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SEG Standards for marine seismic hydrophones and streamer cables[1]

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These standards were approved for publication by the SEG Executive Committee on March 17, 1986. We appreciate the encouragement given by three former Chairmen of the Technical Standards Committee: L. L. Lenz, D. A. Cavers, and J. G. Morgan. The authors who did the writing, are grateful to all the other subcommittee members who reviewed the various drafts and made valuable comments. We would like to especially recognize Joe Blue of Naval Research Laboratory, Underwater Sound Reference Detachment, Orlando, Florida who hosted several subcommittee meetings and provided information on existing standards. In addition to those listed under "Acknowledgments," industry representatives who reviewed drafts and all the companies who contributed time and resources are gratefully recognized.

We anticipate that revisions and additions will be necessary from time to time. Please address all such suggestions to the current Chairman of the SEG Technical Standards Committee, Ben B. Thigpen.

Part I. Standards for specifying hydrophone parameters

Purpose and scope

Purpose. This standard provides minimum recommended descriptive terms for specifying hydrophone parameters such that personnel involved in exploration geophysics can more easily compare and select hydrophones appropriate for their intended application. Other parameters may be provided if the manufacturer so desires.

Scope. This standard covers three types of hydrophones commonly used in geophysical exploration: piezoelectric elements, elements with integral preamplifiers and elements with coupling transformers. The first type consists of one or more piezoelectric elements. They may be bare or encapsulated. The second type consists of one or more piezoelectric elements with an integral preamplifier. The integral amplifier is generally included to provide a larger

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signal and/or lower output impedance than the direct coupled piezoelectric units. The integral preamplifier requires power from either an external power source or an internal battery. The preamplifier may be of the voltage, charge, or current mode type. The third type of hydrophone includes a transformer with one or more piezoelectric elements. Transformer-coupled hydrophones provide lower output impedance than direct coupled piezoelectric units. The coupling transformer is generally wound so as to provide a low nominal output impedance across the operating frequency band.

A form for data presentation is specified so that hydrophones may be readily compared and data sheets easily understood. Parameters are to be specified in Systeme International (SI) metric units but other commonly used units may follow in parentheses.

This standard describes below the parameters *common* to all types of hydrophones, while subsequent sections describe those additional parameters necessary to characterize integral preamplifier and transformer-coupled hydrophones, respectively.

Definitions

Letter symbols. Letter symbols used in this standard comply with those given in American National Standards Letter Symbols for Acoustics, Y 10.11-1953 (R1959), American National Standard Acoustic Terminology, S 1.1-1960 (R1976), American National Standard Preferred Reference Quantities for Acoustical Level, S 1.8-1969 (R1974), and American Society for Testing and Materials Standard Metric Practice Guide, ASTM Designation E 380-79 (also ANSI Z210.1-1976).

Terminology. Terminology used in this standard is based on definitions given in American National Standards S 1.1-1960 (R1976) and American National Standard Procedures for Calibration of Underwater Electroacoustic Transducers, S 1.20-1972.

Metrication. In addition to the terminology and letter symbols listed in the references above, SEG has published a tentative metric standard. This publication, *SI Metric System of Units and SEG Tentative Metric Standard,* SEG Metrication Subcommittee, 1981, should be consulted.

Hydrophone sensor parameter standards

Physical. Hydrophone sensors may consist of more than one sensitive element. They may be bare or encapsulated. The physical standards are common to all three hydrophone types.

(1) **Dimensions**. A drawing of the sensor configuration should be provided with dimensions given in centimeters (inches).

(2) **Materials**. Materials should be specified by the manufacturer to allow judgments as to chemical compatibility with fluids that the hydrophone assembly may contact (e.g., ballast fluids in seismic streamers). A statement assuring materials compatibility may be substituted for the materials specification.

(3) **Weight**. Weight should be given in grams (ounces).

(4) **Displacement**. Displacement should be given in cubic centimeters (cubic inches).

(5) **Temperature**. The operating and storage temperature ranges should be given in degrees Celsius (degrees Fahrenheit).

Electrical

(1) **Leads**. The type and length of electrical leads should be stated.

(2) **Polarity**. The color code or other marking to indicate positive polarity voltage or charge for a positive (increase in) acoustic pressure should be designated. Red is the preferred color for the positive terminal.

(3) **Capacitance**[5]. Capacitance across the hydrophone output terminals should be given in microfarads with tolerance expressed as ± X%.

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[5] Applicable to hydrophones without integral amplifier or transformers.

(4) **Resistance**[6]. The dc resistance across hydrophone output terminals should be given and expressed as greater than X megohms at stated conditions of temperature and humidity.

Performance

(1) **Free-field voltage sensitivity**. Free-field voltage sensitivity should be given in decibels referenced to 1 volt per micropascal with accuracy expressed as ± X decibels. The frequency at which the sensitivity is determined should be stated (e.g., Free-Field Voltage Sensitivity - XXX dB re 1 V per μPa ± XX dB @ XX Hz).

Hydrophone calibration method

The hydrophone calibration method should conform to methods described in ANSI SI.20-1972, *Procedures for Calibration of Underwater Electroacoustic Transducers,* American National Standards Institute, 1430 Broadway, New York, NY, 10018.

If a secondary calibration method is employed, the "calibration-standard-hydrophone" source or method of calibration should be given.

(2) **Mechanical resonance**. The lowest major mechanical resonant frequency for free-field conditions should be stated.

(3) **Sensitivity versus frequency**. A curve or statement should be furnished showing open-circuit free-field voltage sensitivity versus frequency.

(4) **Sensitivity versus depth**. A curve or statement should be furnished showing open-circuit free-field voltage sensitivity versus depth.

(5) **Sensitivity versus temperature**. Maximum change in sensitivity over the operating temperature range should be stated.

(6) **Acceleration sensitivity**. A statement should be given as to acceleration sensitivity along each of the three major orthogonal axes. The measurement method should be given.

(7) **Depth capability**. Depth excursion in meters (feet) to which the hydrophone can be subjected without destruction or significant permanent change in sensitivity (< 1 dB) should be stated.

(8) **High dynamic pressure capability**. The maximum acoustic pressure that the hydrophone can withstand a specified number of cycles without permanent change in characteristics greater than 1 dB should be stated if intended for such usage.

(9) **Free-field charge sensitivity**. Free-field charge sensitivity can be computed from the capacitance and free-field voltage sensitivity of the sensors. Free-field charge sensitivity should be stated in decibels referenced to 1 nanocoulomb per micropascal (nC/μPa) with accuracy of ±X dB. Statement of this parameter is optional.

Additional parameters for integral preamplifier hydrophone

These parameters apply to hydrophones with integral preamplifiers only.

(1) **Impedance**. The nominal output impedance of the device should be specified in ohms. Plots of output impedance magnitude and phase versus frequency should be provided. The minimum load impedance and maximum load capacitance for the preamplifier should also be specified.

(2) **Frequency response**. The free-field voltage sensitivity as a function of frequency should be plotted for the open circuit condition. Both amplitude and phase plots should be provided.

(3) **Power**. The voltage and current requirements of the preamplifiers should be given. If battery powered, the battery type and expected operating and storage life should be given.

(4) **Clipping pressure**. The peak pressure level at which preamplifier saturation occurs should

[6] Applicable to hydrophones without integral amplifier or transformers.

be stated in dB re 1 micropascal.

(5) **Harmonic distortion**. The total harmonic distortion should be given for a specified frequency when the input acoustic signal is at a specified percentage of the clipping pressure.

(6) **Noise**. A plot of the preamplifier noise output spectral density with the sensitive element isolated from noise sources should be provided. The ordinate of the plot should be expressed in terms of the equivalent sound pressure level input; i.e., dB re 1 μPa/Hz.

Additional parameters for transformer coupled hydrophone

(1) **Impedance**. The nominal output impedance of the device should be given in ohms. Plots of impedance magnitude and phase versus frequency should be provided.

(2) **Dc resistance**. Resistance should be given in ohms with tolerance expressed as ± X percent.

(3) **Natural frequency**. The frequency at which the hydrophone circuit sensitivity is greatest should be specified as XX Hz ±X percent.

(4) **Frequency response**. The free-field voltage sensitivity as a function of frequency should be plotted for the open circuit condition and at least one other value of shunt resistance. Both amplitude and phase response should be provided.

(5) **Harmonic distortion**. The maximum acoustic pressure at which total harmonic distortion exceeds a stated percentage at a stated frequency should be given.

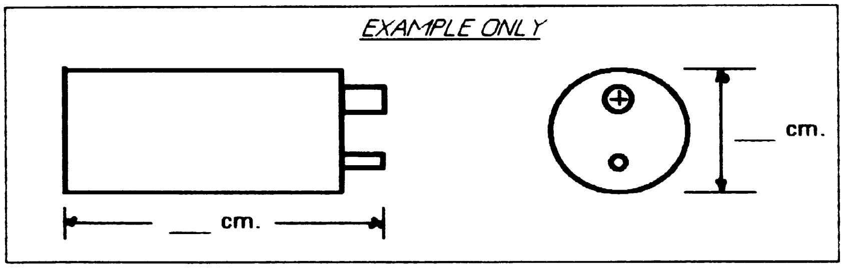
Example of Hydrophone Data Sheet

XYZ CORPORATION

Model______ Hydrophone Specifications

INTENDED USE: **For use in streamer-cable systems with charge coupled amplifiers or transformer coupling.**

PHYSICAL SPECIFICATIONS:



Materials: Surfaces exposed to streamer fluids are _______ and _________ which are compatible with all commonly used ballast liquids.

Weight: _______grams

Displacement: _______cc.

Operating Temperature: ___°C to ___°C

*Maximum Storage Temperature :*___°C

Maximum Depth : _____m (< 1dB permanent change in voltage sensitivity)

ELECTRICAL SPECIFICATIONS (Open-circuit values):

Capacitance: _____ µF ± _____% @ ______ Hz

Resistance: > _____ MΩ @ ____°C @ ______ % humidity

Terminals: Positive polarity marked " + " and with Red dot

PERFORMANCE:

Voltage Sensitivity: -_____ dB re 1V/µPa ± ____dB @_____Hz

Lowest Mechanical Resonant Frequency: ___ Hz

Voltage Sensitivity vs Frequency: < 3dB change from ___Hz to ___Hz

PLOTS ARE AVAILABLE ON REQUEST

Voltage Sensitivity vs Temperature: < 3dB from ___°C to ___°C @ ___ m & ___ Hz

Voltage Sensitivity vs Depth: < 3dB change from 0 to ___m

Charge Sensitivity: ___ dB re 1nC/µPa @ ___m & ___°C (computed)

Acceleration Sensitivity: Output is < ___mV/g due to acceleration in any of the three major axes. Tests made in air at ___ Hz & ___ g.

The Calibration of these units is performed using the secondary or comparison calibration technique described in ANSI S1.20-1972. The standard hydrophone was calibrated by the Naval Research Laboratory, Underwater Sound Reference Detachment, Orlando, Florida.

Part II. Standards for specifying hydrophone streamer-cable characteristics

Purpose and scope

Purpose. In Part I of this document, the specification standards for single sensors were defined. As those who are skilled in the art know, a single sensor or hydrophone is rarely used for commercial operations. Accordingly, it is the set of specifications for the components of the entire streamer cable, as actually used in the field, that is of practical importance. It is the purpose of this section to recommend a uniform set of specifications that will provide essential data to the user.

Scope. The standard specification set to follow will include hydrophone array parameters, physical characteristics of the streamer cable sections, the lead-in cable, isolator sections, deck cable, and optional ancillary equipment. Specifications for acceptable ballast fluids are included.

Units of measurement

Reference standard. Units of measurement shall conform to the recommendations of the SEG Metrication Subcommittee as published in *SI Metric System of Units and SEG Tentative Metric Standard.* The preferred SI unit symbols used here are approved "abbreviations." Alternate units of measurement follow in parentheses. There are two exceptions to the above rule:

Wavelength is expressed by the Greek symbol λ, and array length is expressed symbolically as L.

Tolerance. All measurements should be expressed as typical unless a tolerance (±xxx) is specified.

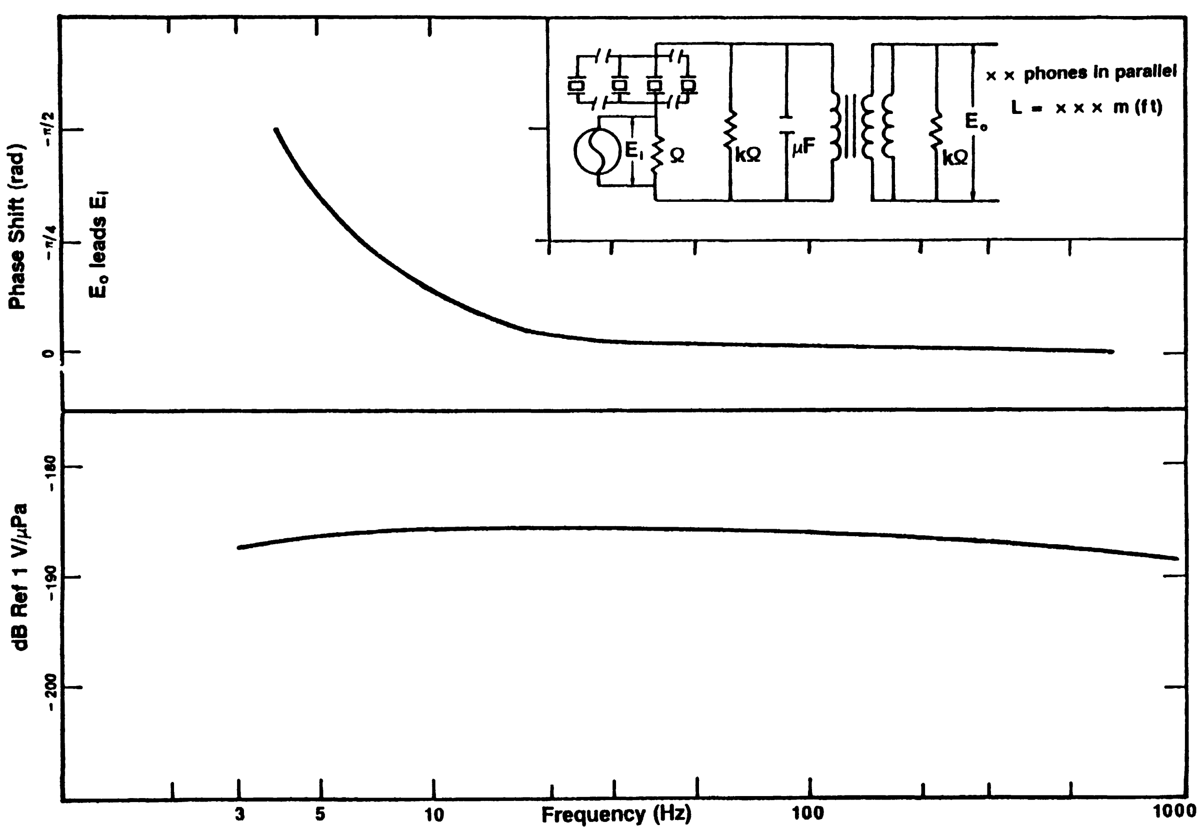


FIG. 1. Array frequency response.

Hydrophone arrays

Physical characteristics.

(1) **Hydrophones**. Number and type of hydrophones per array.

(2) **Arrays**. Number of arrays per section.

(3) **Array dimensions.** Length of active arrays, m (ft).

(4) Array spacing. Array spacing, center-to-center, m (ft).

(5) **Hydrophone spacing**. Hydrophone spacing within array, m (ft).

(6) **Drawings**. Dimensional diagram if hydrophone spacing is not equal, m (ft).

(7) **Operating depth**. Recommended maximum operating depth, m (ft).

(8) **Maximum depth**. Specify depth in m (ft) to which the hydrophone array may be subjected without destruction or significant permanent change in sensitivity exceeding 1 dB.

(9) **Programmability**. If programmable, state configuration options.

(10) **Specification sheet.** Provide specification sheet for typical hydrophone per Part I of "Standards for Specifying Hydrophone Parameters."

Response characteristics.

(1) **Electrical diagram**. Provide schematic electrical diagram of cable section including hydrophone connections, coupling network.

(2) **Capacitance**. Total capacitance of each hydrophone array µF ±x percent.

(3) **Output impedance**. Complex output impedance of hydrophone array in graphical form.

(4) **Sensitivity**. Acoustic sensitivity, V/µPa ±x dB (µV/µbar).

(5) **Sensitivity versus depth.** Change in sensitivity with depth, dB/m (dB/f).

(6) **Weighting, electrical**. Electrical weighting of individual units of array if any.

(7) **Amplitude response.** Amplitude response in graphical form in units of frequency in Hz versus dB referred to 1V/µPa. See Figure 1.

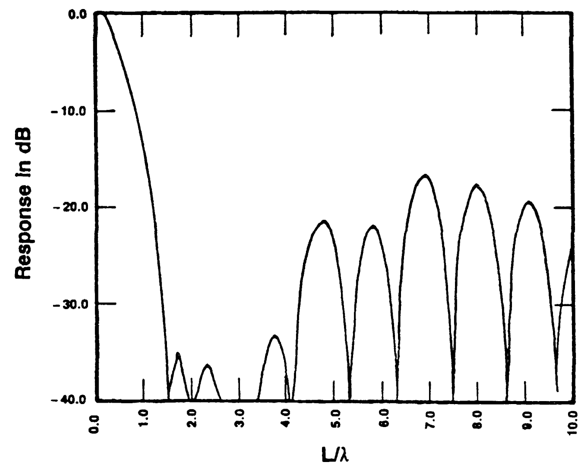


FIG. 2. In-line response of array.

(8) **Phase response.** Phase response of array in graphical form expressed as rad/Hz. See Figure 1.

(9) **Spatial response** Spatial response in graphical form in Hz as a function of the ratio of array length to wave-length, L/λ. See Figure 2.

Streamer cable section.

Physical characteristics

(1) **Length**, m (ft).

(2) **Outside diameter,** cm (in).

(3) **Jacket.** Type of jacket, thickness, cm (in).

(4) **Stress members**. Stress members, material, type, size, number.

(5) **Breaking strength**. Minimum breaking strength, newtons (lb-force).

(6) **Weight dry**. Carcass weight per section in air dry, kg (lb).

(7) **Weight wet**. Weight per section in air, filled with specified quantity of fluid, kg (lb).

(8) **Weight submerged**. Section weight in water, kg (lb). Calculate or, preferably, measure the section displacement in fresh water at a standard temperature of 20°C and a standard pressure of 101325 Pa (1 atm). Users

can then more easily extrapolate to actual field conditions.

(9) **Ballast fluid**. Quantity of ballast fluid required, m^3 (litres, gallons).

(10) **Temperature**, operating. Operating temperature range, °C (°F).

(11) **Temperature, storage**. Storage temperature range, °C (°F).

(12) **Connectors**. Type of cable-section connectors.

(13) **Materials**. Materials should be specified by the manufacturer to allow judgments as to chemical compatibility with fluids that the hydrophone assembly may contact (e.g., ballast fluids in seismic streamers). A statement assuring materials compatibility may be substituted for the materials specification.

(14) **Connector specifications**. Outside diameter, weight in fresh water, and length of cable connectors including active instrumentation modules.

(15) **Depth limits**. The depth, m (ft) to which the streamer cable section may be subjected without destruction or significant physical or electrical change.

(16) **Bend radius**. Specify the minimum bend radius, m (ft) to which the cable section and connectors may be subjected.

Electrical characteristics, analog

Electrical parameters. Conductor round-trip Dc resistance and capacitance in situ, Ω/m, µF/m.

(2) **Channels, active**. Number of active channels and spares.

(3) **Channels, auxiliary**. Number of auxiliary channels and spares.

(4) **Test pairs**. Number of test pairs for quality control testing of active or passive electronic modules.

(5) **Conductors.** Type of conductors, twisted pairs, coaxial optical-fiber, etc., specify functional use.

(6) **Leakage**. Nominal interchannel leakage, MΩ measured in situ.

Electrical characteristics, digital

(1) **Digital specifications**. The specifications here listed apply only to the cable sections themselves. Specifications for digital data acquisition modules should conform to the standards set forth in the SEG Standards Document entitled: "Digital Seismic Recorder Specification Standards" which is incorporated herein by reference.

(2) **Channels per module.** Number of seismic and active auxiliary channels per module.

(3) **Data transmission** link. Type and bandwidth of data transmission link (e.g., coaxial cable, optical fiber, bandwidth in MHz).

(4) **Module separation**. Maximum data transmission distance between modules and/or repeaters, m (ft).

(5) **Power**. Power requirements, kW @ xV.

(6) **Cable length.** Maximum total cable length with respect to power requirements, m (ft).

(7) **Auxiliary conductors**. Number, functional use of, type and specifications of nonseismic-data-transmission conductors.

(8) **Leakage**. Nominal leakage as applicable, MΩ measured in situ.

Ancillary equipment

Types of equipment

(1) **Water break**. Water break detectors, type, number, distribution.

(2) **Cable depth**. Cable depth detectors, type, number, permissible distribution.

(3) **Compasses.** Azimuth indicators (compasses), permissible locations.

(4) **Cable saver.** Cable recovery system, type, description.

(5) **Depth controllers.** Cable depth controllers, auto-matte, manual preset or programmable. Permissible distribution if applicable. Operating-depth range.

(6) **Swivel**. Tail swivel, type, capability.

(7) **Tail buoy**. Tail buoy, active such as transponder, DF radio, GPS or passive such as marker buoy, radar target.

(8) **Cable positioning**. Acoustical positioning devices, locations, types, range, configuration shipboard and in cable. Method of data transmission.

Output signals

(1) **Specification of signal outputs**. For each specialized type of ancillary equipment, where appropriate, specify the type of signal output (digital or analog), the units of measurement, e.g., V/m for a cable-depth detector, resolution, accuracy, power requirements at specified voltage. Specify their physical characteristics, particularly if such devices are external to the cable or if they would affect cable noise or towing configuration.

(2) **Source of specifications**. Many ancillary devices are commercially available off the shelf. To avoid an inordinately long standard specification list, the cable manufacturer may prefer to incorporate by reference the published ancillary-device specifications.

Lead-in cable

Physical description

(1) **Length**, m (ft).

(2) **Outside diameter,** cm (in).

(3) **Jacket.** Type and thickness of jacket, cm (in).

(4) **Conductors**. Number, type, and AWG of conductors and bundle shielding.

(5) **Armoring**. Type of armoring, stress member specifications.

(6) **Strength**. Minimum breaking strength, newtons (lb-force).

(7) **Weight dry**. Weight in air, kg (lb).

(8) **Weight submerged**. Weight in fresh water at standard temperature and pressure, kg (lb).

(9) **Temperature, operating.** Operating temperature range, °C (°F).

(10) **Temperature, storage**. Storage temperature range, °C (°F).

(11) **Fairing**. Type of fairing, if any.

(12) **Electrical characteristics**. Round trip dc resistance, capacitance, and leakage measured in situ, Ω, μF, MΩ.

(13) **Connectors**. Type of connectors.

(14) **Flotation.** Type of flotation if any. Buoyancy, kg (lb).

(15) **Bend radius**. Minimum bend radius, m (ft).

Deck cable

Physical description

(1) **Length,** m (ft)**.**

(2) **Outside diameter,** cm (in).

(3) **Jacket.** Type of jacket.

(4) **Conductors**. Number, type, and AWG of conductors.

(5) **Armoring.** Type of armoring, shielding, stress member.

(6) **Strength**. Breaking strength, if applicable, newtons (lb-force).

(7) **Weight dry**. Weight in air, kg (lb).

(8) **Temperature, operating**. Operating temperature range °C (°F).

(9) **Temperature, storage**. Storage temperature range °C (°F).

(10) **Connectors**. Type of connectors, plug-in, swivels, slip ring, etc.

(11) **Bend radius**. Minimum bend radius, m (ft).

(12) **Electrical characteristics**. Dc resistance, capacitance, nominal leakage, Ω, μF, MΩ measured in situ.

Ballast fluid specifications

(1) **Length**, m (ft).

(2) **Outside diameter**, cm (in).

(3) **Jacket**. Type and thickness of jacket, cm

(in).

(4) **Conductors**. Number, type, and AWG of conductors.

(5) **Stress members**. Type and number of elastic stress members.

(6) **Strength**. Minimum breaking strength, newtons (lb-force).

(7) **Stretchability**. Elongation, meters per newton loading (ft/lb-force). Set of section should not exceed X percent after Y hours of tension at Z newtons loading. Preferably provide a suitable graph.

(8) **Weight dry**. Carcass weight in air dry, kg (lb).

(9) **Weight wet**. Weight in air when filled with specified quantity of ballast fluid.

(10) **Weight submerged.** Weight in fresh water filled with specified quantity of ballast fluid, kg (lb), standard temperature, and pressure.

(11) **Temperature, operating**. Operating temperature range, °C (°F).

(12) **Temperature, storage**. Storage temperature range, °C (°F).

(13) **Electrical characteristics**. Round trip dc resistance, nominal leakage and capacitance per unit length, Ω/m, MΩ, μF/m, measured in situ.

(14) **Connectors**. Type of connectors.

(15) **Ballast fluid**. Quantity of ballast fluid, m^3 (gal).

(16) **Hydrophones**. If active, specify the number and type of sensors. Where applicable, list the electrical analog or digital characteristics as for seismic cable sections.

Ballast fluid specifications

Introduction. Ballast fluids or simply cable oils are odorless kerosenes that have a negligible content of sulfur, aromatics, and olefins. Suitable cable oils are selected from the generic hydrocarbon group of the aliphatics such as normal paraffin, isoparaffin, and naphthene. The properties of hydrocarbon solvents are defined in part by certain arbitrary quantities which will be defined in the following paragraphs. Cable oils that fall outside the below-listed specifications may be hazardous to the well being of the cable structure.

Cable oil properties

(1) **Specific gravity**: 0.750 ± 0.040.

(2) **Flash point.** The flash point is the lowest temperature at which vapors will ignite momentarily when exposed to a flame. Preferably greater than 58°C (136°F).

(3) **Aromatics**. Aromatic content: 10 cm^3/litre (1 percent).

(4) **Plastic compatibility.** The kauri butanol number is a measure of the ability of the oil to attack resinous plastics. The K/B number should be less than 30, and preferably 25.

(5) **Deodorization.** The doctor test is the measure of the degree of deodorization of the solvent with particular reference to sulfur and mercaptans. The doctor test must be negative, particularly since the cable oil must be used within the close confines of a ship.

(6) **Corrosiveness.** The copper-strip corrosive test is a measure of the sulfur content and corrosiveness of the oil. The index should be no greater than 1 or 1a.

(7) **Sulfur.** Sulfur content: 1 mg/kg (1 ppm).

(8) **Paraffin.** The paraffin content should be 99 percent or greater of either normal or isoparaffin.

(9) **Olefin**. The olefin content: 10 cm^3/litre (1 percent).

Conclusions

Special cable configurations

(1) **Specialized cables.** The foregoing specifications are designed to provide a detailed description of streamer cables presently in common use. Exotic cables such as bottom-drag cables, optical-fiber cables, yo-yo cables and the like can be adequately specified by the above guidelines, although the

specification format would require suitable modification.

(2) **Equipment.** Cable handling equipment such as cable reels, special hydraulic accumulators to reduce cable motion, and yo-yo type devices were not considered in this document. Those items are usually specific to a particular operator. The operator will usually provide suitable technical manuals covering the maintenance and operation of such devices.

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