Materials System Specification

17-SAMSS-017 26 November 2012

Impressed Current Cathodic Protection Cables

Document Responsibility: Cathodic Protection Standards Committee

Saudi Aramco DeskTop Standards

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Previous Issue: 6 September 2011 Next Planned Update: 6 September 2016
Revised paragraphs are indicated in the right margin

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Detailed Table of Contents

1 Scope

This Specification, together with the Purchase Order, detail the minimum requirements for impressed current cathodic protection cables. Applications include; cables directly buried in soil, installed in a conduit or cable tray, immersed in water, buried in sea mud, or in free flowing sea water installations.

2 Conflicts and Deviations

2.1 Any conflicts between this specification and other Saudi Aramco Materials System Specifications (SAMSSs), Engineering Standards (SAESs), Standard Drawings (SASDs), or industry standards, codes, and forms shall be resolved in writing by the Company or Buyer Representative through the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

2.2 Direct all requests to deviate from this specification in writing to the Company or Buyer Representative, who shall follow internal company procedure SAEP-302 and forward such requests to the Manager, Consulting Services 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 specification 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 Inspection Requirements

Form 175-171500 *Cables for Cathodic Protection*

3.2 Industry Codes and Standards

American Society for Testing and Materials

ASTM B3 *Standard Specification for Soft or Annealed Copper Wire*

ASTM B8 *Standard Specification for Concentric-Lay- Stranded Copper Conductors, Hard, Medium-Hard, or Soft*

ASTM B33	*Standard Specification for Tin-Coated Soft or Annealed Copper Wire for Electrical Purposes*
ASTM A90	*Standard Method for Weight Mass of Coating on Iron or Steel Articles*
ASTM D150	*Standard Test Methods for A-C Loss Characteristics and Dielectric Constant of Solid Electrical Insulating Materials*
ASTM D257	*Standard Test Methods for DC Resistance or Conductance of Insulating Materials*
ASTM D638	*Standard Test Method for Tensile Properties of Plastics*
ASTM D1248	*Polyethylene Plastics Molding & Extension Materials*

British Standards Institution

BS 5099	*Specification for Spark Testing of Electrical Cables*

Insulated Cable Engineers Association

ICEA-S-95-658 (NEMA WC 70)	*Non-Shielded Power Cable 2000 V or Less*

International Electrotechnical Commission

IEC 60228	*Conductors of Insulated Cables*
IEC 60502-1	*Power Cables with Extruded Insulation for Rated Voltages from 1 kV to 30 kV – Part 1: Cables for Rated voltages of 1 kV and 3 kV*

Underwriters Laboratories, Inc.

UL 83	*Thermoplastic-insulated Wires and Cables*

4 General

4.1 Terms and Definitions

The following terms are used in this specification:

Anode: Where used in this specification, the term “Anode” shall refer to an impressed current anode.

Anode Cable: Where used in this specification, the term “Anode Cable” shall refer to a cable directly connected to an impressed current anode.

Armored Cable: Where used in this specification, the term "Armored Cable" shall refer to single core cable manufactured with a double layer spiral wound galvanized steel sheath to provide mechanical protection.

Bond Cable: A cable providing electrical continuity specifically for the purpose of cathodic protection, between protected structures.

Buyer: Saudi Aramco Purchasing Department Representative.

Buyer's Representative: The person or persons designated by the Purchasing Department to monitor/enforce the contract. Normally, this is the on-site inspector.

Manufacturer: The Company that manufactures the cable.

Negative Cable: A cable between a DC power source and a protected structure or a negative cable junction box, or between two negative cable junction boxes.

Positive Cable: A cable between a DC power source and an anode junction box, or between two positive cable junction boxes, or between an anode junction box and a positive cable junction box.

Pyramid Anode: An offshore anode assembly custom manufactured for Saudi Aramco and typically fabricated with non-tubular mixed metal oxide anode components. The pyramid anode derives its name from the pyramid shaped cement base.

RSA: The RSA is the "Responsible Standardization Agency" representative for Cathodic Protection Materials.

Tension Spring Anode: An offshore anode assembly custom manufactured for Saudi Aramco and typically fabricated with tubular mixed metal oxide anode components. The Tension Spring Anode assembly is suspended on a wire rope/tension spring assembly beneath an offshore platform.

Vendor: The Company that receives the purchase order to supply the cable. The Vendor may also be the Manufacturer if both definitions apply.

4.2 Site Conditions

4.2.1 Onshore

Temperature	0°C to 55°C
pH	1 to 8
Chloride content	up to 31,000 ppm

4.2.2 Offshore

Temperature 10°C to 55°C

pH – No Chlorine Gas 6 to 8

pH – Chlorine Gas 1 to 8

Water velocity up to 1.5 m per second

4.2.3 Special Applications

Special applications such as inside storage tanks or process equipment may present different or extreme operating conditions. If so, the expected conditions shall be specified in the purchase order.

4.3 Manufacturer Technical Document Submittals

The English language shall be used on all documents, drawings, labels, etc.

4.3.1 Technical Documents for Manufacturer Approval to Supply Material

The Vendor shall submit the following documents to the Saudi Aramco Vendor Inspection Division and to the Responsible Standardization Agent (RSA) in the Consulting Services Department.

a) Manufacturer's material specification including service restrictions and recommended service if applicable.

b) Manufacturer certified drawings showing all dimensions and details of the cable assembly.

c) Manufacturer certified test data for the electrical and mechanical properties confirming compliance with Section 5 of this specification.

4.3.2 Technical Documents for Purchase Inquiry and Order

The Vendor shall submit the following documents to the Saudi Aramco Vendor Inspection Division or Buyer's Representative.

a) Manufacturer's material specification including service restrictions and recommended service if applicable.

b) Manufacturer certified drawings showing all dimensions and details of the cable assembly.

5 Design

5.1 General

5.1.1 General Specifications

Cables shall conform to the materials, construction, and testing of ICEA-S-95-658 (NEMA WC 70) or IEC 60502-1, unless otherwise specified in this specification. Cables shall also comply with the requirements detailed in Table 1, Table 2, Table 3 and Table 4 as specified in this specification.

Table 1 – Double Insulated Cables - Insulation Thickness and Stranding

Cable Size AWG (mm²)	Nominal Thickness (mm)		No. of Strands (min)
	*Primary Insulation Polyvinylidene Fluoride (PVDF) Irradiation Cross-Linked, or Ethylene Chlorotrifluoroethylene (ECTFE)	*Secondary Insulation High Density High Molecular Weight Polyethylene (HMWPE)	
6 (16)	0.51	1.65	19
4 (25)	0.51	1.65	19
2 (35)	0.51	1.65	19
1/0 (50)	0.51	1.65	19
2/0 (70)	0.76	1.65	19

* Minimum thickness shall not be less than 90% of the nominal thickness.

Table 2 – Single Insulated Cables - Insulation Thickness and Stranding

Cable Size AWG (mm²)	*Single Insulation High Density High Molecular Weight Polyethylene (HMWPE) Nominal Thickness (mm)	No. of Strands (min)
6 (16)	2.79	7
4 (25)	2.79	7
2 (35)	2.79	7
1/0 (50)	2.79	19
2/0 (70)	3.18	19
4/0 (120)	3.18	19
350 MCM (185)	3.94	37
500 MCM (240)	3.94	37

* Minimum thickness shall not be less than 90% of the nominal thickness.

Table 3 – PVDF ECTFE and HMWPE Insulation Specifications

Insulation Type	Insulation Specifications**	
Polyvinylidene Fluoride (PVDF) Irradiation Cross-Linked	Tensile Break Strength Break Elongation Flexural Strength Resistivity Dielectric Constant	4500 PSI min. 50% min. 8600 PSI min. 2 x 10^{14} ohm-cm min. 8.0 min. at 100 Hz
Ethylene Chlorotrifluoroethylene (ECTFE)	Tensile Break Strength Break Elongation Resistivity Dielectric Constant	6500 PSI min. 100% min. 1 x 10^{15} ohm-cm min. 2.5 min. at 1 Mhz
High Density High Molecular Weight Polyethylene (HMWPE)	Color Density (minimum) ASTM D1248, Type 3, Class C, Category 5, or IEC 60502-1 Temperature Rating	Black 0.941 grams per cm^3 90°C.

** Standard Test Method ASTM D638 shall be used to determine the tensile strength, flexural strength and break elongation. For the resistivity and dielectric constant tests, Standard Test Methods ASTM D257 and ASTM D150 shall be utilized.

5.1.2 Cable Conductors

Conductors of all impressed current cathodic protection cable types shall be annealed copper per ASTM B3 or IEC 60228, and shall be concentric-lay stranded per ASTM B8 Class B or C, or per IEC 60228 Class 2.

5.1.3 Cable Marking

The cable outer insulation layer or jacket for impressed current cathodic protection cables shall be permanently marked at intervals of no greater than one meter with the manufacturer's name or trademark, the conductor size, and the type of insulation. The print color shall contrast with the jacket color.

5.1.4 Cable Reel Labeling

A permanent stainless steel or aluminum tag shall be firmly attached on the outsides of the cable reel. Cable reel tag engraving or stamping shall include the following data:

Destination

Purchase Order Number

Type and Size of Cable (identified as per this specification)

Length of Cable on Reel

Saudi Aramco Specification #_____, Dated_____

Date of Manufacture and Batch Number

5.2 Positive Cables

Positive cables shall be HMWPE insulated in accordance with Table 3 of this specification. The copper conductor sizes, and number of strands shall be per Table 2 of this specification and shall be concentric-lay stranded, Class C per ASTM B8 or Class 2 per IEC 60228.

5.3 Negative and Bond Cables

Negative and bond cables shall be HMWPE, THHN, THWN, RHH-RHW, or USE type. The copper conductor sizes, and number of strands shall be per Table 2 and shall be concentric-lay stranded, Class C per ASTM B8 or Class 2 per IEC 60228. THHN, THWN, RHH-RHW, and USE type cables shall be UL 83 or approved equivalent labeled or listed. HMWPE type cables shall comply with Table 2 and Table 3 of this specification.

5.4 Onshore Anode Cables

Impressed current anode cables for onshore cathodic protection systems shall be manufactured with stranding and double insulation in accordance with the details specified in Table 1 and Table 3 and shall be tinned in accordance with ASTM B33.

5.5 Offshore Anode Cables

5.5.1 Anode Cable Requirements for Common Offshore Anodes

The most common types of anodes for offshore cathodic protection systems used by Saudi Aramco are Mixed Metal Oxide (MMO) assembled as Pyramid, Tension Spring, and Pile Mount anodes. The cable requirements for offshore anodes used by Saudi Aramco are described below. Refer to Table 4 for additional clarification of the cable requirements for the most common types of offshore anodes used by Saudi Aramco.

- Anode cables for pyramid anodes or other anodes that are installed with the cable lying directly on the sea bed shall be armored.
- Anode cables for pile mount anodes that are installed in conduit or J-tubes through the splash zone do not require armored cable.

- Armored cable is required if the anodes are installed with the cable directly fastened against the offshore structure through the splash zone, without fully enclosed mechanical protection such as conduit or J-Tubes.
- Anode cables for Tension Spring anodes or other anodes that are installed with mechanical support and are not fastened directly to the offshore structure through the splash zone do not require armor.

Table 4 – General Requirements for Typical Offshore Anodes

Anode Type	Jacket over Armor	Armor	Bedding	Jacket over Core	Inner Jacket over Core	(2)Core
Pyramid	HMWPE	Double Layer	PVC	HMWPE	None	50 mm^2 for rating ≤150 A 70 mm^2 for rating ≤ 200 A
(1)Tension Spring	None	None	None	HMWPE	PVDF	35 mm^2 minimum
(1)Pile Mount	None	None	None	HMWPE	PVDF	35 mm^2 minimum

Note (1): Armored cable is required if the anode cable is fastened directly to the offshore structure through the splash zone without fully enclosed mechanical protection such as conduit or J-tube (open channel iron is not sufficient mechanical protection and requires armored cable). If armored cable is used, the PVDF layer is not required.

Note (2): The core must be sufficiently sized to compliment the output current rating of the rectifier corrected to 40°C. Cores of armored cables may be tinned (not mandatory) and have been rated to account for the thermal insulation characteristics of the armoring and the correction to ambient of 55°C.

5.5.2 Armored Cables for Offshore Anodes

5.5.2.1 Offshore anode cables are either armored or double insulated. Armored cables do not require an inner PVDF jacket against the cable core.

5.5.2.2 Armored cables shall be terminated with a NEMA listed MC cable fitting.

5.5.2.3 Anode cables for the following types of installations shall be armored:

- The cable or any section of it is lying directly on the sea bed.

- The cable or any section of it is directly fastened against the offshore structure through the splash zone, without full enclosed protection of conduit or J-Tubes.

5.5.2.4 Bedding

The cable core and insulation layers shall be covered with an extruded layer of Polyvinyl Chloride (PVC) compound with an average thickness of 1.2 mm in accordance with ICEA-S-95-658 (NEMA WC 70) or the requirements of IEC 60502-1.5.4.2.2.

5.5.2.5 Armoring

Armored cables for cathodic protection applications shall have two layers of armor wires spirally wound over the PVC bedding to provide complete armor coverage. The first layer shall be a right hand lay and the second layer shall be a left hand lay. The armor wires shall be 0.8 mm in diameter and made of galvanized steel. The weight of the zinc coat shall be in accordance with Table 4-14 of ICEA-S-95-658 (NEMA WC 70).

5.5.2.6 Outer Jacket

Cable outer jacket shall be black, high density and high molecular weight polyethylene (HMWPE) in accordance with Table 3 of this specification. The HMWPE shall conform to requirements of IEC 60502-1, Section 12, or to ASTM D1248, Type 3, Class C and Category 5. The jacket shall be extruded over the armor layers. The average thickness of the jacket shall be in accordance with ICEA-S-95-658 (NEMA WC 70), Table 4.24 or IEC 60502-1, Section 12.

5.5.3 Anode Cables for Direct Chlorine Gas Exposure

Anode cables attached to Tension Spring Anode assemblies, Pile Mounted Anode assemblies, or other anode construction configurations that place the anode cable within the envelope of chlorine gas that evolves from the anode surface shall be fabricated with double layered insulation as detailed in Table 1 of this specification.

5.5.4 Anode Cables **not** for Direct Chlorine Gas Exposure

Anode cables attached to Pyramid anode assemblies, or other anode construction configurations that do not place the anode cable within the envelope of chlorine gas that evolves from the anode surface, shall be

fabricated with single layered insulation as detailed in Table 2 of this specification.

5.6 Tank and Vessels (Internal) Anode Cables

Impressed current anode cables for tank and vessels internal cathodic protection systems shall be manufactured with stranding and double insulation in accordance with the details specified in Table 1 and Table 3 and shall be tinned in accordance with ASTM B33.

6 Inspection and Factory Tests

6.1 Inspection

Items manufactured to this specification are subject to verification by the Saudi Aramco Vendor Inspection Division and the Buyer's Inspector per Saudi Aramco Inspection Requirements Form 175-171500, attached to the Purchase Order.

6.2 Manufacturer's Test Requirements for Initial Material Approval

6.2.1 Test results and data must be submitted to the Saudi Aramco Vendor Inspection Division and the Saudi Aramco RSA for review and approval prior to issuance of a Purchase Order.

6.2.2 Cable shall be tested at the Manufacturer's factory to verify compliance with the requirements of this specification and the referenced industry standards.

6.2.3 The cable shall be tested by an approved and recognized testing organization to certify that the cables are designed and manufactured in accordance with this specification. The Vendor shall provide the test results to the Saudi Aramco Vendor Inspection Division and the Saudi Aramco RSA.

6.2.3.1 For positive cables, negative cables, bond cables, onshore anode cables, and non-armored anode cables for offshore applications, voltage and spark tests for the cable insulations shall be conducted in accordance with ICEA-S-95-658, Table 3-2A, or BS 5099. For the insulation thickness exceeding 3.56 mm, the test voltage for the 3.56 mm thickness shown in Table 3-2A shall be applied. Any flaws shall constitute rejection.

6.2.3.2 For the armored cable, the holiday test or spark tests shall be performed on the cable bedding layer. The voltage shall be

applied between the cable conductor and the bedding material in accordance with ICEA-S-95-658, Table 3-2A or BS 5099.

6.2.3.3 The weight of zinc coating on the galvanized steel armor wires shall be determined by the test methods described in ASTM A90.

6.2.4 For armored anode cable, the anode assembly Manufacturer or Vendor shall perform a resistance test on the insulation of the anode cable assembly. A DC voltage of 5000 volts shall be applied between all the armor wires twisted together and the copper conductor. If the measured resistance is less than one megohm, the entire anode and cable assembly shall be rejected.

6.3 Manufacturer's Test Requirements for Subsequent Material Approval

6.3.1 Manufacturer's certified cable specifications must be submitted to the Buyer's representative for review and approval prior to issuance of a Purchase Order.

6.3.2 For armored anode cable, the anode assembly Manufacturer or Vendor shall perform a resistance test on the insulation of the anode cable assembly. A DC voltage of 5000 volts shall be applied between all the armor wires twisted together and the copper conductor. If the measured resistance is less than one megohm, the entire anode and cable assembly shall be rejected.

7 Packing and Shipping

7.1 Packing and Shipping shall comply with Saudi Aramco Material Instructions for Export Shipments MI 1110.000, 1110.001 or 1110-000-1. The Vendor shall assume probable long term storage in desert summer sun, wind and sand conditions and take appropriate measure to protect the cables and associated anodes.

7.2 All cable shall be shipped on Vendor's standard reel sizes with one continuous cable length per reel unless otherwise specified in the purchase order. No reel shall have an outside diameter greater than 1370 mm, unless approved by the Buyer. Heavy-duty non-metallic reels are preferred. Each end of the cable shall be firmly secured to the reel and durably sealed to prevent entrance of moisture. The reel shall be covered with suitable material to provide physical protection to the cable during shipping and storage.

Revision Summary

6 September 2011	Revised the "Next Planned Update." Reaffirmed the contents of the document, and reissued with the following minor revisions: a) To correct number of strands required for 35 mm^2 cable. b) To correct amperage rating for HMWPE 50 mm^2 and 70 mm^2 cables for pyramid anode. c) To correct maximum ambient onshore and offshore temperature to 55°C. d) To specify the requirement for tinning for anode cables. e) Added reference to ASTM B33 for tinned copper cables.
26 November 2012	Editorial revision as Paragraph 5.6 was added for clarity.