Engineering Standard

SAES-T-919 17 September 2013

Submarine Fiber Optic Cable

Document Responsibility: Communications Standards Committee

Saudi Aramco DeskTop Standards

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1 Scope

This standard defines the minimum mandatory requirements for engineering, design and installation of repeaterless standalone or composite optical fiber/electrical submarine cable system. This standard also covers some of the required characteristics of optical fiber submarine cables, including mechanical characteristics and resistance to the environment.

2 Conflicts and Deviations

Any deviations, providing less than the mandatory requirements of this standard, require written waiver approval as per Saudi Aramco Engineering Procedure SAEP-302.

3 References and Definitions

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

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedures

SAEP-13	*Project Environmental Impact Assessments*
SAEP-302	*Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement*
SAEP-339	*Marine Dredging and Landfilling Approval and Permitting*

Saudi Aramco Engineering Standards

SAES-T-624	*Telecommunications Outside Plant - Fiber Optics*
SAES-T-634	*Telecommunications - Cable Testing and Acceptance*
SAES-P-104	*Wiring Methods and Materials*

Saudi Aramco Materials System Specifications

18-SAMSS-006	*Specifications of Standalone Submarine Fiber Optic Cable*
18-SAMSS-008	*Specifications of Fiber Optic Cable for Composite Submarine Cable*
15-SAMSS-503	*Submarine Power Cable 5 kV through 115 kV*

15-SAMSS-504	*Submarine Power Cable 69 kV through 230 kV*

Saudi Aramco Engineering Report

SAER-5711	*Submarine Pipeline Engineering Guidelines*

3.2 Industry Codes and Standards

International Telecommunications Union – Telecommunications Standardization Sector (ITU-T)

G.971	*General features of Optical Fiber Submarine Cable Systems*
G.972	*Definition of Terms Relevant to Optical Fiber Submarine Cable Systems*
G.973	*Characteristics of Repeaterless Optical Fiber Submarine Cable Systems*
G.976	*Test Methods Applicable to Optical Fiber Submarine Cable Systems*
G.978	*Characteristics of Optical Fiber Submarine Cables*

Institute of Electrical and Electronics Engineers

IEEE 1120-2004	*Guide for the Planning, Design, Installation, and Repair of Submarine Power Cable Systems*

3.3 Definitions

Availability: (See the definitions provided in [ITU-T G.602]). The ability of the system to be in a state to perform adequately at a given instant of time within a given time interval. The availability of an optical fiber submarine cable system is quantified by the ratio of the time during which the system is operating to a specified total time.

Beach joint: The cable joint made between the optical fiber submarine cable and the optical fiber land cable.

Cable section margin: A parameter included in the optical power budget, to take into account the variation of the fiber attenuation due to ageing during the system design life.

Deep water: Water depths exceeding the limit of shallow water.

Dense wavelength division multiplexing (DWDM): An aggregate of a large number of LOCs to be carried through part or the whole of the submarine line on the same line fiber.

Land cable: Cable with suitable protection for installation in ducts or direct burying in the ground.

Lowest Astronomical Tide (LAT): the height of the water at the lowest possible theoretical tide.

Loose cable structure: A cable structure where the fibers are free to move inside the cable, so that the fiber elongation is lower than that of the cable, staying at zero until the cable elongation reaches a given value.

Optical detector input: The point where the received optical power is measured.

Optical fiber submarine cable system: A set of equipment designed to permit the interconnection of two or more terminal stations. The optical fiber submarine cable system is usually composed of terminal equipment [terminal transmission equipment, power feeding equipment, maintenance controller, etc.), and submersible equipment (cable, repeater(s), branching unit(s), etc.].

Optical fiber submarine cable network: A network which interconnects three or more terminal stations using a single optical fiber submarine cable system or an integrated system made of system portions supplied by different suppliers.

Optical power budget: The allocation of the available optical power in an optical section.

Optical source output: The point where the launched power is measured.

Optical Time Domain Reflectometer (OTDR): is an optoelectronic instrument used to characterize an optical fiber. OTDRs are commonly used to characterize the loss and length of fibers.

Power feeding equipment (PFE): The equipment providing, through a power conductor in the optical fiber submarine cable, a stabilized constant electrical current for powering optical submarine repeaters and/or optical submarine branching units.

Repeaterless submarine cable: An underwater optical fiber cable designed for unrepeatered applications and suitable for shallow and deep water use. It should be extensively tested to show it can be installed and repaired insitu, even in the worst weather conditions, without any impairment of optical, electrical or mechanical performance or reliability. The term “repeaterless” is also known as “unrepeatered” or “non-repeatered”.

Route survey: The activity performed prior to cable laying so as to select the cable route and cable protection (fish-bite protection, armor, burying).

Shallow water: Water depths down to a given limit, corresponding to the depths of fishing activity, or more generally of marine activity, creating a risk of cable fault.

***NOTE** – The limit of shallow water is of the order of 7.5 m below Lowest Astronomical Tide (LAT).*

Surf Zone: The area between the shoreline and the outermost breaking wave, which occurs when the water depth equals 130% of the 100-year maximum wave height.

Tight cable structure: A cable structure where the fibers are strongly maintained in the cable, so that the fiber elongation is essentially equal to that of the cable.

Wavelength division multiplexing (WDM): An aggregate of several Line Optical Channels (LOCs) to be carried through part or the whole of the submarine line on the same line fiber.

4 Design Requirements

The International Telecommunication Union (ITU) Optical fiber submarine cable systems defined in ITU-T G.970–G.979 series are hereby adopted as Saudi Aramco standards for submarine fiber optic systems.

4.1 The optical fiber submarine cable shall be designed to ensure protection of optical fibers against water pressure, longitudinal water propagation, chemical aggression and the effects of hydrogen contamination throughout the cable design life.

The optical fiber submarine cable shall be designed also to ensure that there will be no fiber performance degradations when the cable is laid, buried, recovered and operated using standard undersea practices.

4.2 Standalone submarine fiber optic cables shall be designed in accordance to 18-SAMSS-006. Optical fiber unit within composite power-fiber optic submarine cables shall be designed in accordance with 18-SAMSS-008.

4.2.1 Composite Power-Fiber Optic Submarine Cables

The design and installation of composite power-fiber optic submarine cables shall also comply with SAES-P-104, 15-SAMSS-503 and 15-SAMSS-504.

The maintenance responsibility of composite power-fiber optic cables must be agreed on in writing by relevant Saudi Aramco departments.

Commentary Note:

The Department responsible for the maintenance of the fiber optic cables and fiber optic components may impose additional requirements related to splicing and terminating the fiber optics, and other.

4.2.2 Repeaterless Optical Fiber Submarine Cable

Only repeaterless submarine optical fiber cables are allowed.

4.3 Cable Protection: submarine fiber cables shall be manufactured for protection against the environmental hazards at its depth of utilization: protection against marine life, fish-bite and abrasion, and armors against aggression and ship activities. Different types of protected cable are defined in 18-SAMSS-006, in particular:

4.3.1 Lightweight Cable (LW cable);

4.3.2 Lightweight Protected cable (LWP cable);

4.3.3 Single Armored cable (SA cable);

4.3.4 Double Armored cable (DA cable);

4.3.5 Rock Armored cable (RA cable).

Commentary Note:

It is recommended to use SA cable for composite submarine cable and DA for segregated fiber optic cable.

4.4 Route Selection

A number of factors must be considered when evaluating potential cable routes. Most of these factors influence the cost, constructability, reliability, and reparability of the proposed cable system, and they should be weighed along with the desired communications benefits/requirements. Route survey shall be conducted prior to the design where the following factors shall be considered, but not limited to:

- **Water Depth**: As the depth increases, cable-laying tensions will increase.
- **Rock and pinnacles**: Laying a cable over sharp object may kink the cable.
- **Tidal, current, or surf action**: Currents may carry silt or gravel that may abrade the cable. Strong tidal currents may wash the cable back and forth across the bottom, thus damaging it.
- **Marine slope stability**: Underwater landslides can damage cable system.

- **Chemical attack/corrosion**: Corrosive properties of some soils, or from gas emanation, may affect the cable design.
- **Storm action**: Wave action from storms may result in beach erosion.
- **Sensitive marine habitats**: avoiding sensitive marine habitats such as mangrove, seagrass and coral reefs
- **Man-made obstacles**: It is common to encounter manmade obstacles in the proposed submarine cable corridor, which may include:
  - Other power, communication, submarine cables and pipelines
  - Pipelines, including sewer, water, and gas lines
  - Effluent outfalls
  - Sunken ships and debris, especially near docks and bridges
  - Piers, docks, boat ramps, foundations, buildings, etc. These may be abandoned and not visible from the surface of the water.
  - Disposal areas, either from dredging or dumping of refuse
  - Restricted areas (for example, Naval training or testing areas)

4.5 Double armor in opposite directions, also called "double-cross armor," is recommended for deep-water projects because it allows building a "torque balanced" cable whose elongation under high tension is reduced to its minimum.

4.6 Cable Mechanical Performance

Submarine cables should be handled with safety by cable ships during laying and repair operation; it should withstand multiple passages over the bow of a cable ship.

4.7 New submarine cables shall be designed as one piece (no splicing) with the ability of the cable to be installed, recovered and repaired.

4.8 The fiber attenuation, chromatic dispersion and PMD should remain stable within specified limits for the system design life; in particular, the design of the cable should minimize, to an acceptable levels, both hydrogen penetration from outside and hydrogen generation within the cable, even after a cable break at the depth of utilization; the sensitivity of optical fiber to gamma radiation should also be taken into account.

4.9 Crossing of other cable/pipeline shall be avoided when minor rerouting is practical.

5 Installation

5.1 Submarine Route Survey

5.1.1 Project Environmental Impact Assessments (EIA) shall be conducted, per SAEP-13, to identify any environmental issues at a very early in the project in order to consider project alternatives that would reduce or eliminate adverse impacts and resource conservation potential. The EIA should recommend appropriate, cost-effective measures, which will mitigate significant environmental impacts, and describe how implementation of these recommendations will be monitored during construction and operation.

5.1.2 Route survey shall be performed prior to cable laying to select the cable route and means of cable protection (lightweight protection, armor, burial or combination methods). The route survey shall be also determine and address the sea bottom environmental sensitivity and ecological integrity. Refer to Appendix I for all applicable surveys needed prior to the installation.

5.1.3 The route survey report should consists of sea depth profile, the sea bottom temperature and seasonal variations, the morphology and nature of the sea bottom, the position of existing cables and pipes, the cable fault history, fishing and mining activities, sea current, seismic activity, laws, etc.

Commentary Note:

> *Cable route study should normally be carried out prior to the start of a route survey to determine all environmental, political, economical and practical aspects related to the route. Discussions should be held with local authorities and fishing bodies for this purpose, together with inspection of landing sites and access points as necessary.*

5.2 Submarine Cable Laying

Cable laying is normally performed using a recognized cable-ship after any necessary route clearance in shallow water has been carried out. Laying is normally undertaken only when weather and sea conditions do not create severe risk of damage to the submarine portion, cable ship and laying equipment, or of injury to the personnel. Cable ships shall be equipped with dynamic positioning and dynamic tracking systems. Cable laying & trenching equipment, Remote Operated Vehicles (ROV), shallow water barge, shore-end jack-up barge, cable storage barge and work boats shall be required for laying and repair operation.

5.3 The cable system should be tested during the laying and at the end of laying, so as to ensure that no significant system degradation has been induced.

Laying testing includes transmission and functional tests, and may include tests on redundant subassemblies.

5.4 Cable Burial

To increase cable protection, cables installed in shallow water shall be buried (refer to the shallow water definition). Trenching requirements are determined upon careful consideration of the balance between economics and safe operation and acceptable risk.

5.4.1 Burial Depth

The depth of burial depends on what is being protected against. For example, a cable may be buried deeper than the deepest expected dredging activity, deeper than an anchor will penetrate into the bottom when dropped, deep enough to avoid the flukes of a dragging anchor, or deep enough to avoid the abrasion of high tidal currents or surf. Proper burial survey must be conducted in advance to determine the required burial depth (see Appendix I for details on how to conduct burial assessment survey).

5.4.1.1 Cables crossing ship route corridor (navigation channel) shall be buried a minimum depth of 1 meter, including 20 meters long at each side of the navigation channel corridor.

5.4.1.2 Submarine 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).

5.4.1.3 Submarine cable shall be buried in surf zone area. Beach joint (surf zone) trenching and burial shall comply with SAES-T-624 guidelines.

5.4.1.4 Submarine cable close to platforms shall be protected using Grout bags, made bags, mattresses, or equivalent methods.

5.4.2 Horizontal directional drilling may be used to install a conduit under part or all of a waterway. Commonly, this method is used to install conduit for the shore ends of a cable installation. Near shore and on land, concrete half-tiles are sometimes laid over the cable before it is backfilled to protect the cable from being dug into per SAEP-339.

5.4.3 Cables installed in deep water (refer to the deep water definition) and does not meet the above mentioned conditions; specially made bags ("mattresses") may be set over the cable and filled with concrete or gravel. Blankets or scour mats can be made of either tires or precast concrete blocks that are lashed together and laid over the cable. When heavy mattresses or blankets are used, the soil should be firm enough to support the mattress without settling and care should be taken to prevent the cables from being compressed by the mattresses.

5.4.4 Marine Dredging and Landfilling

Work permit and approvals shall comply with all Saudi Aramco procedures including SAEP-339 for marine dredging and landfilling.

5.5 Platform Transition

Submarine fiber 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.

5.5.1 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.

5.5.2 To enable the safe installation of the cable to the platform or riser deck, J-tube shall be used to ensure that all mechanical forces associated with pulling the cable are borne by the armor with minimal transference of strain to the internal cable. Proper filling material or proper accessories shall be installed at both ends of the J-tube to minimize any damage to the cable due to any subsea activities.

5.6 Cable Crossing

Crossing of other cable/pipeline as shall be avoided when minor rerouting is practical. When a crossover is required, the type of crossing and protection methods shall conform to SAER-5711 recommendations. The same protection requirements/methods highlighted in SAER-5711 is applicable to pipelines as well as power/Fiber Optics cables.

6 Testing and Inspection

6.1 The Fiber Optic Cables shall be tested in accordance with SAES-T-634.

6.2 All strands shall be tested per wavelength, per direction per section and end-to-end using OTDR. OTDR is one of the cable performance testing systems and is used primarily for the characterization and the fault localization of optical fibers, and can be achieved as a monitoring system of optical amplifier gain characteristics. A recent certificate of OTDR calibration shall be presented as part of the test and installation procedure.

6.3 Cable pulling tensions and bending radii shall be monitored and maintained within the limits specified by the manufacturer.

Revision Summary

31 January 2010	New Saudi Aramco Engineering Standard.
22 May 2012	Editorial revision to change the primary contact.
17 September 2013	Minor revision of SAES-T-919 deleting 18-SAMSS-625 which is not the correct material specification for submarine cables and aligned with 18-SAMSS-006 and 18-SAMSS-008.

Appendix I

LANDING (TOPOGRAPHIC) AND ONSHORE SURVEY

This task provides the topographic maps of the landing area on shore.

- A suitable sized area for the joint bay (site of junction between the submarine and land cables), is surveyed in order to provide the required topographic and physical data for the construction works.
- This survey provides results in appropriate format (graphics, text, multimedia) with regard to the morphology of the seabed (Echo Sounder and Side Scan Sonar), its nature (sub bottom stratigraphy, and video tape, picture, soil probing performed by divers).
- This task is carried out on all landing sites.
- The positioning is logged by Differential GPS (DGPS) with accuracy at surface typically in the range of +/- 1 m and navigation accuracy typically in the range of +/- 5 m on the survey track line.
- Once the survey is completed, the data, the complete results and the selected cable routes are transferred to the offshore team for continuing the survey.

OFFSHORE GEOPHYSICAL SURVEY

From the limit of the inshore surveys and with a convenient overlap that depends on the seabed morphology, the survey continues through shallow and deep waters, in order to collect the required data all over the assigned corridor.

- It is generally advisable to perform a high resolution bathymetric survey on a corridor width depending on the water depth, number of cables and seabed morphology.
- The on line processing is necessary in order to evaluate the results and to decide if more line survey is necessary.
- This survey should be performed by suitable Multi Beam Echo Sounder (MBES) all over the corridor and by Side Scan Sonar, in addition to a Single Beam Echo Sounder (SBES).
- Optionally a Sub bottom Profiler (SBP) (narrow beam) can be used in order to obtain qualitative information on the soil density.
- This data are necessary in case of cable burial.
- The results of investigation with electronic/acoustic systems should be integrated with soil sampling just with the purpose to verify the data collected and to help their interpretation.
- The Positioning system is the DGPS, and the navigation accuracy is typically within +/- 10 m off track.
- The navigation and data logging is performed by high tech navigation computer at state of the art.
- Determine sea bottom environmental sensitivity and ecological integrity.

BURIAL ASSESSMENT SURVEY

Along the selected cable route, a burial assessment survey (BAS) is generally carried out in areas where cable burial is required at the end of the geophysical survey.

- The BAS is the better way to achieve the required level of confidence about the expected burial level and, as a consequence, to define the main burial equipment and the corrective protections, if any, to be implemented.
- The BAS may be performed by a vibrocore (VBC) spread sampling the route at defined intervals, for example every 1 km. Gravity cores and grab samples are also typically planned as a complement to the VBC.
- The vessel positioning system provides the same accuracy as per the cable survey.
- Thermal Resistivity Tests in site could be also required at different depth under the sea-bottom.

REPORTING AND CHARTING

Initial interpretation of data is normally carried out on board to enable the preliminary charts to be used for assessing the completeness of the data, and the planning of further survey or route deviations where necessary. Data can be unloaded from the vessel at time to time in order to allow the beginning of final processing in advance from the operations end. The reporting activity is focused on the preparation of a preliminary and final report. The latter will normally include:

- Scope of work
- Summary of the results
- Personnel and equipment used
- Geodetic and navigation parameters
- Diary of events
- Survey charts