EOM CABLE SPECIFICATION FOR MBARI COILCORD CORE
Specification CC-0601-01, Rev. 3.3
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Contact: Mark Chaffey, MBARI, 831 775 1708, email chma@mbari.org

Rev 3.3 30APR08 mrc Added CCC cable note back to fig. 1.
Rev 3.2 02NOV06 mrc Modified for Minnesota Wiring RFQ. Restored fig. 1. mrc
Rev 3.0 08FEB05 mrc Canceled fig. 1, specified BFO 6160 SMF. Deleted appendix B.
Rev. 2.1 22MAR02 mrc Revised resistance specification to match coilcord requirement. Added design elements detail in section 3.4 requiring separation of HV conductors from datacom conductors. Revised fig. 1. Deleted Appendix B, Bending Attenuation Test Results graph.

1.0 Introduction

This is a specification for the Electro-Optical and Mechanical (EOM) core of a future coil-cord cable, to be used in an open ocean mooring system. Its purpose is to form a reliable well cushioned and insulated electrical power and signal path as well as an optical signal path between submerged sensors and a surface buoy in the highly fatiguing upper ocean environment.

This specification only addresses the design of this EOM core. A specialized manufacturing facility will extrude a heavy jacket of unvulcanized rubber over the EOM core, and will produce through coiling and vulcanization of the rubber jacketed cable a highly elastic coil cord.

The cord will be subjected to low but potentially snapping tensions (under 200 lbs) in service in the presence of hydrostatic pressure up to 300 psi. The cable will be working inside a stretch and tension hose cavity filled with tap water.

The specification is prepared as a performance specification, and one example for a workable cable construction is provided as Appendix A. The cable vendor is encouraged to discuss design options with MBARI or propose more than one design. The acceptance tests for the cable core listed under Section 5 of this specification

2.0 Performance Requirements

2.1 General and Environmental

The performance of the coilcord core cable shall work satisfactorily under the following environmental conditions:

2.1.1 Wet Operation: Although the core cable will be surrounded with a heavy rubber jacket, wetting of the core in service is to be expected.

2.1.2 Temperature Range: 0-25^0 Celsius under working environment, -25^0 to +65^0 Celsius during transit and storage.

2.1.3 Hydrostatic Pressure: The cable core will be subjected up to 200 psi at max. working load, up to 300 psi survival pressure. The pressure level may be fluctuating rapidly depending on the tension and stretch applied to the hose in the dynamic upper ocean environment.

2.1.4 Material Compatibility: All components must tolerate the presence of pressurized tap water under working conditions, and be unaffected by tap water environment under storage conditions in a temperature range of 0^0 to +65^0 Celsius, and to -25^0 Celsius under dry conditions.

2.1.5 Service Life: To operate under the above requirements as long as possible. The expected service life is three years. Goal is to have the cable core survive this service time and perform its functions.

2.2 Mechanical Requirements

The coilcord cable core has to include a strength member of Aramid (*Kevlar, Twaron*) or preferred of liquid crystal polymer *Vectran* high-performance fibers with a breaking strength of at least 6,000 lbs. The strength member has to support peak working tensions estimated to be 130 lbs. The strength member stretch at the maximum working load has to keep the copper conductor and optical fiber stretch below 0.5 percent. Under cable stretch up to the maximum working load the radius of curvature of the optical fibers in the cable assembly has to be at least 25 mm or 1.0 inch, in order to minimize macro-bending losses. In order to reduce micro-bending losses the construction must arrange optical fibers in a way, that local pressure points and sharp bends are avoided.

2.3 Optical Requirements:

2.3.1 Attenuation: Under cable working conditions the optical attenuation in each of the four optical fibers should not exceed:

- 0.7 dB per kilometer at 1,310 Nm wavelength, and
- 0.7 dB per kilometer at 1,550 Nm wavelength.

2.3.2 Optical Attenuation Uniformity: No single point attenuation discontinuity in any fiber in the completed cable shall be greater than 0.15 dB at either 1,310 Nm or 1,550 Nm wavelengths, when measured with an OTDR.

2.3.3 Optical Dispersion: Individual fiber specifications for optical dispersion in the completed cable shall meet the pre-cabled fiber manufacturer's specifications, as measured by EIA/TIA 455-175.

2.3.4 Fiber Proof Test: A statement is requested that the cable is constructed with 150 ksi single mode fibers. The fibers used are to be traceable to the fiber manufacturer's lot supplied to the cable vendor.

2.3.5 Fiber Identification: Fibers or their over-jacketing shall be color coded or otherwise indelibly marked at least every meter for identification.

2.4 Electrical Requirements:

2.4.1 General: The EOM coilcord core will be used for electrical power and signal transmission while suspended inside a tap water filled rubber stretch hose. Eight electrical conductors are required.

2.4.2 Working Voltage: The conductors described as **High Voltage** in the cable will be exposed to a maximum of 425 Volts DC working voltage. At this voltage, the maximum voltage stress present at any point in the cable insulation shall not exceed 2.0 kV/mm (51 Volts/mil). The insulation must be suitable for continuous high D.C. electric field stress. The conductors described as **Low Voltage** in the cable will be exposed to a maximum of 18 Volts DC working voltage. At this voltage, the maximum voltage stress present at any point in the cable insulation shall not exceed 2.0 kV/mm (51 Volts/mil). The insulation must be suitable for continuous D.C. electric field stress.

2.4.3 Insulation Resistance: The Insulation Resistance of each conductor in the completed cable shall be at least 3,000 Megohms per kilometer, measured at the working voltage under 2.4.2. The resistance shall be measured between the test conductor, and the other conductors, plus any metallic cable elements, tied together.

2.4.4 Conductor Resistance: The **High Voltage** cable conductors will be used at a working current of up to one Ampere per conductor. The maximum as cabled resistance of each of the three separate **High Voltage** cable conductors should not exceed 33.30 ohms per kilometer. The resistance is measured at a conductor temperature of 20^0 Celsius with a resistance tolerance of +/- 5%. The **Low Voltage** cable conductors resistance values should match the standard resistances for their nominal wire gauge +/- 5%.

2.4.5 Production Testing: Each individually insulated conductor shall be tested for insulation resistance in a water bath before cable assembly. Test conditions and acceptance criteria are specified under 2.4.2 above. No detectable discharge is permitted within the detection limits of the employed test equipment.

2.4.6 Conductor Identification: The individual conductors shall be color coded or otherwise made visually distinguishable from one another, either throughout their length or in at most one ft intervals.

3.0 Design Elements

The cable core, shown in Figure 1, will consist of:

3.1 Four Single Mode Optical Fibers, suitable for use in oceanographic working cables, with a minimum radius of curvature of 25 mm, and a minimum proof stress of 150 ksi, preferably higher. Preferably the fibers will be packaged into a reinforced and jacketed assembly to allow cable manufacturing. Such assembly typically is consisting of a small Kevlar or Vectran strength member, one or several single mode optical fibers, and an overall extruded jacket. The outer diameter of each single fiber reinforced jacketed element assembly should be between 0.07 +/- 0.01 inch (1.8 +/- 0.2 mm), preferably not exceeding 0.07 inch. Fiber must be Lucent/BFO 6160 or equivalent.

3.2 Three insulated **High Voltage** stranded copper conductors #20 AWG, or equivalent multiple of smaller conductors. The selected insulation material and insulation thickness have to allow the safe electrical power and signal transport through the cable, see section 2.4.

3.3 Two insulated **Low Voltage** stranded copper conductors #20 AWG, The selected insulation material and insulation thickness have to allow the safe electrical power and signal transport through the cable, see section 2.4.

3.4 Three insulated **Low Voltage** stranded copper conductors #22 AWG, The selected insulation material and insulation thickness have to allow the safe electrical power and signal transport through the cable, see section 2.4. These conductors should be physically separated from the High Voltage conductors as much as feasible to reduce capacitive noise coupling.

3.3 A strength member made from Vectran (Liquid Crystal Polymer) fibers, in the form of a 12 strand braided spliceable construction, with a minimum breaking strength of 6,000 lbs and a stretch of under ½ percent under 130 lbs tension. A "fluffy" braided jacket from polyester is optional, to create a soft surface for the conductors to be wrapped around the strength member, as long as the ½ percent stretch under 130 lbs tension is not exceeded.

4.0 Length, Diameter

Length: For a single coilcord the total cable core length is 71.5 ft, for the number of units see purchase order. To the total length of the ordered cable cores we add a 37 ft test length and 60 ft to start the cable in the extruder at the coil cord manufacturer. Or the total needed length is 71.5 ft times the number of cords ordered + 37 ft+ 60 ft = 71.5 ft times number of units + 97 ft. The EOM core is to be made in one continuous length.

Diameter: The overall diameter of this EOM core including the wrapped conductors should not exceed 0.46 inches (11.6 mm), in order to allow sufficient space for the to be added outer rubber jacket. The strength member core, with or without a braided jacket option, must have an outer diameter of 0.3 +/- 0.03 inch (7.6 +/- 0.8 mm), measured under hand tension.

5.0 Qualification Tests

The following tests are to be performed prior to the acceptance of the completed, still unjacketed cable core by the coilcord core manufacturer:

5.1 Optical Attenuation: The cable core will be tested for optical attenuation at 1310 Nm and at 1550 Nm. The test results should meet the requirements of section 2.3.

5.2 Electrical: Conductor resistance and insulation resistance on the completed cable core, to be checked for compliance with section 2.4 of the unstretched cable.

5.3 Mechanical Behavior: Prepare a six ft straight long specimen of the cable with eye-splices on each end and load it to a load equal to 30 percent of its strength member's minimum breaking strength. Measure elongation and diameter of the free cable length. Pull the test sample to destruction to observe the sequence of failure of the cable components and record the actual breaking strength and location of the break area.

5.4 Electrical and Optical Performance under Load: Load a cable sample from zero to 800 lbs. Measure and record the change in optical attenuation and conductor resistance. The optical attenuation during this test should not increase by more than 20 percent, and the conductor resistance should not vary by more than +/- 10%.

5.5 Performance under Cyclic Loading: Subject the cable specimen to 100 load cycles between zero and 800 lbs. Repeat optical attenuation and conductor resistance measurements after the 10^{th}, 20^{th}, 50^{th}, and 100^{th} load cycle and record the data. .

6.0 Price and Delivery

- Cable quote to include CIF to Moss Landing, California.
- The cable manufacturer is requested to separately quote the cost for qualification testing. MBARI may opt to have these tests done at their facility or an independent testing firm, or to witness the tests at the cable vendor's facility
- Customary cable packaging on shipping reel with 2 ft barrel diameter.
- Cable to be delivered in one length as ordered, from which suitable sections for individual coil cords will be cut. A minimum cable length of 2 ft each shall be accessible at both ends of the cable core in order to allow testing on the shipping drum.

Appendix A: Cable Design Example Under this Specification

Design Emphasis:

This cable is designed to allow its conversion of the rubber jacketed EOM cable into a coil cord with a radius of curvature for the optical fibers of at least 25 mm after coiling and has to avoid localized point pressure on the optical elements during manufacturing.

Design Description:

A cross section of the coilcord cable design with its future neoprene rubber jacket is shown in Figure 1. The cable is constructed around small spliceable 12-strand Vectran Braid (with or without a braided outer polyester sleeve) of 0.30 +/- 0.03 inch in diameter, and a breaking strength of 6,000 lbs. Around this strength member optical and electrical conductors are spiraled with a wrap angle of 21 +/- 1 degrees, measured between conductor axis and cable axis [= pitch length of 3.75 +/- 0.2 inch or 95 +/- 5 mm]. Four optical fiber assemblies with a diameter of 0.06 to 0.08 inches, three #20 AWG power conductors for 425 VDC service with an outer diameter of 0.069 inch, three #22 AWG signal conductors for 18 VDC service and 0.056 inch diameter, and two #20 AWG signal conductors for 18 VDC service with outer diameters of 0.063 inches form the electro-optical components of this cable core. The design results in a radius of curvature of 1.47 +0.15/-0.12 inch for the optical fibers, and an outer diameter of the coilcord core of 0.46 inch. A light and open binder wrap - No! Needs to be a continous tissue wrap to prevent bunching during jacket extrusion (mrc) - can be applied with low tension to secure the conductors' positions around the strength member core. Around this EOM core the coilcord manufacturer applies a jacket from unvulcanized neoprene rubber. The outer diameter of the finished cable assembly is 0.8 inch nominal. A portion of the jacketed cable is spiraled around a mandrel and the entire assembly subjected to a steam cure, which vulcanizes the rubber jacket. The vulcanized jacket provides the needed compliance, elasticity, retraction, and shape stability of the coilcord. All dimensions are approximate and nominal.

This cable seems to be producible. With a rubber jacket, extruded to an outer diameter of 0.8 inches, it will have 67 percent of its volume consisting of rubber, which will provide sufficient retraction and shape stability in the completed coilcord. The conductor layer is open enough to allow the coiling geometry without layer blockage. The wires cover 74 percent of available space in the straight cable, and 90 percent in the coiled condition on the inside of the wrap.

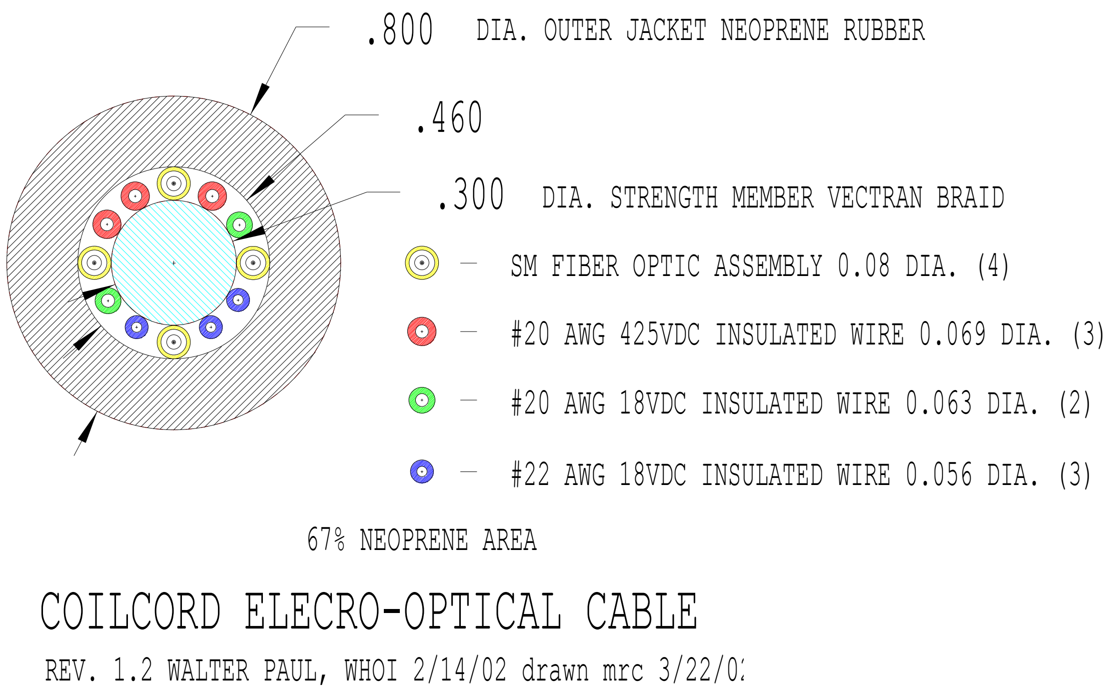

Fig. 1. Illustration of cable example. NOTE: THIS DRAWING HAS BEEN REPLACED BY CCC DESIGN DRAWING 2030185.DWG by DPB dated 26MAR02.