U.S. Department of Transportation
United States Coast Guard

Lifesaving and Fire Safety Stds Division
U.S. Coast Guard (CG-5214)
2100 Second St., S.W.
Washington, DC 20593

Phone: (202) 372-1385
FAX: (202) 372-1924
E-mail: george.g.grills@.uscg.mil

**Fire Retardant Resin**

Guideline for the Approval of Laminating Resin for Fiber-Reinforced Composites Used in Life-saving Equipment and Small Passenger Vessels

1. SCOPE. This guideline prescribes material requirements, performance standards, tests, and procedures for approval of laminating resin for fiber-reinforced composites used in: (a) the construction of lifeboats, rescue boats, and other life-saving appliances approved under 46 CFR Subchapter Q; and (b) the construction of small passenger vessels regulated by Subchapter T.

2. REQUIREMENTS.

2.1 Approval Procedure. Laminating resin is approved by the Coast Guard under the procedures in 46 CFR 159.005

2.1.1 Pre-approval review.

.1 Pre-approval review is not required for fire-retardant, polyester, low-pressure laminating resin.

.2 An application for pre-approval review shall be submitted for all other resins as per 159.005-5 of 46 CFR, and shall include at least a general description of the proposed resin.

2.1.2 Approval tests. The approval inspection and tests under 201-7 are the responsibility of the manufacturer.

2.1.3 Application for approval. The manufacturer shall submit the test report, material data sheet including instructions for use, and quality control procedures in accordance with 46 CFR 159.005-9.

2.2 Performance. The laminating resin must pass the inspections and tests specified in one of the following options.

2.2.1 Option 1; for polyester resins only. Fire-retardant polyester resins may be tested and accepted via the procedure specified in 46 CFR 160.035-8(b).

2.2.2 Option 2; for all resins.

.1 Laminate samples. The laminate sample for physical and mechanical tests shall be fabricated in the form of sheets of 3.2 mm $\pm$ 0.25 mm (0.125 $\pm$ 0.010 in) in thickness, using the resin which is under test and 12 plies good quality E-glass laid up in parallel. The sample shall be laminated at a pressure not exceeding 207 kPa (30 lb/in$^2$) and shall be fully cured in accordance with the resin supplier's instruction

sheet. The sample shall be essentially void-free and shall have a resin content by weight that will produce a laminate with optimum properties.

.2 Each resin formulation submitted for Coast Guard approval must be tested and meet the requirements of Table 2.2.2. NOTE: Alternative procedures for flame resistance and flame spread testing are further described in section 4 of this guideline and in 46 CFR 177.410(b).

2.2.3 Option 3; for vinyl ester resins.

.1 Complete all test requirements specified in military specification MIL-R-24719(SH); and

.2 Complete the flexural properties tests on weathered specimens. Tests shall be as specified in either ISO 178 or ASTM D 790 to determine ultimate strength and initial modulus of elasticity. Specimens shall be fabricated in accordance with paragraph 2.2.2.1 of this guideline and exposed to outdoor weathering for one year on a land rack inclined 45 degrees to the horizontal, facing south. The laminate shall be turned over every 15 days. At the end of the weathering period, specimens shall be cut from the laminate, subjected to standard conditions for 96 hours, and tested at standard conditions. (ref: MIL-R-7575). In lieu of the tests on 1-year outdoor weathered specimens, it is acceptable to run a 500 hour accelerated weathering using a UVB-313 lamp in accordance with ASTM G 53. This accelerated weathering test shall be conducted with alternating cycles of 8 hours UV exposure at 70 degrees C and 4 hours condensation exposure at 50 degrees C. A second alternative to the weathering is for the manufacturer to provide justification as to why the one-year weathering tests should not be required or do not apply to their particular brand of vinyl ester resin used in boat hulls.

2.3 Quality control and conformance on production units.

2.3.1 Quality control procedure. The manufacturer shall institute a quality control procedure to ensure that all Coast Guard approved resin is produced to the same standard, and in the same manner as the tested resin approved by the Commandant (CG-5214). The manufacturer's quality control personnel shall not work directly under the department or person responsible for either production or sales.

2.4 Marking and labeling. Each container for the resin must be permanently marked with at least the following information:

(a) Manufacturer's name or trademark, batch number, date of manufacture, and date of expiration;

(b) Chemical type of the resin;

(c) Maximum usable storage life of the resin (uncatalyzed and catalyzed) and recommended storage conditions;

(d) Maximum allowable shelf life at various temperatures of impregnated fabric before curing; and

(e) Precautionary markings.

2.5 Instructions for use. Instructions for use shall be included with each shipment of approved material and must include as a minimum:

(a) Recommended mixing and impregnating procedures, including recommended types, percentages and manner of utilization of catalysts, retardants, and fillers, as applicable;
(b) Range of time, temperature, and pressure cycles recommended to effect the cure for laminates; and
(c) Precautionary information on usage, storage, and handling.

3. APPLICABLE REFERENCES.

a) ASTM G 53 ("Standard Practice for Operating Light- and Water-Exposure Apparatus for Exposure of Nonmetallic Materials", 1996
b) ASTM D 543-84, Standard Test Method for Resistance of Plastics to Chemical Reagents.
c) ASTM D 570-81, Standard Test Method for Water Absorption of Plastics
d) ASTM D 635-81, Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position
e) ASTM D 638-84, Standard Test Method for Tensile Properties of Plastics
f) ASTM D 695-84, Standard Test Method for Compressive Properties of Rigid Plastics
g) ASTM D 790-84a, Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
h) ASTM D 792-66(1979), Standard Test Methods for Specific Gravity and Density of Plastics by Displacement
i) ASTM D 1045-80, Standard Methods of Sampling and Testing Plasticizers used in Plastics
j) ASTM D 1824-83, Standard Test Method for Apparent Viscosity of Plastisols and Organosols at Low Shear Rates by Brookfield Viscometer
k) ASTM D 2471-71(1979), Standard Test Method for Gel Time and Peak Exothermic Temperature of Reacting Thermosetting Resins
l) ASTM D 2583-81, Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor
m) ASTM D 2584-68(1979), Standard Test Method of Ignition Loss for Cured Reinforced Resins
n) IMO Resolution A.689(17), "Recommendation on Testing of Life-saving Appliances", International Maritime Organization, 6 November 1991
o) ISO 62 : 1977 Plastics - Determination of water absorption
p) ISO 178 : 1975 Plastics - Determination of flexural properties of rigid plastics
q) ISO/R 527 : 1966 Plastics - Determination of tensile properties
r) ISO/604 : 1973 Plastics - Determination of compressive properties
s) ISO 1172 : 1975 Textile glass reinforce plastic- Determination of loss on ignition
t) ISO 1183 : 1987 Plastics - Methods for determining the density and relative density of non-cellular plastics
u) ISO 1210 : 1982 Plastics - Determination of flammability characteristics of plastics in the form of small specimens in contact with a small flame
v) ISO 1675 : 1985 Plastics - Liquid resins - Determination of density by the pyknometer method

w) ISO 2039-1 : 1987 Determination of hardness - Part 1: Ball indentation method
x) ISO 2039-2 : 1987 Determination of hardness - Part 2: Rockwell hardness
y) ISO 2114 : 1974 Unsaturated polyester resins - Determination of acid value
z) ISO 2535 : 1974 Plastics – Unsaturated polyester resins - Measurement of gel time at 25 degrees C
aa) ISO 2555 : 1989 Plastics - Resins in the liquid state or as emulsions or dispersions - Determination of apparent viscosity by the Brookfield test method
bb) MIL-R-21607E; Resins, Polyester, Low Pressure Laminating, Fire-Retardant, 25 May 1990.
cc) MIL-R-7575C, Resin, Polyester, Low-Pressure Laminating, 29 June 1966.
dd) MIL-R-24719(SH), Resins, Vinyl Ester, Low Pressure Laminating, 4 May 1989.

4. EXPLANATORY MATERIAL.

4.1 MIL-R-21607 Flame resistance test procedure.

4.1.1 Fabrication of laminates for tests. Glass reinforced plastic panels shall be fabricated in the form of sheets, nominally 12.7 mm thick and 30.5 by 30.5 cm in size. The cloth shall conform to type XII or XIIA, class 1 of MIL-C-9084. Forty plies of cloth shall be impregnated with catalyzed resin at a press cured to 12.7 mm stops at such temperature and pressure as will provide a fully cured laminate with a resin content of 38 to 44 percent and a Barcol hardness of 45 minimum.

4.1.2 Test for resin content.

4.1.2.1 Test specimen. The test specimens shall have a minimum weight of 3 g and a maximum size of 2.54 by 2.54 cm by the thickness as supplied. The sides shall be square to the faces and the edges shall not be frayed.

4.1.2.2 Test apparatus. Test apparatus shall consist of an analytical balance, a desiccator, heat-resistant nonreactive crucibles, and a muffle furnace equipped with temperature controls.

4.1.2.3 Test procedure.

4.1.2.3.1 Weighing of specimen. The specimen shall be weighed on an analytical balance in a previously weighed, ignited crucible.

4.1.2.3.2 Ignition. The specimen shall be placed in the furnace at a temperature not greater than 343_C. Temperature of the furnace shall be raised to 565 $\pm$ 28_C at a rate that will not cause blowing or loss of inorganic filler. The specimen and crucible shall be ignited at this maximum temperature to a constant weight (2 to 6 hours depending on the thickness), and allowed to cool in a desiccator. The loss in weight shall be determined by weighing the specimen and the crucible after cooling.

4.1.2.4 Calculation of resin content. Resin content shall be calculated as follows:

$$\text{Resin content, percent by weight} = \frac{\text{Loss in weight}}{\text{Original weight}} \text{ X } 100$$

4.1.3 One-year outdoor weathering. Panels of laminate shall be exposed to an outdoor environment for 1 year on a land rack inclined 45 degrees to the horizontal, facing south. The laminate shall be turned over every 15 days. At the end of the weathering period, specimens shall be cut from the laminate, subjected to standard conditions (air temperature 23 ± 1_C and relative humidity 50 ± 4 percent) for at least 96 hours prior to testing. The panels shall meet the flame resistance test requirements for standard or superior flame resistance.

4.1.4 Flame resistance test.

4.1.4.1 Test specimens. Five specimens, each measuring 12.7 by 1.27 by 1.27 mm shall be tested.

4.1.4.2 Test apparatus.

4.1.4.2.1 Enclosure. An enclosure large enough to contain the specimen, supports, heater coil, spark plugs, flame travel gauge, and their associated accessories shall be arranged to eliminate air drafts and permit a clear view of the interior through shatterproof glass windows. Vent holes distributed around the sides adjacent to the base shall be provided to admit fresh air when an exhaust fan, which is connected to the top of the enclosure, is operated at a minimum suction just sufficient to carry off smoke and gases.

4.1.4.2.2 Supports. Top and bottom supports shall hold the specimen in a vertical position. The unsupported span between the supports shall be a minimum of 10 cm. The lower end of the specimen shall be wrapped in such a manner that gases released through this end are diverted toward the spark plugs.

4.1.4.2.3 Heating coils. Heating coils shall consist of seven turns of no. 10 (0.26 cm diameter) resistance wire, QQ-R-175 grade E, space wound to O.64 cm per turn. The nominal inside diameter of the coil used shall be 3.02 cm. The lower end of the heated coil shall be located 3.81 cm above the top of the lower specimen support.

4.1.4.2.4 Spark plugs. Two spark plugs with extended electrodes spaced 0.32 cm from the surface of the specimen shall be located on diametrically opposite sides of the specimen. The spark plugs shall be placed with their longitudinal center lines in a horizontal plane 1.27 cm above the top of the anheater coil to ignite the gases emitted from the heated specimen. An electric circuit shall be provided to maintain continuous sparking at the electrodes during the specified time. The spark plugs shall be mounted so they may be moved away from the specimen after ignition takes place so as not to impede the travel of the flame and to prevent their electrodes from becoming fouled by soot.

4.1.4.3 Test procedure.

4.1.4.3.1 Ignition time. With the specimen centered in the heater coil, and the spark plugs and frame gauge properly located, the enclosure shall be closed and ventilated. A stop watch shall be started simultaneously with the energizing of the heater coil and spark plugs. A constant current of 55 amperes shall be supplied from a transformer to the heater coil. Ignition shall be considered as occurring when the flame transfers from the escaping gases to the surface of the specimen and continues there, disregarding the flashes which may occur in the gassing space prior to the sustained flame.

4.1.4.3.2 Time of heating. Heating shall be discontinued 30 seconds after ignition occurs. If ignition does not occur within 600 seconds, the test will be discontinued.

4.1.4.3.3 Ignition. Immediately after ignition occurs (see 4.1.4.3.1), the electrical supply to the spark plugs shall be cut off and the spark plugs shifted away from the flame.

4.1.4.3.4 Burning time. The number of seconds that the specimen continues to burn, until the cessation of all flaming, after the current in the heater coil has been cut off shall be recorded as the time required for self-extinction.

4.1.4.4 Test results.

4.1.4.4.1 Calculation of average ignition time. The average ignition time shall be calculated as the arithmetic mean of the ignition time of the five specimens.

Minimum average ignition time: 55 s (standard flame resistance)
70 s (superior flame resistance)

4.1.4.4.2 Calculation of average burning time. Average burning time shall be calculated as follows. Arrange the five values of the time required for self-extinction in increasing order of magnitude as T1, T2, T3, T4, and T5. Compute the following ratios:

$$\frac{T2 - T1}{T5 - T1} \quad \text{and} \quad \frac{T5 - T4}{T5 - T1}$$

If either of these ratios exceeds 0.642, then T1 or T5 is judged to be abnormal and is eliminated. The average burning time reported shall be the average of the remaining four values. If neither of these ratios exceeds 0.642, the average burning time shall be the average of all five values.

Maximum average burning time: 125 s (standard flame resistance)
65 s (superior flame resistance)

**Table 2.2.2 - REQUIREMENTS FOR LAMINATING RESINS FOR USE IN LIFEBOATS, RESCUE BOATS, AND OTHER LIFESAVING EQUIPMENT, AND SMALL PASSENGER VESSELS**

**MATERIAL IDENTIFICATION TESTS [1]**

| UNCATALYZED LIQUID RESIN | TEST METHODS [2] | | |
|---|---|---|---|
| Specific gravity | ISO 1675 | Or | ASTM D 1045 |
| Viscosity | ISO 2555 | Or | ASTM D 1824 |
| Acid number | ISO 2114 | Or | ASTM D 1045 |
| CATALYZED RESIN | | | |
| Max gel time | ISO 2535 | Or | ASTM D 2471 |
| Peak exotherm | | | ASTM D 2471 |
| CURED UNFILLED RESIN | | | |
| Barcol hardness | ISO 2039 | Or | ASTM D 2583 |
| Specific gravity / density | ISO 1183 | Or | ASTM D 792 |

**LENGTHWISE MECHANICAL AND PHYSICAL PROPERTIES OF GLASS CLOTH BASE PLASTIC LAMINATE [3]**

| TESTED UNDER STANDARD CONDITIONS | TEST METHODS [2] | | | REQUIREMENTS [4] |
|---|---|---|---|---|
| Flexural properties, flatwise | ISO 178 | Or | ASTM D 790 | |
| Ultimate Strength | | | | 345 MPa (50,000 lb/in$^2$) |
| Initial modulus of elasticity | | | | 18,616 MPa (2.7 x 10E6 lb/in$^2$) |
| Ultimate tensile strength | ISO/R 527 | Or | ASTM D 638 | 278 MPa (40,000 lb/in$^2$) |
| Ult. Compressive strength, edgewise | ISO 604 | Or | ASTM D 695 | 241 Mpa (35,000 ln/in$^2$) |
| Flammability (horizontal) | ISO 1210 | Or | ASTM D 635 | 25.4 mm/min (max) (1.0 in/min) |
| Flame Resistance (alternative 1) | [5] | | | MIL-R-21607E, Grade A |
| Flame Resistance (alternative 2) | [5] | | ASTM E 84 | Flame Spread Index ≤ 100 |
| Water absorption (24 hr immersion) | ISO 62 | Or | ASTM D 570 | 0.5% max change in weight |
| Barcol hardness | ISO 2039 | Or | ASTM D 2583 | 55 |
| Specific gravity / density | ISO 1183 | Or | ASTM D 792 | [1] |
| Resin content, % | ISO 1172 | Or | ASTM D 2584 | [1] |
| TESTED UNDER WET CONDITIONS | | | | |
| (Specimens shall be immersed for 2 hrs in boiling distilled water as per ASTM D 570-81 para 6.5. The specimens shall then be cooled in water at 23 deg C and tested wet at standard conditions immediately after removal from the water) | | | | |
| Flexural properties, flatwise | ISO 178 | Or | ASTM D 790 | |
| Ultimate Strength | | | | 310 MPa (45,000 lb/in$^2$) |
| Initial modulus of elasticity | | | | 17,237 MPa (2.5 x 10E6 lb/in$^2$) |
| Ultimate tensile strength | ISO/R 527 | Or | ASTM D 638 | 278 MPa (40,000 lb/in$^2$) |
| Ult. Compressive strength, edgewise | ISO 604 | Or | ASTM D 695 | 241 MPa (35,000 ln/in$^2$) |

*(table continued next page)*

**Table 2.2.2 (cont'd) - REQUIREMENTS FOR LAMINATING RESINS FOR USE IN LIFEBOATS, RESCUE BOATS, AND OTHER LIFESAVING EQUIPMENT, AND SMALL PASSENGER VESSELS**

| TESTED UNDER ELEVATED TEMPERATURE CONDITIONS | TEST METHODS [2] | | | REQUIREMENTS [4] |
|---|---|---|---|---|
| (Specimens shall be exposed to 70 deg C for 1 hour and tested at that temperature.) | | | | |
| Flexural properties, flatwise | ISO 178 | Or | ASTM D 790 | |
| Ultimate Strength | | | | 276 MPa (40,000 lb/in$^2$) |
| Initial modulus of elasticity | | | | 15,858 MPa (2.3 x 10E6 lb/in$^2$) |
| TESTED AFTER EXPOSURE TO LIQUID CHEMICALS | | | | |
| (Standard test chemical reagents.) | | | | |
| Change in mass & dimensions | ISO 175 | Or | ASTM D 543 | 0.1% max |
| Ultimate Strength | | | ASTM D 790 | [1] |
| TESTED AFTER ONE YEAR OUTDOOR WEATHERING | | | | |
| Flexural properties, flatwise | ISO 178 | Or | ASTM D 790 | |
| Ultimate Strength | | | | 310 MPa (45,000 lb/in$^2$) |
| Initial modulus of elasticity | | | | 17,237 MPa (2.5 x 10E6 lb/in$^2$) |
| Flame Resistance (alternative 1) | [5] | | | MIL-R-21607E, Grade A |
| Flame Resistance (alternative 2) | [5] | | ASTM E 84 | Flame Spread Index ≤ 100 |

[1] There are no requirements for these properties, but the values must be determined and reported. Calculations for ultimate flexural strength after immersion in chemical fluids shall be based on the dimensions of the specimens before immersion.

[2] Either the ISO or ASTM test method is acceptable. The test methods are considered technically equivalent though not necessarily identical, and might yield slightly different numerical results.

[3] Lengthwise direction of test specimens is parallel to the warp direction of glass fabric.

[4] The specimens shal show no cracking, crazing, softening, delamination, nor any other visible deterioration after conditioning exposure or immersions.

[5] Either the flame resistance procedure specified in MIL-R-21607 or the flame spread test specified in ASTM E-84 may be completed.