of cables is not recommended. Under special circumstances, as determined by the cable Proponent, the cable may be 5 kV megger tested, and, if it has been in service for less than five years, it may be high-potential tested to the voltage listed in Table 3. Other test method such as Very Low Frequency (VLF) test may be applied to determine the condition of old cables. DC high-potential testing shall not be performed on cables that have been in service for more than five years.

d) The high potential test on medium voltage cables may be performed after mounting or forming the terminations, provided: (i) terminations have creepage distances per Section 6.12; (ii) terminations are not connected to equipment, unless the equipment can also be tested at the same voltage; and (iii) there are sufficient clearances from enclosures and other adjacent objects.

e) If separable connectors (elbows) conforming to ANSI/IEEE 386 are used, the high potential test on medium voltage cables may, at the request of the cable Proponent, be performed after installation of the elbows. In this case: (i) the test must be performed with the elbows plugged into insulated parking bushings; and (ii) test voltage shall be the lesser of the ICEA cable test voltage listed in Table 3 and the ANSI/IEEE 386 DC withstand voltage.

Commentary Notes 13.2 (e):

A) For new 15 kV cable, when tested with elbows, the test voltage is reduced from 64 kV to 53 kV DC; for 35 kV cable it remains unchanged at 100 kV DC (the ICEA cable test value);

B) If 200 A elbows are installed on both ends of the cable, a feed-thru bushing instead of one of the two parking bushings may be used to apply the test voltage;

C) In most cases, it is chosen to test the cables without the elbows.

13.3 High voltage cables (69 kV and above) shall be tested after installation (during commissioning) to the voltage level listed in Table 3.

Commentary Note 13.2 and 13.3:

It is recommended, wherever possible, to perform high potential tests on buried cables prior to backfilling, to avoid excavation costs if the cables do not pass the tests.

Table 3 – DC and AC High-Potential Field Test Voltages

Cable Voltage Rating (Insulation Thickness)	After Installation – before Cable is Placed in Regular Service	In Service – First 5 Years
5 kV (115 mils) or 6/10 kV (3.4 mm)	36 kV DC [(a)(c)]	11 kV [(a)(c)]
15 kV (220 mils) or 12/20 kV (5.5 mm)	64 kV DC [(a)(c)]	20 kV [(a)(c)]
35 kV (345 mils or 9 mm)	100 kV DC [(a)(c)]	31 kV [(a)(c)]
69 kV (650 mils or 16.5 mm)	192 kV AC [(b)(c)(d)]	-----
115 kV and above	240 kV AC [(b)(c)(d)]	-----

Notes:

a) Source of test voltage values: ICEA S-94-649 and ICEA S-97-682

b) Source of test voltage values: EPR insulated 69 kV cables: AEIC CS6; XLPE insulated 69 and 115 kV cables: AEIC CS7 2nd Edition (1987), IEC-60840. See also paragraph 5.3.4.

c) Values apply to both AEIC and IEC type cables.

d) Soak test is an acceptable alternative for cables rated at 69 kV and above.

13.4 The integrity of the overall jacket of direct buried cables rated 5 kV and higher shall be tested by conducting a 5 kV megger and high potential test between the cable insulation metallic shield (and sheath or armor, if any) and ground. The DC high potential value shall be 4 kV/1 mm for one minute and not to exceed 10 kV. IEC 60229 shall be used for HV cable jacket integrity testing.

13.5 The integrity of the overall jacket of direct buried low voltage armored or metal clad cables shall be tested by conducting a 500 V megger test.

Commentary Note 13.5:

For this test to be meaningful, (a) the direct buried cable must be backfilled, and the backfill must be soaked in water, or, (b) (only for cables 69 kV and above) the outer jacket of the cable must be coated with manufacturer-applied graphite. If graphite coating is applied, it must be removed from the cable ends and splice points very thoroughly, because otherwise it may lead to termination or splice failures. For this reason, it must not be used on cables rated below 69 kV. It may be used for cables rated 69 kV and above, because installation of high voltage cables is more carefully monitored.

13.6 The results of all tests performed on cable rated 5 kV and above shall be documented on the Saudi Aramco H.V. Cable Test Record Form 7823-ENG, or on an equivalent form containing the same information.

Commentary Notes 13.6:

A) Examples of acceptable forms are Saudi Aramco Pre-Commissioning Forms P-004 and P-005.

B) In the event of conflict between this standard and information listed on the forms, this standard takes precedence over the forms.

14 Cable Separation

14.1 Minimum separation between (a) power or control conductors, and (b) instrument conductors (see paragraphs 1.2 and 1.3) shall be in accordance with SAES-J-902.

14.2 There are no minimum separation requirements between power and/or control conductors for DC or AC circuit voltages less than 1000 V, provided the insulation is rated at least 600 V or 450/750 V.

Commentary Note 14.2:

While it is technically acceptable to install power cables operating at less than 1000 V with no separation or with little separation, this may require a significant increase in conductor size, because separation between power cables affects their ampacity.

14.3 Minimum separation (above or below ground) between a power cable operating at 1000 V or above, up to 34.5 kV, and a parallel or crossing power or control cable operating at less than 1000 V, shall be 300 mm.

Exception:

Except when the medium voltage cable is armored or metal clad or is installed in rigid steel conduit, or is installed in aluminum cable tray and is separated from the lower voltage cable by solid fixed metallic barriers, or when the low voltage cable is installed in rigid steel conduit.

14.4 Minimum separation requirements between a power or control cable and any communication conductors shall be in accordance with SAES-T-911 or SAES-T-928.

14.5 Redundant feeders, direct buried or in direct buried conduit, supplying industrial loads or other loads that are critical in accordance with SAES-P-100 paragraph 4.3, shall be separated by a minimum distance of 1.8 meters.

Commentary Note 14.5:

Two feeders are considered redundant if they are capable of supplying power to the same loads so that each feeder can be considered a backup supply circuit for the other. Examples include the feeders that provide power for double-ended switchgear (including feeders to the related transformers) and the feeders supplying each end of a loop fed distribution system.

14.6 Minimum separation (above or below ground) between any cable operating at above 34.5 kV, and cables operating at or below 34.5 kV, shall be 1 m.

15 Conduit and Cable Sealing

The following requirements Supplement NEC Articles 501 and 502:

15.1 Conduit sealing fittings shall not be used.

15.2 Conduits that cross hazardous location boundaries shall terminate in the open air at both ends of the conduit.

15.3 When cables entering enclosures are required to be sealed by the NEC, they shall be sealed by means of barrier type cable glands, utilizing sealing compound, (EEx d) or MI cable. These are called explosion proof glands by some manufacturers, flameproof by others. See SAES-P-100 for third party approval requirements. Flameproof (EEx d) non-barrier type cable glands, without sealing compound, are not acceptable.

15.4 Cable entry into control buildings and similar buildings in hydrocarbon processing plants below grade shall be in accordance with all of Paragraphs 15.4.1 to 15.4.4 below.

15.4.1 Penetration of the wall of the building basement or underfloor space shall be via short horizontal sections of PVC conduits (sleeves) that will be encased or grouted into the wall.

15.4.2 The inside of the sleeves shall be sealed to provide fire retardancy on the building interior side.

15.4.3 The cables outside the building shall be direct buried for a distance of at least 2 meters (see also paragraph 10.14).

15.4.4 Multi-conductor cable penetrations shall be made with intact cable jackets. If individual conductors are required to be sealed by other Saudi Aramco standards, the sealing shall be done at the most convenient location inside the building.

Commentary 15.4:

If cables or conduits entering buildings are required to be sealed by the NEC, sealing must meet requirements of the NEC and paragraphs 15.1, 15.2 and/or 15.3 above.

	Revision Summary
6 May 2007	Major revision.
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