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Ships and marine technology — Standard specification for thermosetting resin fibreglass pipe and fittings to be used for marine applications

Navires et technologie maritime — Spécification normalisée pour les tuyaux et raccords en résine thermodurcissable avec renforcement en fibre de verre pour des applications maritimes

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15840 was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 3, *Piping and machinery*.

Ships and marine technology — Standard specification for thermosetting resin fibreglass pipe and fittings to be used for marine applications

1 Scope

This International Standard applies to reinforced thermosetting resin pipe systems with nominal diameter (DN) 0 through 1 200 mm and nominal pipe sizes (NPS) 0 through 48, which are to be used in marine piping systems.

Values stated in SI units are to be regarded as the standard. Values given in English units are for information only.

The dimensionless designators DN and NPS have been substituted for traditional terms such as “nominal diameter”, “size”, and “nominal size”.

The following safety hazard caveat pertains to the test methods that are included in this International Standard. This standard does not purport to address all of the safety concerns associated with its use.

SAFETY PRECAUTIONS — It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

American Society of Mechanical Engineers (ASME) B16.1:1998, *Cast Iron Pipe Flanges and Flanged Fittings*

American Society of Mechanical Engineers (ASME) B16.5:1996, *Pipe Flanges and Flanged Fittings*

American Society for Testing and Materials (ASTM) D883, *Standard Terminology Relating to Plastics*

ASTM D1598, *Standard Test Method for Time-To-Failure of Plastic Pipe Under Constant Internal Pressure*

ASTM D1599, *Standard Test Method for Resistance to Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings*

ASTM D2310, *Standard Classification for Machine-Made Fibreglass (Glass-Fibre-Reinforced Thermosetting-Resin) Pipe*

ASTM D2583, *Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor*

ASTM D2584, *Standard Test Method for Ignition Loss of Cured Reinforced Resins*

ASTM D2924, *Standard Test Method for External Pressure Resistance of Fibreglass (Glass-Fibre-Reinforced Thermosetting-Resin) Pipe*

ASTM D2992: 2001, *Standard Practice for Obtaining Hydrostatic or Pressure Design Basis for Fibreglass (Glass-Fibre-Reinforced Thermosetting-Resin) Pipe and Fittings*

ASTM D3567, *Standard Practice for Determining Dimensions of Fibreglass (Glass-Fibre-Reinforced Thermosetting Resin) Pipe and Fittings*

ASTM E1529: 2000, *Standard Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies*

ASTM F412, Standard *Terminology Relating to Plastic Piping Systems*

International Maritime Organisation (IMO), *International Convention for the Safety of Life at Sea (SOLAS)*

International Maritime Organisation (IMO) Resolution A.753 (18), *Guidelines for the Application of Plastic Pipes on Ships*

IMO Resolution MSC 61 (67), *International Code for Application of Fire Test Procedures*

ISO 75-1:—[1)], *Plastics — Determination of temperature of deflection under load — Part 1: General test method*

ISO 75-2:—[2)], *Plastics — Determination of temperature of deflection under load — Part 2: Plastics and ebonite*

ISO 4901, *Reinforced plastics based on unsaturated polyester resins — Determination of residual styrene monomer content*

ISO 9001:2000, *Quality management systems — Requirements*

ISO 11357-2 *Plastics — Differential scanning calorimetry (DSC) — Part 2: Determination of glass transition temperature*

National Sanitation Foundation (NSF) International, Standard 61 *Drinking Water System Components — Health Effects*

United Kingdom Health and Safety Executive (HSE) Offshore Technology Report (OTI) 95 634, *Jet-Fire Resistance Test of Passive Fire Protection Materials*

United States Code of Federal Regulations (CFR), Title 21 — Food and Drugs, Sections 175.105,177.2280,177.2410 and 177.2420.

United States CFR, Title 46 — Shipping

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ASTM D883 and ASTM F412 and the following apply.

3.1
continuously conductive
pipe and fittings made conductive using continuous conductive filaments, liners or layers

1) To be published. Revision of ISO 75-1:1993.

2) To be published. Revision of ISO 75-2:1992.

3.2
homogeneously conductive
pipe and fittings made conductive using a resin additive so that conductivity is maintained between any two points on the pipe or fitting

NOTE For conveying non-conducting fluids (those having conductance less than 1 000 picosiemens per metre), pipe systems which are homogeneously conductive or have conductivity from the inside surface to the outside surface are recommended.

3.3
maximum operating pressure
highest pressure that can exist in a system or subsystem under normal operating conditions

3.4
non-conducting fluid
fluid having conductance less than 1 000 picosiemens per metre

3.5
representative piping system
system composed of a single manufacturer's pipes, fittings, joints and adhesives that would normally be used by a customer or installer

4 Classification

4.1 General

Pipe and fittings are to be classified using the system described in 4.2 through 4.6, which are similar to the requirements of ASTM D2310 for pipe.

4.2 Types

The following are pipe and fitting types:

a) Type I — Filament wound

b) Type II — Centrifugally cast

c) Type III — Moulded (fittings only)

4.3 Resin

The following are examples of resin classifications:

a) Resin 1 — Epoxy resin

b) Resin 2 — Vinylester resin

c) Resin 3 — Polyester resin

d) Resin 4 — Phenolic resin

e) Resin 5 — Customer-specified resin

4.4 Class

The following represent class types:

a) Class A — No liner

b) Class B — Reinforced liner

c) Class C — Non-reinforced liner

4.5 Pressure rating (see Annex A)

The following are examples of pressure test classifications:

a) Rating Method 1 — Short-term test

b) Rating Method 2 — Medium-term (1 000 h) test

c) Rating Method 3 — Long-term (10 000 h) test

d) Rating Method 4 — Long-term (10 000 h) regression test

4.6 Fire endurance (see Annex B)

4.6.1 Fluid

The following fluid types are specified for fire endurance testing:

a) Fluid E — Empty

b) Fluid EF — Initially empty for 5 min, followed by flowing water. [Fluid velocity of 1 m/s (3 ft/s) maximum during qualification test.]

c) Fluid S — Stagnant water

4.6.2 Fire type

The following represent types of fire test:

a) Fire Type JF — Jet fire with heat flux between 300 kW/m^2 and 400 kW/m^2 (95 100 Btu/h/ft^2 and 126 800 Btu/h/ft^2)

b) Fire Type IF — Impinging flame with heat flux of 113,6 kW/m^2 (36 011 Btu/hr/ft^2)

c) Fire Type HF — Hydrocarbon furnace test at 1 100 °C (2 012 °F).

4.6.3 Integrity

The following represent various classifications of piping integrity:

a) Integrity A — No leakage during or after test

b) Integrity B — No leakage during fire test except a slight weeping may be accepted. Capable of maintaining rated pressure for a minimum of 15 min with a leakage rate of 0,2 l/min (0,05 gal/min) after cooling.

c) Integrity C — Minimal or no leakage [less than or equal to 0,5 l/min (0,13 gal/min)] during fire test. Capable of maintaining rated pressure with a customer-specified leakage rate after cooling.

4.6.4 Duration

The duration of the test shall be expressed in minutes and shall be specified or approved by the authority having jurisdiction.

5 Ordering information

5.1 General

When ordering pipe and fittings in accordance with this International Standard, the items described in 5.2 through 5.5 should be specified:

5.2 Service conditions

The following service conditions should be specified:

a) Fluid being transported

b) Design temperature (see 6.6)

c) Internal design pressure

d) External design pressure

5.3 General information

The following general information should be specified:

a) Type (see 4.2)

b) Resin (see 4.3)

c) Class (see 4.4)

5.4 Fire endurance

The following information regarding fire endurance should be specified:

a) Fluid (see 4.6.1)

b) Fire type (see 4.6.2)

c) Integrity (see 4.6.3)

d) Flame-spread rating (see 6.4)

e) Smoke and other toxic products of combustion (see 6.5)

5.5 Additional required information

The following additional required information should be specified:

a) Pressure rating method (Internal only) (see 4.5)

b) Size (DN and/or NPS)

c) Manufacturer’s identification (part number, product name, etc.)

d) Specific job requirements (i.e. potable water usage, electrical conductivity)

6 Performance requirements

6.1 Internal pressure

All components included in the piping system shall have pressure ratings suitable for the intended service. Pressure ratings shall be determined in accordance with Annex A using the method specified by the customer or a longer-term method, if available. If, for example, a rating method 2 (medium-term test) is specified and data for rating method 3 (long-term test) is available, then the long-term test data are acceptable. Note that, for some components, particularly specialty fittings, long-term testing is not practical and ratings for these items will typically be determined using rating method 1.

6.2 External pressure

All pipe included in the piping system shall have external pressure ratings suitable for the intended service. External pressure ratings shall be determined by dividing the results of ASTM D2924 by a minimum safety factor of 3.

6.3 Fire endurance

The piping system shall have the fire endurance required by the authority having jurisdiction based on the intended location and service. Fire endurance shall be determined using the appropriate method in Annex B.

6.4 Flame spread

The authority having jurisdiction shall designate any flame spread requirements based on the location of the piping. For ships, mobile offshore drilling units (MODUs), and floating oil production platforms subject to the requirements of SOLAS or Title 46 of the U.S. Code of Federal Regulations, performance shall be determined by test procedures given in IMO Resolution MSC.61 (67), Annex 1, Part 5 — Test for Surface Flammability, as modified for pipes in Appendix 3 of IMO Resolution A.753 (18).

6.5 Smoke and other toxic products of combustion

The authority having jurisdiction shall designate any smoke and toxicity requirements based on the location of the piping. For ships, mobile offshore drilling units (MODUs), and floating oil production platforms subject to the requirements of SOLAS or Title 46 of the U.S. Code of Federal Regulations, performance shall be determined by test procedures given in IMO Resolution MSC.61 (67), Annex 1, Part 2 — Smoke and Toxicity Test, as modified in Clause B.9.

6.6 Temperature

For epoxy resins, the maximum allowable design temperature shall be 30 °C less than the glass transition temperature (T_g) of the resin used in the qualified component 8.1.4. For polyester and vinyl ester resins, the maximum allowable design temperature shall be 20 °C less than the heat distortion temperature (HDT) of the resin used in the qualified component determined in accordance with ISO 75-1 and ISO 75-2.

6.7 Material compatibility

The piping material shall be chemically compatible with the fluid being carried and any fluid in which it may be immersed.

6.8 Electrical resistance

Conductive piping systems shall have a resistance per unit length not exceeding $1 \times 10^5\ \Omega$/m ($3{,}05 \times 10^4\ \Omega$/ft) when tested in accordance with Clause C.2. Resistance to earth at any location on an installed piping system shall be no greater than $1 \times 10^6\ \Omega$.

6.9 Static charge shielding

Conductive piping systems shall have a maximum resulting voltage not exceeding 2 % of the supply voltage induced on the exterior surface of the pipe when tested in accordance with Clause C.1.

6.10 Potable water usage

The material, including pipe, fittings, adhesive, and any elastomeric gaskets required, shall have no adverse effect on the health of personnel when used for potable water service. Material shall conform to NSF International, Standard 61 or meet the requirements of FDA regulations 21 CFR 175.105 and 21 CFR 177.2280, 21 CFR 177.2410, or 21 CFR 177.2420.

7 Other requirements

Standard flanges shall have bolt patterns in accordance with ASME B16.5:1996, Class 150 for nominal pipe sizes 610 mm (24 inch) and smaller, and in accordance with ASME B16.1:1998, Class 125 for larger flanges. Consult the manufacturer's literature for bolt length, torque specifications and tightening sequence.

8 Inspection and sampling

8.1 Pipe

8.1.1 Pressure tests: a minimum of 10 % of pipe joints shall be tested at a pressure of not less than 1,5 times the pipe-system pressure rating.

8.1.2 Lot size: a lot of pipe shall consist of 150 joints, or fractions thereof, of one size, wall thickness, and grade in continuous production.

8.1.3 Short-term hydrostatic burst tests shall be conducted in accordance with ASTM D1599 at a minimum frequency of one test per lot. If the measured value is less than 85 % of the published value, the lot is rejected or subject to retest.

8.1.4 The degree of cure shall be determined by either measuring the glass transition temperature in accordance with ISO 11357-2, the residual styrene content in accordance with ISO 4901, or the barcol hardness in accordance with ASTM D2583. The minimum frequency shall be one test per production lot. The following shall apply, depending upon the method used to determine the degree of cure:

— If the glass transition temperature is 5,5 °C (10 °F) less than the value in the manufacturer's specifications, the lot shall be rejected or subject to retest.

— If the styrene content is more than 2 % of the resin content by weight, the lot shall be rejected or subject to retest.

— If the barcol hardness is less than 90 % of the value in the manufacturers specification, the lot shall be rejected or subject to retest.

8.1.5 The glass content (mass fraction expressed as percentage) of at least one sample per production lot shall be determined in accordance with ASTM D2584. If the measured glass content is not within 5 % of the value in the manufacturer's specification, the lot is rejected or subject to retest.

8.1.6 The total wall thickness and reinforced wall thickness shall be determined using ASTM D3567 once per every production lot. The total and reinforced wall thickness shall be as specified in Table 1. Any out-of-tolerance components shall be rejected and the remainder of the lot shall be subject to retest.

8.2 Fittings

8.2.1 Pressure tests: a minimum of 10 % of each fitting lot shall be tested at a pressure of not less than 1,5 times the pipe-system pressure rating. All samples shall hold the test pressure for a minimum of 2 min.

8.2.2 Lot size: a lot shall consist of 50 fittings or one day's production of a specific fitting.

8.2.3 Short-term hydrostatic burst tests shall be conducted in accordance with ASTM D1599 at a minimum frequency of one test per lot. If the measured value is less than 85 % of the published value, the lot is rejected or subject to retest.

8.2.4 The degree of cure shall be determined by either measuring the glass transition temperature in accordance with ISO 11357-2, the residual styrene content in accordance with ISO 4901, or the barcol hardness in accordance with ASTM D2583. The minimum frequency shall be one test per production lot. The following shall apply, depending upon the method used to determine the degree of cure:

— If the glass transition temperature is 5,5 °C (10 °F) less than the value in the manufacturer's specifications, the lot shall be rejected or subject to retest.

— If the styrene content is more than 2 % of the resin content by weight, the lot shall be rejected or subject to retest.

— If the barcol hardness is less than 90 % of the value in the manufacturer's specification, the lot shall be rejected or subject to retest.

8.2.5 The glass content (mass fraction expressed as percentage) of at least one sample per production lot shall be determined in accordance with ASTM D2584. If the measured glass content is not within 5 % of the value in the manufacturer's specification, the lot is rejected or subject to retest.

8.2.6 The total wall thickness and reinforced wall thickness shall be determined using ASTM D3567 once per every production lot. The total and reinforced wall thickness shall be as specified in Table 1. Any out-of-tolerance components shall be rejected and the remainder of the lot shall be subject to retest.

8.3 Flanges and mitred fittings

8.3.1 Pressure tests: one mitred fitting from each lot shall be tested to a pressure equal to or greater than 1,5 times the pipe system rating. All samples shall hold the pressure for a minimum of 2 min.

8.3.2 Lot size: a lot shall consist of 20 flanges or 10 mitred fittings of any given configuration.

8.3.3 The degree of cure shall be determined by either measuring the glass transition temperature in accordance with ISO 11357-2, the residual styrene content in accordance with ISO 4901, or the barcol hardness in accordance with ASTM D2583. The minimum frequency shall be one test per production lot. The following shall apply, depending upon the method used to determine the degree of cure:

— If the glass transition temperature is 5,5 °C (10 °F) less than the value in the manufacturer's specifications, the lot shall be rejected or subject to retest.

— If the styrene content is more than 2 % of the resin content by weight, the lot shall be rejected or subject to retest.

— If the barcol hardness is less than 90 % of the value in the manufacturers specification, the lot shall be rejected or subject to retest.

8.3.4 The glass content (mass fraction expressed as percentage) of at least one sample per production lot shall be determined in accordance with ASTM D2584. If the measured glass content is not within 5 % of the value in the manufacturer's specification the lot is rejected or subject to retest.

8.3.5 The total wall thickness and reinforced wall thickness shall be determined using ASTM D3567 once per every production lot. The total and reinforced wall thickness shall be as specified in Table 1. Any out-of-tolerance components shall be rejected and the remainder of the lot shall be subject to retest.

Table 1 — Wall thickness tolerances

Dimension	Tolerance
Total wall thickness	+ 22,5 %[a] − 0 %
Reinforced wall thickness	+22,5 %[a] − 0 %
[a] The tolerance on total and reinforced wall thickness for fittings shall refer to the manufacturer's designated location on the body of the fitting.	

8.4 Retest

If any test result in 8.1, 8.2 and/or 8.3 fails to conform to the specified requirements, the manufacturer may elect to reject the entire lot, or retest two additional samples from the same lot. If both of the retest specimens conform to the requirements, all items in the lot shall be accepted except the sample that initially failed. If one or both of the retest samples fails to conform to the specified requirements, the manufacturer may reject the entire lot or test individually for the remaining samples in the lot in accordance with 8.1.1, 8.2.1 or 8.3.1, as applicable. Note that, in the final case, all samples need only be subjected to the tests that the original samples failed.

8.5 Production quality documentation

The manufacturer shall have manufacturing procedures for each component to be supplied, raw material test certificates for each component to be used in manufacturing, and production quality-control reports available for the procurement officer.

9 Appearance and workmanship

All pipe, fittings and spools shall be visually inspected for compliance with the requirements stated in Table 2, and, if appropriate, either repaired or rejected. After all minor repairs, a pressure test in accordance with 8.1.1, 8.2.1, or 8.3.1 shall be performed on the component.

Table 2 — Visual inspection requirements

Defect type	Description	Acceptance criteria	Corrective action
Burn	Thermal decomposition indicated by distortion or discolouration of the laminate surface.	None permitted	Reject
Chip	Small piece broken from edge or surface. If reinforcement fibres are broken, the damage is considered as a crack.	If there are undamaged fibres exposed over any area; or no fibres are exposed but an area greater than 10 mm × 10 mm (0,4 in × 0,4 in) lacks resin. If no fibres are exposed, and the area lacking resin is less than 10 mm × 10mm (0,4 in × 0,4 in)	Minor repair Accept
Crack	Actual separation of the laminate that is visible on opposite surfaces and often extends through the wall. Reinforcement fibres are often visible/broken.	None permitted	Reject
Crazing	Fine hairline cracks at or under the surface of the laminate. White areas are not visible.	Crack lengths greater than 25,4 mm (1,0 in) Crack lengths less than 25,4 mm (1,0 in)	Minor repair Accept
Dry spot	Area of incomplete surface film where the reinforcement has not been wetted by resin.	None permitted	Reject
Fracture	Rupture of the laminate with complete penetration. Majority of fibres broken. Visible as lighter coloured area of interlaminar separation.	None permitted	Reject
Inclusion	Foreign matter wound into the laminate	None permitted in structural wall. (Treat the same as pit if located at the surface.	Reject
Pit (pinhole)	Small crater in the surface of the laminate. Width is of the same order of magnitude as the depth.	Diameter greater than 0,8 mm (0,032 in) and/or depth greater than 10 % of wall thickness Diameter less than 0,8 mm (0,032 in) and depth less than 10 % of wall thickness	Minor repair Accept
Restriction	Excessive resin, adhesive, or foreign matter on the internal wall of pipe/fittings.	None permitted	Remove by careful grinding.
Wear scratch	Shallow mark caused by improper handling, storage, and/or transportation. If reinforcement fibres are broken, the damage is considered to be a crack.	Undamaged fibres exposed over any area, or no fibres are exposed but an area greater than 10 mm × 10 mm (0,4 in × 0,4 in) lacks resin	Minor repair
		No fibres exposed and the area lacking resin is less than 10 mm × 10 mm (0,4 in × 0,4 in)	Accept

10 Product marking

Pipe and fittings shall be marked with the name, brand or trademark of the manufacturer, standard pipe size, manufacture date, pressure rating, pressure rating method, and other information upon agreement between the manufacturer and purchaser.

11 Certification

The pipe manufacturer shall be registered by an accredited agency to meet the requirements of ISO 9001. For the purposes of this specification, the manufacture shall be considered a “special process” as defined in ISO 9001:2000, 7.5.2.

Internal pressure rating for a piping system shall be determined using one of four methods. The method used to determine this rating shall be clearly identified by the manufacturer in the published literature.

Annex A
(normative)

Determination of internal pressure rating for pipes, fittings and joints

A.1 Rating method 1: short-term test

Two samples of each pipe, joint, fitting, or other component shall be tested in accordance with ASTM D1599 at ambient temperature. The maximum rating for mitred (hand lay-up) fittings shall be determined by dividing the lesser result by a safety factor of 5,0. The maximum rating for all other components shall be determined by dividing the lesser result by a safety factor of 4,0.

A.2 Rating method 2: medium-term (1 000 h) test

Two samples of each pipe, joint, fitting or other component shall be tested in accordance with ASTM D1598 for a period of 1 000 h at the rated temperature. Both specimens must survive the exposure period without leakage. The maximum rating for mitred (hand lay-up) fittings shall be determined by dividing the pressure by a safety factor of 2,5. The maximum rating for all other components shall be determined by dividing the pressure by a safety factor of 2,2.

A.3 Rating method 3: long-term (10 000 h) test

Two samples of each pipe, joint, fitting or other component shall be tested in accordance with ASTM D1598 for a period of 10 000 h at the rated temperature. Both specimens must survive the exposure period without leakage. The maximum rating for mitred (hand lay-up) fittings shall be determined by dividing the pressure by a safety factor of 2,0. The maximum rating for all other components shall be determined by dividing the pressure by a safety factor of 1,87.

A.4 Rating method 4: long-term (10 000 h) regression test

Pipe, fittings, and joints shall be tested in accordance with ASTM D2992:2001, Procedure B at the rated temperature. The pressure rating for all components shall be determined according to the hydrostatic design basis (HDB) and Lower Confidence Limit (LCL) as calculated in the test method. Ratings shall be determined by dividing the LCL at 20 years by a factor of 1,5. Scaling of the results is allowed for pipe bodies only according to the following equation:

$$S \times \mathrm{SF} = \frac{P(D - t_\mathrm{r})}{2t_\mathrm{r}}$$

where

S is the hoop stress, in kPa;

SF is the service factor;

D is the mean reinforced diameter (OD – t) or (ID + t), in mm;

P is the internal pressure, in kPa;

t_r is the minimum reinforced wall thickness, in mm.

NOTE The liner thickness is not to be used in determining ID and the coating thickness is not to be used in determining OD.

Annex B
(normative)

Fire performance tests

B.1 Third-party testing

Fire performance tests shall be performed at an independent third-party laboratory to the satisfaction of the authority having jurisdiction.

B.2 Piping material systems

B.2.1 All fire endurance, flame spread, smoke and toxicity testing, where required, shall be conducted on each piping material system.

B.2.2 Changes in either the type, amount, and/or architecture, of either the reinforcement materials, resin matrix, liners, coatings, or manufacturing processes shall require separate testing in accordance with the requirements of this standard.

B.3 Fire protective coatings

B.3.1 Where a fire protective coating is necessary for achieving the fire endurance, flame spread, or smoke and toxicity criteria, the requirements of B.3.2 through B.3.5 shall apply.

B.3.2 Pipes shall be delivered from the manufacturer with the protective coating applied. On-site application will be limited to what is physically necessary for installation (i.e. joints).

B.3.3 The fire protection properties (i.e. fire endurance, flame spread, smoke production, etc.) of the coating shall not be diminished when exposed to salt water, oil, or bilge slops, or when exposed to other environmental conditions such as high and low temperatures, high and low humidity, and ultraviolet rays.

B.3.4 The adhesion qualities of the coating shall be such that the coating does not flake, chip or powder, when subjected to an adhesion test.

B.3.5 The fire protective coating shall be resistant to impact.

B.4 General fire endurance test requirements

B.4.1 All typical joints, including but not limited to pipe to pipe, fibreglass flange to fibreglass flange and fibreglass flange to metallic flange, intended to be used, shall be tested. Elbows and tees need not be tested, provided the same adhesive or method of joining utilised in straight piping tests will be used in the actual application.

B.4.2 Qualification of piping systems of sizes different than those tested shall be allowed as provided for in Table B.1. This applies to all pipe, fittings, system joints (including joints between metal and fibreglass pipes and fittings), methods of joining, and any internal or external liners, coverings and coatings required to comply with the performance criteria.

Table B.1 — Qualification sizes

Size tested mm (in)	Minimum size approved	Maximum size approved mm (in)
0 to 40 (0 to 1,5)	Size tested	Size tested
50 to 100 (2 to 4)	Size tested	100 (4)
125 to 250 (5 to 10)	Size tested	250 (10)
300 to 550 (12 to 22)	Size tested	550 (22)
600 to 850 (24 to 34)	Size tested	850 (34)
900 to 1 200 (36 to 48)	Size tested	1 200 (48)
NOTE Size refers to the outer diameter of piping tested (see also B.4.2).		

B.4.3 No alterations to couplings, fittings, joints, fasteners, insulation or other components shall be made after the commencement of the fire endurance testing. Flange bolts shall not be retorqued after completion of the fire exposure testing, prior to hydrostatic testing. Post fire hydrostatic testing shall be conducted without altering the component in any way.

B.5 Fire type JF: jet fire

NOTE This test is based upon Health & Safety Executive document OTI 95 634: *Jet Fire Resistance Test of Passive Fire Protection Materials*, except that it is modified so that actual pipe, joints and fittings are exposed to the flame.

B.5.1 Equipment

B.5.1.1 Propane vaporisation and propulsion system, capable of delivering $0{,}3 \pm 0{,}05$ kg/s ($0{,}66 \pm 0{,}11$ lb/s) flow under controlled conditions into a backing "box" which has the test specimen mounted at its front opening. The nozzle shall be a tapered, converging type, 200 mm (7,875 in) in length with an inlet diameter of 52 mm (2,0 in) and an outlet diameter of 17,8 mm (0,70 in). The nozzle is to be located 1,0 m (3,281 ft) from the front of the box, centred across the box and mounted horizontally between 375 mm (15 in) and 750 mm (30 in) from the bottom of the box. The flow shall directly impinge on the test specimen.

B.5.1.2 Water handling and timing equipment, suitable for delivering sufficient quantities of water to produce a fluid velocity of 1 m/s (3 ft/s) at the rated pressure of the piping system being tested.

B.5.1.3 Instrumentation, to record fuel flow rate, water flow rate, temperatures in the specimen and in various locations in the backing panel, and water leakage rate from the pipe assembly or individual components.

B.5.2 Test specimen

The test specimen shall be constructed of a single size of piping with a diameter of less than 305 mm (12 in). The test shall qualify all sizes below 457 mm (18 in) diameter which have a thickness-to-diameter (t/d) equal to or greater than that of the test specimen. If fire protective coatings or layers are included with the specimen, the test will only qualify products in the range noted above with the same or greater thickness of protection, regardless of the t/d value. The test specimen shall be constructed with a permanent joint and/or fitting showing the most vulnerability (highest leakage rate) when tested in accordance with Clause B.7 or IMO Resolution A.753 (18), Appendix 2.

B.5.3 Test conditions

B.5.3.1 If fire-protected coatings or coverings contain or are liable to absorb moisture, the test specimen should not be tested until the insulation has reached an air-dry condition. This condition is defined as

equilibrium with an ambient temperature of 20 ± 5 °C (70 ± 10 °F) at 50 % relative humidity. Where fire protective coatings or coverings are required to enable a pipe system to pass a fire endurance test, the properties of coatings or coverings should not degrade over time and/or due to exposure to the environment as discussed in IMO Resolution A.753 (18), paragraph 2.2.6.

B.5.3.2 The test specimen shall be planar and shall be mounted flush to the opening of a 1,5 m × 1,5 m (5 ft × 5 ft) open ended, steel box [closed back panel with a depth of 0,5 m (1,64 ft)]. Suitable auxiliary equipment shall be attached to the box to assure its structural stability and to prevent any transient ambient conditions from significantly affecting the testing. The purpose of the box is to provide a "backstop" to the flame and cause swirling of the fire to completely engulf the sample.

B.5.3.3 Thermocouples may be mounted on the specimen and within the box or its structure to record temperature conditions during testing.

B.5.3.4 The test building shall be suitably constructed in order to assure that there is not a hazardous amount of heat or smoke allowed to accumulate during or after the test.

B.5.3.5 Prior to conducting the test, calibration runs of the gas flow controls and water flow system shall be conducted.

B.5.3.6 The fuel used shall be commercial grade propane delivered to the nozzle as a vapour without a liquid fraction.

B.5.4 Test procedure

NOTE See Figure B.1 for the basic configuration of a jet fire test set-up.

B.5.4.1 Each test specimen shall be pressure tested to 1,5 times its rated pressure prior to mounting in the test rig. No leakage is allowed during this test.

B.5.4.2 Unless fluid S is specified, the specimen is to be completely drained of water after the initial test and secured into position. All thermocouple and plumbing connections are to be made at this time. For fluid S conditions, the specimen is secured into position when filled with water.

B.5.4.3 A small "pilot" flame may be started to assure safe ignition of the fuel prior to establishing full flow.

B.5.4.4 The flow is to be increased to the rate as specified in B.5.1.1. This rate has been shown to produce a heat flux between 300 and 400 kW/m^2 (95 100 and 126 800 Btu/hr/ft^2). Timing of the test is to begin when the specimen is fully engulfed. A fully controlled flow is to be established within 30 s of the start of the test.

B.5.4.5 If fluid E or S in 4.6.1 is specified, the test will be continued for a minimum of 20 min under the initial conditions.

B.5.4.6 If fluid EF in 4.6.1 is specified, the steps in B.5.4.6.1 through B.5.4.6.3 shall be taken.

B.5.4.6.1 Continue the test in the dry condition for 5 min.

B.5.4.6.2 After the 5 min dry period, introduce water at a flow velocity not exceeding 1 m/s (3,3 ft/s). Pressure in the system is to be maintained at a minimum of 90 % of the rated pressure for the system. These conditions are to be established within 1 min after the flow of water begins.

B.4.5.6.3 Continue the test under flowing water conditions for a minimum of 15 min.

B.5.4.7 Increased exposure times over those specified above are acceptable upon agreement between the manufacturer and buyer.

B.5.4.8 Upon completion of the fire exposure period, the fuel flow is to be discontinued, the flame extinguished, and the sample allowed to cool (with flowing water, if desired) to room temperature.

B.5.4.9 After cooling, the specimen is to be pressurised at its rated pressure for a minimum of 15 min with stagnant water. Adding water is allowed. Overall leakage and leakage of each component is to be measured and recorded after this period.

B.5.5 Acceptance criteria

Piping shall be deemed to have passed the test if the performance meets the criteria for integrity and duration set by the authority having jurisdiction (see 4.6.3).

B.5.6 Test report

The following information shall be reported:

a) complete identification of the pipe or fitting tested, including the manufacturer's name and code;

b) description of fire protective coating, if applicable;

c) diameter of pipe, fitting or joint;

d) endurance time;

e) appearance of test specimen;

f) date of test;

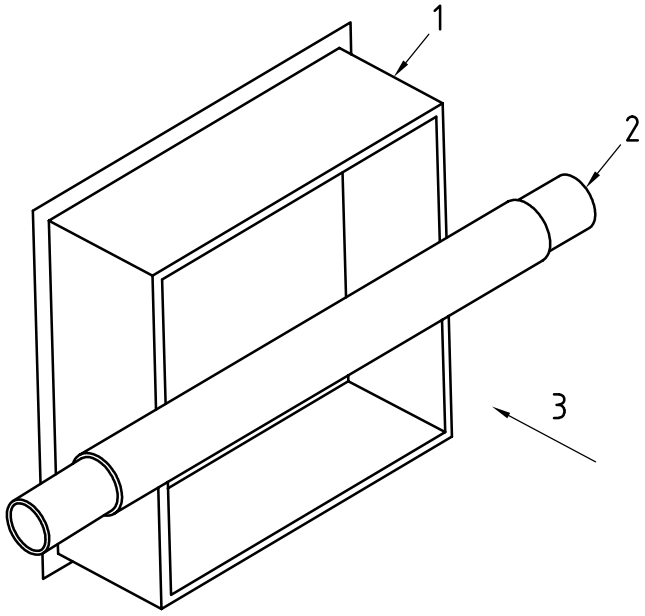
g) leakage rate.

B.6 Fire type HF: Hydrocarbon furnace test

This test method covers the determination of the fire endurance of thermosetting resin fibreglass pipe, fittings and joints to be used in marine applications. The procedure in ASTM E1529:2000, with additional steps as outlined below, shall be followed. This procedure is similar to IMO Resolution A.753 (18), Appendix 1, which is an alternative to this test.

B.6.1 Significance

This test method is intended to provide a basis for evaluating the time period during which fibreglass pipe will continue to perform its intended function when subjected to a controlled, standardised fire exposure. In particular, the standard exposure condition in ASTM E1529:2000 simulates the condition of total continuous engulfment of a pipe or piping system in the luminous flame (fire plume) area of a large, free-burning hydrocarbon pool fire. The standard fire exposure is defined in terms of the total flux incident on the test specimen together with the appropriate temperature conditions.



Key

1 box
2 GRP pipe
3 jet

NOTE GRP refers to Glass Reinforced Plastic pipe.

Figure B.1 — Basic configuration of a jet fire test set-up

B.6.2 Test equipment

The following test equipment shall be provided:

a) furnace;

b) nitrogen tank with regulator or water circulating system with flow meters.

The set up and control of the test shall be as specified in Clauses 6 through 11 of ASTM E1529:2000.

B.6.3 Test specimen

B.6.3.1 If fire-protective coatings or coverings contain or are liable to absorb moisture, the test specimen should not be tested until the insulation has reached an air-dry condition. This condition is defined as equilibrium with an ambient temperature of 20 ± 5 °C (70 ± 10 °F) at 50 % relative humidity. Where fire-protective coatings or coverings are required to enable a pipe system to pass a fire endurance test, the properties of coatings or coverings should not degrade over time and/or due to exposure to the environment as discussed in IMO Resolution A.753 (18), paragraph 2.2.6.

B.6.3.2 Accelerated conditioning is permissible, provided the method does not alter the properties of component materials.

B.6.3.3 Special samples shall be used for moisture content determination and conditioned with the test specimen. These samples should be so constructed as to represent the loss of water vapour from the specimen by having similar thickness and exposed faces.

B.6.3.4 The test specimen should be prepared with the joints, fittings and fire protection coverings, if any, intended for use in the proposed application.

B.6.3.5 The number of specimens shall be sufficient to test typical joints.

B.6.3.6 For specimens to be tested using fluid E, the ends of the specimen shall be closed with one end allowing pressurised nitrogen to be connected. Specimens to be tested with fluid EF and S shall have both ends closed with means to connect the water supply.

B.6.3.7 The pipe ends and closures may be outside the furnace.

B.6.3.8 The general orientation of the specimen should be horizontal and it should be supported by one fixed support. Remaining supports should allow free movement.

B.6.3.9 When testing with fluid E, nitrogen pressure inside the test specimen should be maintained automatically at 0,7 ± 0,1 bar (10,1 ± 1,5 psi) during the test. Means should be provided to record the pressure inside the pipe and the nitrogen flow into and out of the specimen in order to indicate leakage.

B.6.4 Test procedure

The following procedures shall be used when conducting the hydrocarbon furnace test.

a) Measure the dimensions of the specimen in accordance with ASTM D 3567. Include measurements of liner thickness and external coatings, if applicable.

b) Place the specimen in the furnace.

c) Specimens to be tested with fluid E shall be pressurised with nitrogen maintaining the pressure in accordance with B.6.3.9. Specimens to be tested with fluid EF shall be initially filled with ambient air for 5 min and then with water flowing with a maximum velocity of 1 m/s (3 ft/s) and 3 ± 0,5 bar (44 ± 7 psi). Specimens to be tested with fluid S shall be filled with water at 3 ± 0,5 bar (44 ± 7 psi).

d) Subject the piping or piping system to the fire exposure specified in Clause 6 of ASTM E1529:2000 for the time specified.

e) After termination of the furnace test, the specimen, together with any fire protective coating, should be allowed to cool in still air to ambient temperature and then tested to the rated pressure for 15 min.

B.6.5 Acceptance criteria

Pipe shall be deemed to pass the test if the performance meets the customer-specified integrity/duration in 4.6.3.

To meet IMO Resolution A.753 (18), Level 1 or Level 2 requirements, fluid E should be tested and there should be no nitrogen leakage during the test or water leakage during the hydrostatic test in B.6.4. For Level 1 or Level 2, the duration of the test is 60 min or 30 min, respectively.

B.6.6 Test report

The following information shall be reported:

a) complete identification of the pipe or fitting tested, including the manufacturer's name and code;

b) description of fire protective coating, if applicable;

c) diameter of pipe, fitting or joint;

d) endurance time;

e) appearance of test specimen;

f) date of test.

B.7 Fire type IF: impinging flame

B.7.1 Scope

This test method covers the determination of the fire endurance of thermosetting resin fibreglass pipe, fittings and joints to be used in marine applications. This test procedure is based on IMO Resolution A.753 (18), Appendix 2, which is an alternative procedure.

B.7.2 Summary of test method

This test method subjects a pipe sample to a constant 113,6 kW/m^2 (36 011 Btu/h/ft^2) net flux to determine a pipe system's fire endurance.

B.7.3 Test equipment

The following test equipment shall be provided:

a) burner that produces an air mixed flame:

   1) the inner diameter of the burner heads should be 29 mm (1,14 in);

   2) the burner heads should be mounted in the same plane and supplied with gas from a manifold (see Figure B.2);

   3) each burner should be equipped with a valve, if necessary, in order to adjust the flame height;

   4) the height of the burner stand should also be adjustable;

   5) the distance between the burner heads and the pipe should be maintained at 125 ± 10 mm (5 ± 3/8 in) during the test;

b) two thermocouples capable of measuring up to 1 100 °C (2 012 °F);

c) water;

d) thermometer to measure internal water temperature;

e) pressure gauge capable of reading up to 5 bar (73 psi) ± 5 %;

f) V-shaped pipe supports (2); the free length of pipe between supports should be 800 ± 50 mm (31,5 ± 2 in);

g) propane with a minimum purity of 95 %

B.7.4 Test specimen

The test specimen shall be arranged as follows.

a) The test specimen shall be 1,5 m (59 in) long.

b) Pipe with permanent joints or fittings intended for use in marine applications shall be used in the specimen.

c) All joint types should be tested as noted in B.4.1.

d) The quantity of pipe specimens should be sufficient to test all typical joints and fittings.

e) A pressure-relief valve should be connected to one of the end closures of the system.

B.7.5 Test conditions

B.7.5.1 If fire-protective coatings or coverings contain or are liable to absorb moisture, the test specimen should not be tested until the insulation has reached an air-dry condition. This condition is defined as equilibrium with an ambient temperature of 20 ± 5 °C (70 ± 10 °F) at 50 % relative humidity. Where fire-protective coatings or coverings are required to enable a pipe system to pass a fire endurance test, the properties of coatings or coverings should not degrade over time and/or due to exposure to the environment as discussed in IMO Resolution A.753 (18), paragraph 2.2.6.

B.7.5.2 Accelerated conditioning is permissible, provided the method does not alter the properties of component materials.

B.7.5.3 Special samples shall be used for moisture content determination and conditioned with the test specimen. These samples should be so constructed as to represent the loss of water vapour from the specimen by having similar thickness and exposed faces.

B.7.5.4 The test should be carried out in a sheltered test site in order to prevent any drafts from influencing the test.

B.7.5.5 Specimens to be tested with fluid E shall be pressurised with nitrogen, maintaining the pressure in accordance with B.7.3 e). Specimens to be tested with fluid EF shall be initially filled with ambient air for 5 min and then with water flowing with a maximum velocity of 1 m/s (3 ft/s) and 3 ± 0,5 bar (44 ± 7 psi). Specimens to be tested with fluid S shall be filled with water at 3 ± 0,5 bar (44 ± 7 psi).

B.7.5.6 The water temperature when testing with fluid S or EF should not be less than 15 °C (59 °F) at the start and should be measured continuously during the test.

B.7.5.7 Flame temperature

B.7.5.7.1 The exterior flame temperature shall be measured by means of two thermocouples mounted not more than 25 mm (1 in) from the pipe near the centre span of the assembly.

B.7.5.7.2 The thermocouples shall be mounted on the horizontal plane at the level of the pipe.

B.7.5.7.3 The test temperature shall be taken as the average of the two thermocouple readings.

B.7.6 Test procedure

The following procedure shall be followed when conducting the impinging flame test.

a) Measure the dimensions of the specimen in accordance with ASTM D3567. Include measurements of liner thickness and external coatings, if applicable.

b) Place the specimen on two v-shaped supports. The supports may consist of two stands as shown in Figure B.2.

c) Pressurise the specimen with water as required in accordance with 4.5.

d) Arrange the burners' configuration for constant heat flux.

e) For piping 152 mm (6 in) or less in diameter, the fire source should consist of two rows of 5 burners as shown in Figure B.2.

f) A constant heat flux averaging 113,6 kW/m^2 (36 011 Btu/h/ft^2) $\pm$ 10 % should be maintained 125 $\pm$ 10 mm (5 $\pm$ 3/8 in) above the centreline of the array. This flux corresponds to a pre-mix flame of propane with a fuel flow rate of 5 kg/h (11,02 lb/h) for a total heat release of 65 kW (221 780 Btu/h). The gas consumption should be measured with an accuracy of $\pm$ 3 % in order to maintain a constant heat flux.

g) For piping greater than 152 mm (6 in) in diameter, one additional row of burners should be included for each 51 mm (2 in) increase in diameter while maintaining the heat flux in B.7.2.

h) Begin the heat flux.

i) Record the test temperature, water temperature and pressure, if applicable, at the beginning of the test, at the end of the test and at maximum 5 min intervals during the test.

j) The test specimen shall be exposed to flame for 30 min.

k) After termination of the burner regulation test, the test sample, together with the fire-protective coating, if any, should be allowed to cool to ambient temperature and then tested to the rated pressure of the pipe. If fire-protective coverings are used, the pressure test shall be conducted without the covering, where practical. The pressure shall be held for a minimum of 15 min.

B.7.7 Acceptance criteria

Piping shall be deemed to have passed the test if the performance meets the criteria set by the authority having jurisdiction regarding integrity and duration in 4.6.3.

B.7.8 Test report

The following information shall be reported:

a) complete identification of the pipe or fitting tested, including the manufacturer's name and code;

b) description of fire-protective coating, if applicable;

c) diameter of pipe, fitting or joint;

d) endurance time;

e) appearance of test specimen;

f) date of test;

g) leakage rate.

Dimensions in millimetres

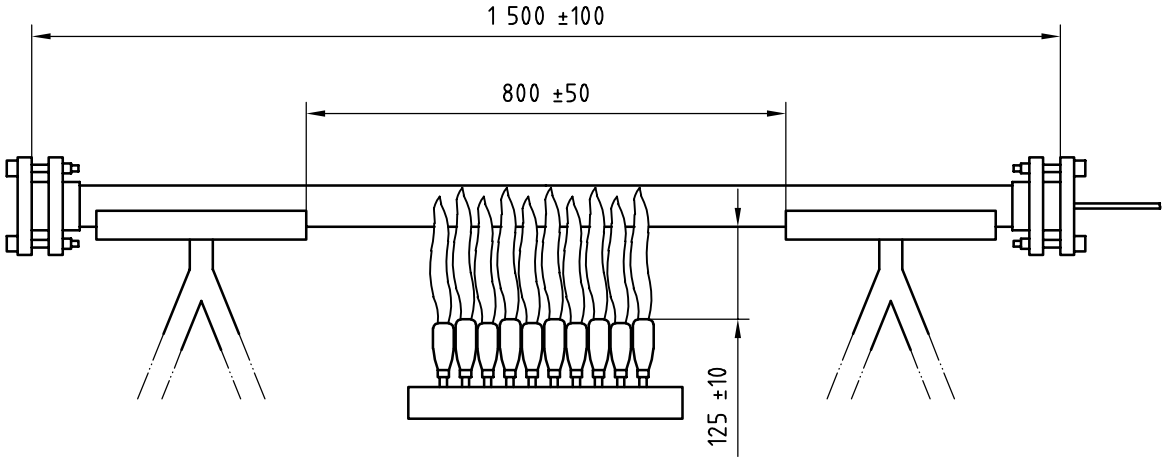


Figure B.2 — Basic configuration of an impinging flame test set-up

B.8 Flame spread

B.8.1 Flame spread testing of fibreglass piping shall be conducted in accordance with Appendix 3 of IMO Resolution A.753 (18) except as modified in B.8.2.

B.8.2 Testing need not be conducted on all piping sizes. Only the sizes with the maximum and minimum wall thickness to be used must be tested.

B.9 Smoke and toxicity

B.9.1 Smoke and toxicity testing of fibreglass piping shall be conducted in accordance with Annex 1, Part 2 — Smoke and Toxicity Test, of IMO Resolution MSC.61 (67) except as modified in B.9.2 through B.9.12. These modifications are similar to those in Appendix 3 of IMO Resolution A.753 (18), except that they apply to the smoke and toxicity test, not the surface flammability test.

B.9.2 Testing shall be conducted on piping sizes with the maximum and minimum wall thickness intended to be used.

B.9.3 The test sample shall be fabricated by cutting pipes lengthways into individual sections and then assembling the sections into a test sample as representative as possible of a flat surface. All cuts shall be made normal to the pipe wall.

B.9.4 The number of sections that must be assembled together to form a square test sample with sides measuring 76 mm (3 in) shall be that which corresponds to the nearest integral number of sections that will result in a test sample with an equivalent linearized surface width between 76 mm (3 in) and 89 mm (3,5 in). The surface width is defined as the measured sum of the outer circumference of the assembled pipe sections normal to the lengthways section.

B.9.5 The assembled test sample shall have no gaps between individual sections.

B.9.6 The assembled test sample shall be constructed in such a way that the edges of two adjacent sections will coincide with the centreline of the test holder.

B.9.7 The test samples shall be mounted on calcium silicate board and held in place by the edges of the test frame and, if necessary, by wire.

B.9.8 The individual pipe sections shall be mounted so that the highest point of the exposed surface is in the same position as the plane of an equivalent flat plate.

B.9.9 The space between the concave unexposed surface of the test sample and the surface of the calcium silicate backing board shall be left void.

B.9.10 The void space between the top of the exposed test surface and the bottom edge of the sample holder frame shall be filled with a high temperature insulating wool where the pipe extends under the frame.

B.9.11 When the pipes are to include fireproofing or coatings, the composite structure consisting of the segmented pipe wall and fire proofing shall be tested, and the thickness of the fireproofing shall be the minimum thickness specified for the intended usage.

B.9.12 The test sample shall be oriented in the apparatus such that the pilot burner flame will be normal to the lengthways piping sections.

Annex C
(normative)

Electrical property test methods for conductive fibreglass piping

C.1 Test method for determination of charge shielding properties of reinforced thermosetting resin pipe, fittings and joints

C.1.1 Summary of test

In this test, a high voltage electric field is applied to the interior surface of a grounded reinforced thermosetting resin pipe, fitting, or joint and the resulting voltage on the exterior surface, if any, is measured. This test can also be used to determine the effect of typical chemical exposure on the conductive properties of the pipe, fittings and joints.

C.1.2 Test equipment

The following test equipment shall be provided:

a) **DC supply**, capable of producing a minimum voltage of 1 000 V.

b) **Field meter**, capable of measuring and displaying electric field strengths of 100 $V \cdot m^{-1}$ with zero stable within 50 $V \cdot m^{-1}$ over at least 1 000 s. A reading of 100 $V \cdot m^{-1}$ shall be at least 10 % of an analogue scale reading or at least the second digit of a digital display. The instrument display shall give a linear response to electric field, symmetric with polarity and with no hysteresis. These properties shall be within 5 % of full-scale reading of the operating range. The output time constant at the display shall be less than 1 s.

C.1.3 Sample preparation

C.1.3.1 The minimum pipe size of the pipe, fitting or joint tested shall be DN 50 (2 NPS).

C.1.3.2 For pipe specimens, the minimum length of the sample should be seven times the standard pipe size.

C.1.3.3 Additional sections of conductive pipe can be added as necessary to the specimen using the manufacturer's normally recommended assembly methods for conductive joints. This may be necessary to provide space for a grounding clamp. If a joint is required then the resistance across the joint shall be determined in accordance with Clause C.2.

C.1.3.4 A minimum of five locations on the outside of the component shall be identified for positioning the field meter. The locations should generally extend around the periphery and be equally spaced over the length of the component. Additional locations may be needed to account for regions where there is a change in component geometry.

C.1.4 Conditioning

C.1.4.1 The test specimen should not be tested until the material has reached an air-dry condition. This condition is defined as 16 to 24 h at an ambient temperature of 23 ± 2 °C (73,4 ± 3,6 °F) and 50 ± 5 % relative humidity.

C.1.4.2 If the effect of the environment on the electrical properties is required, place the specimens in a test tank so that they are completely immersed in the test fluid. The temperature of the bath shall be maintained at 15 to 27 °C (60 to 80 °F) throughout the test.

C.1.4.2.1 At the end of three months, remove the test specimen from the tank and rinse thoroughly with tap water if the specimen has been exposed to a water-soluble product, or a hydrocarbon solvent if the specimen has been exposed to a petroleum product.

C.1.4.2.2 Wipe dry and place the test specimen in an oven at 65 ± 5 °C (149 ± 10 °F) for a period of 2 h.

C.1.4.2.3 Remove the specimen from the oven and allow it to cool to 21 to 27 °C (70 to 80 °F) in a 50 ± 5 % relative humidity environment for 16 to 24 h.

C.1.5 Test procedure

The following procedure shall be followed when conducting the test for determining the charge shielding properties.

a) Install a grounding clamp of the earthing system on the exterior of the specimen at each end of the component in accordance with the manufacturer's instructions. Any surface preparation shall not exceed that normally required when installing a piping system.

b) Blank off each termination of the specimen assembly with a suitable removable plug made from an insulating material that is in contact with just the inside surface of the component. One of the plugs shall be provided with an electrode that passes through the thickness of the material. For fittings, this electrode shall be a minimum distance of 305 mm (12 in) away from the main body of the fitting. An additional section of conductive pipe shall be added as necessary to the component in accordance with C.1.3.3.

c) Completely fill the inside of the specimen with a suitable conducting fluid. One or more of the plugs may have to be fitted with a vent fitting to enable air to be expelled. Ensure that the outside of the specimen is dry.

d) Position the specimen vertically on a nonconducting surface or suspend it with nonelectrically conducting materials in a manner to insure that the outside of the component under test is accessible on all sides. The plug with the electrode shall be positioned such that the inside is in contact with the conducting fluid.

e) Connect the electrode in the plug to the DC supply.

f) Position the field meter 25 mm (1 in) from the exterior surface of the component under test. The field meter shall be a minimum distance of 305 mm (12 in) away from the wire connecting the DC supply to the electrode in the plug.

g) With the specimen connected to earth using the grounding clamp, turn the DC supply on and monitor the output of the field meter for 1 min. Turn off the DC supply.

h) Repeat steps f) and g) for the remaining test positions.

C.1.6 Test report

The report shall include the following:

a) manufacturer of pipe, fitting or joint;

b) designation of the product being tested;

c) description of the test sample, including diameter of pipe, fitting or joint and lengths of pipe extenders, if used;

d) description of grounding details;

e) test media if exposure is carried out;

f) conducting fluid utilised;

g) DC supply voltage;

h) record of voltage output from field meter for 1 min for each test position and after exposure for 1, 3, 6 and 12 months when exposure testing is done;

i) appearance of test specimen;

j) date of the test.

C.2 Test method for determining the electrical resistance per unit length of fibreglass pipe, fittings, joints and representative piping systems

C.2.1 Summary of test procedure

In this test, the length of the potential current path is measured and then the resistance is determined using a suitable megohmmeter capable of measuring resistance between 2 000 and 1×10^{10} ohms. The test method may also be used to determine the effect of typical chemical exposures on the conductive properties of the pipe. The results are expressed in terms of resistance per unit length.

C.2.2 Test equipment

The following test equipment shall be provided.

a) **DC supply**, capable of producing a minimum voltage of 1 000 V.

b) **Field meter**, capable of measuring and displaying electric fields values of 100 $V \cdot m^{-1}$ with zero stable within 50 $V \cdot m^{-1}$ over at least 1 000 s. A reading of 100 $V \cdot m^{-1}$ shall be at least 10 % of an analogue scale reading or at least the second digit of a digital display. The instrument display shall give a linear response to electric field, symmetric with polarity and with no hysteresis. These properties shall be within 5 % of the full-scale reading of the operating range. The output time constant at the display shall be less than 1 s.

C.2.3 Test specimen

C.2.3.1 Pipe

The pipe length shall be 1 m (3,28 ft) or six times the nominal diameter of the product plus two times the width of the grounding clamps, if applicable, whichever is greatest.

C.2.3.2 Pipe with fitting and/or joint

C.2.3.2.1 DN 50 (NPS 2) size piping shall be used unless otherwise specified.

C.2.3.2.2 The electrical construction of the pipe shall be consistent with that of the fitting and joint.

C.2.3.2.3 The joint of the fitting shall be attached to two lengths of pipe. This may require some fittings to be assembled in pairs. The length of each pipe shall be six times the nominal diameter of the product, plus the width of the grounding clamps, if applicable. Additional sections of conductive pipe may be added using the manufacturer's recommended assembly methods to achieve this length.

C.2.4 Conditioning

C.2.4.1 The test specimen should not be tested until the material has reached an air-dry condition. This condition is defined as 16 to 24 h at an ambient temperature of 23 ± 2 °C (73,4 ± 3,6 °F) and 50 ± 5 % relative humidity.

C.2.4.2 If the effect of the environment on the electrical properties is required, place the specimens in a test tank so that they are completely immersed in the test fluid. Maintain the temperature of the bath at 15 to 27 °C (60 to 80 °F) throughout the test.

C.2.4.3 At the end of three months, the test specimen shall be removed from the tank and rinsed thoroughly with tap water if the specimen has been exposed to a water-soluble product, or a hydrocarbon solvent if the specimen has been exposed to a petroleum product.

C.2.4.4 Wipe dry and place the test specimen in an oven at 65 ± 5 °C (149 ± 10 °F) for a period of 2 h.

C.2.4.5 Remove the specimen from the oven and allow it to cool to 21 to 27 °C (70 to 80 °F) in a 50 ± 5 % relative humidity environment for 16 to 24 h.

C.2.5 Test procedure

C.2.5.1 Evaluating electrical conductivity

Where the electrical conductivity properties of the pipe and joint/fitting combination are to be evaluated, the electrical properties of the pipe on its own shall be determined first.

C.2.5.2 Current path selection

The current paths of interest are as follows.

a) Inside surface of the pipe at one end of the test assembly to the outside surface of the pipe at the other end of the test assembly.

b) Outside surface of the pipe at one end of the test assembly to the outside surface of the pipe at the other end of the test assembly.

C.2.5.3 Sample preparation

C.2.5.3.1 Attach a suitable electrode (see second paragraph of C.2.5.3.4) or grounding clamp to the OD of a pipe on one end of the pipe or assembly.

C.2.5.3.2 Where a grounding clamp is applied, the surface preparation shall not exceed that used when piping systems are installed according to the manufacturer's recommendations.

C.2.5.3.3 Apply two suitable electrodes, one around the interior circumference of the specimen and one around the exterior circumference, on the other end of the pipe or assembly. Where the test is being carried out to confirm continuity of the embedded conducting elements within the component body, the exterior electrode may be a grounding clamp that is applied in a similar manner to the first.

C.2.5.3.4 The distance of the electrodes from the end of the specimen shall be greater than or equal to twice the specimen thickness. The width of the electrodes shall be between four and six times the specimen wall thickness.

A suitable electrode shall provide the necessary conductivity to the surface of the pipe without causing damage to the surface. Examples include conductive paints, conductive adhesive tape and brine-soaked sponges held in place with clamps.

C.2.5.4 Outside to outside surface electrical measurement

C.2.5.4.1 Isolate the test specimen from ground.

C.2.5.4.2 Attach suitable wires to the two external electrodes.

C.2.5.4.3 Determine the resistance using the megohmmeter.

C.2.5.4.4 The power applied should neither exceed 1 W (3,41 Btu/hr) nor should the electrification time exceed 1 min unless otherwise specified. Record the readings from the megohmmeter and its accuracy at that range.

C.2.5.4.5 If the effect of the environment on the electrical properties is required, place the specimens in the test tank so that they are completely immersed in the test fluid. Maintain the temperature of the bath at 15 to 27 °C (59 to 80 °F) throughout the test. At the end of 3 months, remove the test specimen from the bath and rinse thoroughly with tap water if the specimen has been exposed to a water soluble product, or a hydrocarbon solvent if the specimen has been exposed to a petroleum product. Wipe dry and place the test specimen in an oven at 65 °C ± 5 °C (149 °F ± 9 °F) for a period of 2 h. Remove the specimen from the oven and allow it to cool to 21 to 27 °C (70 to 80 °F) in a 50 ± 5 % relative humidity environment for 16 h to 24 h. Determine the resistance using the megohmmeter. Note the appearance of the test specimen and the condition of the clamps.

C.2.5.5 Inside to outside surface electrical measurement

C.2.5.5.1 Isolate the test specimen from ground.

C.2.5.5.2 Attach suitable wires to the internal and external electrode.

C.2.5.5.3 Carry out the procedure given in C.2.5.4.

C.2.6 Calculation of pipe and joint/fitting electrical resistance

C.2.6.1 The electrical resistance shall be calculated for the two cases:

a) external to external surface of component;

b) external to internal surface of component.

C.2.6.2 Care shall be taken to ensure that these two situations are treated separately.

C.2.6.3 For the pipe tested on its own, the resistance per unit length of pipe shall be calculated by dividing the resistance of the pipe by the length between electrodes.

C.2.6.4 The resistance of the fitting or joint shall be calculated as follows.

a) Calculate the resistance of each length of pipe attached to the joint or fitting by multiplying the resistance per unit length by the distance from the electrode to the fitting/joint. This should be the same for both lengths of pipe.

b) Subtract two times the pipe resistance from the overall resistance measured across the assembly to give the resistance across the coupling.

C.2.6.5 The resistance per unit length shall be determined by dividing the resistance by the effective path length. The effective path length depends on the type of fitting and mode tested.

C.2.6.6 For pipes, straight joints, adapters, couplings, plugs, caps and bushings, the path length shall be parallel to the centreline axis of the component and shall encompass the length of the component.

C.2.6.7 For elbows, the path length shall be the length of the component at the mid-bend radius.

C.2.6.8 For crosses and tees, one path length shall be parallel to the centreline axis of the component and shall encompass the length of the component. The other path length shall be along the shortest path from adjacent openings through each 90° bend.

C.2.6.9 For laterals, one path length shall be parallel to the centreline axis of the component and shall encompass the length of the component. The second path length shall be along the shortest distance

between adjacent openings through the oblique angle. The third path length shall be along the shortest distance between adjacent openings through the obtuse angle.

C.2.7 Test report

The test report shall include the following:

a) complete identification of the pipe and fitting/joint/fire-protection coating tested including the manufacturer's name and code;

b) diameter of pipe, fitting or joint;

c) details of megohmmeter, including name and model number, resolution capability, and voltage applied;

d) mode of testing, i.e. external surface to external surface or external surface to internal surface and whether grounding clamps were used;

e) results of testing;

f) resistance per unit length of pipe;

g) resistance of fitting/joint;

h) environmental exposure time and media where applicable;

i) appearance of specimen;

j) date of test.

Annex D
(informative)

Fire endurance requirements matrix [excerpt from IMO Res. A.753(18)]

	A	B	C	D	E	F	G	H	I	J	K
Piping System	Machinery spaces of category A	Other machinery spaces and pump rooms	Cargo pump rooms	Ro-ro cargo holds	Other dry cargo holds	Cargo tanks	Fuel oil tanks	Ballast water tanks	Cofferdams, void spaces, pipe tunnels and ducts	Accommodation, service and control spaces	Open decks
CARGO (FLAMMABLE CARGO f.p. $\leqslant$ 60 °C) Cargo lines	NA	NA	L1	NA	NA	0	NA	0[10]	0	NA	L1[2]
Crude oil washing lines	NA	NA	L1	NA	NA	0	NA	0[10]	0	NA	L1[2]
Vent lines	NA	NA	NA	NA	NA	0	NA	0[10]	0	NA	X
INERT GAS Water seal effluent line	NA	NA	0[1]	NA	NA	0[1]	0[1]	0[1]	0[1]	NA	0
Scrubber effluent line	0[1]	0[1]	NA	NA	NA	NA	NA	0[1]	0[1]	NA	0
Main line	0	0	L1	NA	NA	NA	NA	NA	0	NA	L1[6]
Distribution lines	NA	NA	L1	NA	NA	0	NA	NA	0	NA	L1[2]
FLAMMABLE LIQUIDS (f.p. $>$ 60 °C) Cargo lines	X	X	L1	X	X	NA[3]	0	0[10]	0	NA	L1
Fuel oil	X	X	L1	X	X	NA[3]	0	0	0	L1	L1
Lubricating oil	X	X	L1	X	X	NA	NA	NA	0	L1	L1
Hydraulic oil	X	X	L1	X	X	0	0	0	0	L1	L1
SEAWATER Bilge main and branches	L1[7]	L1[7]	L1	X	X	NA	0	0	0	NA	L1
Fire main and water spray	L1	L1	L1	X	NA	NA	NA	0	0	X	L1
Foam system	L1	L1	L1	X	NA	NA	NA	NA	0	L1	L1
Sprinkler system	L1	L1	L3	X	NA	NA	NA	0	0	L3	L3
Ballast	L3	L3	L3	L3	X	0[10]	0	0	0	L2	L2
Cooling water, essential services	L3	L3	NA	NA	NA	NA	NA	0	0	NA	L2

	A	B	C	D	E	F	G	H	I	J	K
Piping System	Machinery spaces of category A	Other machinery spaces and pump rooms	Cargo pump rooms	Ro-ro cargo holds	Other dry cargo holds	Cargo tanks	Fuel oil tanks	Ballast water tanks	Cofferdams, void spaces, pipe tunnels and ducts	Accommodation, service and control spaces	Open decks
Tank cleaning services fixed machines	NA	NA	L3	NA	NA	0	NA	0	0	NA	L3[2]
Non-essential systems	0	0	0	0	0	NA	0	0	0	0	0
FRESH WATER Cooling water essential services	L3	L3	NA	NA	NA	NA	0	0	0	L3	L3
Condensate return	L3	L3	L3	0	0	NA	NA	NA	0	0	0
Non-essential systems	0	0	0	0	0	NA	0	0	0	0	0
SANITARY/DRAINS/SCUPPERS Deck drains (internal)	L1[4]	L1[4]	NA	L1[4]	0	NA	0	0	0	0	0
Sanitary drains (internal)	0	0	NA	0	0	NA	0	0	0	0	0
Scuppers and discharges (overboard)	0[1,8]	0[1,8]	0[1,8]	0[1,8]	0[1,8]	0	0	0	0	0[1,8]	0
SOUNDING /AIR Water tanks/dry spaces	0	0	0	0	0	0[10]	0	0	0	0	0
Oil tanks (f.p. $>$ 60 °C)	X	X	X	X	X	X[3]	0	0[10]	0	X	X
MISCELLANEOUS Control air	L1[5]	L1[5]	L1[5]	L1[5]	L1[5]	NA	0	0	0	L1[5]	L1[5]
Service air (non-essential)	0	0	0	0	0	NA	0	0	0	0	0
Brine	0	0	NA	0	0	NA	NA	NA	0	0	0
Auxiliary low-pressure steam ($\leqslant$ 7 bar)	L2	L2	0[9]	0[9]	0[9]	0	0	0	0	0[9]	0[9]

ABBREVIATIONS FOR FIRE ENDURANCE MATRIX:

L1 Fire endurance test in dry conditions, 60 min

L2 Fire endurance test in dry conditions, 30 min

L3 Fire endurance test in wet conditions, 30 min

0 No fire endurance test required

NA Not applicable

X Metallic materials having a melting point greater than 925 °C

NOTES IN FIRE ENDURANCE MATRIX:

1 Where non-metallic piping is used, remotely controlled valves to be provided at ship's side (valve is to be controlled from outside space).

2 Remote closing valves to be provided at the cargo tanks.

3 When cargo tanks contain flammable liquids with f.p. $>$ 60 °C, "0" may replace "NA" or "X".

4 For drains serving only the space concerned, "0" may replace "L1".

5 When controlling functions are not required by statutory requirements or guidelines, "0" may replace "L1".

6 For pipe between machinery space and deck water seal, "0" may replace "L1".

7 For passenger vessels, "X" is to replace "L1".

8 Scuppers serving open decks in positions 1 and 2, as defined in regulation 13 of the International Convention on Load Lines, 1966, should be "X" throughout unless fitted at the upper end with the means of closing capable of being operated from a position above the freeboard deck in order to prevent down flooding.

9 For essential services, such as fuel oil tank heating and ship's whistle, "X" is to replace "0".

10 For tankers where compliance with paragraph 3 (f) of regulation 13F of Annex 1 of MARPOL 73/78 is required, "NA" is to replace "0".

Table D.1 — Location definitions for fire endurance matrix

Location	Definition
A — Machinery spaces of category A	As defined in SOLAS regulation II-2/3.19
B — Other machinery spaces and pump rooms	Spaces, other than category A machinery spaces and cargo pump rooms, containing propulsion machinery, boilers, steam and internal combustion engines, generators and major electrical machinery, pumps, oil filling stations, refrigerating, stabilizing, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces.
C — Cargo pump rooms	Spaces containing cargo pumps and entrances and trunks to such spaces.
D — Ro-ro cargo holds	Ro-ro cargo spaces and special category spaces as defined in SOLAS regulation II-2/3.14 and 3.18.
E — Other dry cargo holds	All spaces other than ro-ro cargo holds used for non-liquid cargo and trunks to such spaces.
F — Cargo tanks	All spaces used for liquid cargo and trunks to such spaces.
G — Fuel oil tanks	All spaces used for fuel oil (excluding cargo tanks) and trunks to such spaces.
H — Ballast water tanks	All spaces used for ballast water and trunks to such spaces.
I — Cofferdams, void spaces, pipe tunnels, and ducts	Empty spaces between two bulkheads separating adjacent compartments.
J — Accommodation, service and control spaces	As defined in SOLAS regulation II-2/3.10, 3.12, 3.22
K — Open decks	As defined in SOLAS regulation II-2/26.2.2(5)

Bibliography

[1] ASTM D618, *Standard Practice for Conditioning Plastics for Testing*

[2] ASTM D1141, *Standard Practice for the Preparation of Substitute Ocean Water*

[3] ASTM D1898, *Standard Practice for Sampling Plastics* (Withdrawn 1998)

[4] ASTM D2105, *Standard Test Method for Longitudinal Tensile Properties of Fibreglass (Glass-Fibre-Reinforced Thermosetting-Resin) Pipe and Tube*

[5] ASTM D2925, *Standard Test Method for Beam Deflection of Fibreglass (Glass-Fibre-Reinforced Thermosetting-Resin) Pipe Under Full Bore Flow*

[6] ASTM D4496, *Standard Test Method for D-C Resistance or Conductance of Moderately Conductive Materials*

[7] ASTM D5028, *Standard Test Method for Curing Properties of Pultrusion Resins by Thermal Analysis*

[8] ASTM E162, *Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source*

[9] ASTM E662, *Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials*

[10] ASTM E800, *Standard Guide for Measurement of Gases Present or Generated During Fires*

[11] ASTM E1317, *Standard Test Method for Flammability of Marine Surface Finishes*

[12] IMO Resolution A.653 (16), *Recommendation on Improved Fire Test Procedures for Surface Flammability of Bulkhead, Ceiling, and Deck Finish Materials*

[13] American Society for Testing and Materials (ASTM) D257:1999, *Standard Test Methods for D-C Resistance or Conductance of Insulating Materials*

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