

**SPECIFICATIONS FOR FABRICATION
OF FIBERGLASS-REINFORCED PLASTIC
HOODS AND GLOVEBOXES**

AGS-G011-2005

**AMERICAN GLOVEBOX SOCIETY
STANDARDS DEVELOPMENT COMMITTEE**

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- DISCLAIMER -

This American Glovebox Society (AGS) Specifications for Fabrication of Fiberglass-Reinforced Plastic Hoods and Gloveboxes, AGS-G011-2005, has been compiled from established practices, and membership and contributor experiences. Its intended use is strictly as a guide and it may be altered to suit individual applications. The AGS, its membership, and contributors assume no responsibility for any liability arising out of its use or application.

Introduction and Background for Specifications for Fabrication of Fiberglass-Reinforced Plastic Hoods and Gloveboxes

AGS-G011-2005

One of the reasons for the formation of the American Glovebox Society (AGS) was to compile and preserve technical information regarding the design, fabrication, operation, and related aspects of glovebox technology. These particular specifications have been republished by the AGS with this goal in mind. However, they have not been reviewed and updated by the AGS prior to this publishing; they are provided in their original content for historical purposes. The specifications were developed in the late 1950's timeframe at Argonne National Laboratory. The specifications were used for the shell materials for gloveboxes, vacuum-frame hoods, and related containment appurtenances that were built to support the nuclear chemistry research that was planned for newly commissioned hot cells at Argonne National Laboratory. The research involved the high-level neutron irradiation of plutonium alloys as a means of producing heavier elements and nuclides. Fiberglass was chosen because it does not degrade like metal under the conditions expected for the research projects and is considered to be reasonably easy to repair and replace. Mr. Fred A. Schmitz of Envirochem Consulting provided the specification to the AGS so that it could be made available to glovebox designers, fabricators, operators, etc. Prior to his association with Envirochem Consulting, Mr. Schmitz worked for Argonne National Laboratory. Caution must be exercised if these specifications are utilized for any new applications. Some of the information within the specifications, such as methods and references, may be out-of-date, not available, and/or no longer applicable.

Specifications for Fabrication of Fiberglass-Reinforced Plastic Hoods and Gloveboxes

14.00 Materials and Process of Fabrication - Fiberglass Reinforced Polyester Resin
The processes and the materials to be employed in the fabrication of fiberglass reinforced polyester resin (FRP) laminates for the hoods and glove boxes are defined hereinafter, as follows:

14.10 Documents

The following specifications and standards, of the issue in effect on date of invitation for bids, form a part of the specification.

14.11 Specifications:

Federal - L-P-406 -- Plastics, Organic: General Specification Test Methods

Military - MIL-R-7575 -- Resin, Low Pressure Laminating

MIL-F-9084 -- Fabrics, Woven Glass, Finished, for Plastic Laminates

MIL-F-9118 -- Finish, for Glass Fabric

MIL-P-9400 - Plastic Laminate Materials and Sandwich Construction,
Glass Fiber Base, Low Pressure Aircraft Structural Process
Specification Requirements

MIL-M-15617-- Mats, Fibrous, Glass, for Reinforcing Plastics

14.12 Standards: MIL-STD-105 --Sampling Procedures and Tables for Inspection by Attributes.

14.20 Requirements

14.21 Preproduction sample to be submitted.

14.22 Materials -- as specified herein. If materials not specifically designated are used, such materials shall be subject to approval of the Laboratory. The fiberglass and resin must be qualified by the Military Specifications in 14.11 above.

14.221 Fiberglass reinforcement finish must be of Garan, Silane or Volana A.

14.222 Fiberglass mat must be of 3/4 to 2 oz/sp. ft. per layer.

14.223 Resin - whenever this specifications refers to resin, it is understood to mean the following formulation.

14.2231 Hetron 92 or equivalent as received from Ashland Chemical or equivalent source must be compounded with 5 - 7% antimony trioxide by weight. An addition of up to 5% styrene by weight may be added.

14.224 The resin manufacturing instruction sheet shall be followed in the use of the catalyst and recommended curing cycles. Fabricators using systems not described by the manufacturer may be acceptable but must be fully described in the fabricator's process specifications approved by the Laboratory.

14.225 Antimony trioxide should be stirred in must prior to or restirred before using to avoid settling.

14.226 Resin must be brought up to room temperature before addition of catalyst before application or before container is opened.

14.227 Pigment -- The Laboratory will supply a sample for color match. No more than 0.25% to be added.

14.30 Process

14.31 A detailed description of the manufacturing and fabrication process and methods of control of manufacturing variables in the form of a titled, numbered, and dated process specification shall be submitted by the Contractor to the Laboratory for approval in conformance to Specification MIL-P-9400 and this specification. After approval, the process specification shall form a part of this specification and copies shall be made available by the Contractor for use by authorized inspectors of the Laboratory at the vendor's plant. The materials and processes in production shall conform to the requirements of the process specification, in addition to this specification, and shall not be changed in production without approval of a new superseding process specification.

14.32 Approval of the fabricator's process specification shall constitute compliance only with minimum acceptable requirements of this specification and MIL-P-9400 and does not obviate any additional requirements as may be specified in any specific procurement of laminated FRP. Additional requirements are specified in this contract drawings or detail specifications applied to the procurement.

14.33 Any fabrication problems necessitating change sin drawings or specifications shall be submitted to the Laboratory for approval. .

14.40 Foreign Materials

14.41 No staples may be used. No paper tape nor other foreign materials which produce a deleterious effect on the properties of the part shall remain in the finished laminate.

- 14.42** Outside surface contamination of parts shall be cleaned and removed of any waxes, release agents, etc., that adversely affect adhesion of a coating.
- 14.43** Silicone must not be used or incorporated in a release agent or in a wax.
- 14.44** Putties may be used for filling of voids. If the laminate is colored the putty should be of the same shade in color. Resin in putty shall comply with 14.2231.

14.50 Gaps

- 14.51** Unless otherwise approved by the procuring activity, there shall be no gaps between one piece of reinforcement and a previous piece as they are laid up.
- 14.52** Laps, where necessary, shall be laid up with a lap width of at least 1 1/2 inch. No two laps shall be superimposed upon each other unless they are crossing in direction.

14.60 Workmanship

- 14.61** Except as otherwise specifically approved by the Laboratory, the laminate shall be uniform, smooth, and free from uncurved or unbounded areas, gaps, cracks, holes, blisters, resin pockets, starved areas, tackiness, excess surface resin, laps, wrinkles, delaminations, air or gas pockets, patches, porosity, voids and other similar defects. Defects above may be reason for rejecting the laminate.
- 14.62** Defects -- Allowable defects shall be as indicated below. Any departure, or defects greater than listed and not covered by repairable defects shall be reason for rejecting the laminate.
- 14.621** Excess Resin -- On surface of the part and adjacent to sharp changes in the contour excess resin thickness up to 0.025 inches is allowed. There shall be no resin pockets which will produce unserviceability of the part.
- 14.622** Starved Areas -- There shall be no starved areas. Starved areas are considered as a area in which the reinforcement is not impregnated with resin. Crowfeet shall not be defined as a starved area.
- 14.623** Delamination - Delamination is defined as a separation of the lay-up piles and is not permitted except around drilled holes and sheared edges where only 1/32 inch delmination is permissible. These areas shall be coated an cured with a dilute solution of the parent resin prior to shipment, as defined in Paragraph 14.10.
- 14.624** Unbonded Areas -- There shall be no unbounded areas in any part of the laminate.

- 14.625 Tackiness** – The laminate surface shall be free of tackiness on both sides which when tested with a Barcol Hardness tester will render an average reading of 45 or more on the outside. Inside surface must reach a Rockwell M of 95.
- 14.626 Voids** – Internal voids shall not be larger than .03 inch in diameter and shall not materially affect the chemical or mechanical properties of the laminates. Laminate shall be essentially void free.
- 14.627 Pitted or Porous Surfaces** – Pit or pores shall not exceed .01 inch in diameter on interior surfaces or .05 inch in diameter on exterior surfaces. The maximum allowable pitted area for either surface shall be limited to .001 percent of the total area (approximately 1 hole per 10 square inches).
- 14.628 Holes** – There shall be no holes which penetrate the gel coat.
- 14.629 Blisters** – There shall be no blisters in any part of the laminate.
- 14.62(10) Cracks** – There shall be no cracks in any part of the laminate.
- 14.63 Repairable defects in the laminate shall consist of those which can be made without affecting the service-ability of the part.**
- 14.631** All repairs shall be brought to the attention of the Laboratory.
- 14.632** Methods used in repair of some defect in the laminate must be submitted for approval if the Laboratory's accepted method, "Method for the repair of Defects in Fiberglass Reinforced Plastic Laminates," is not followed.
- 14.64 Critical areas are designated in the drawings and specifications.**
- 14.641** Critical areas shall be free of all defects as listed under 14.60.
- 14.642** All flanges and/or gasket surfaces are considered as a critical surface and therefore they shall be free from nicks, scratches, burrs, cavities, pits and bubbles.
- 14.643** A semi-critical area means that the surface gel coat must not be broken and there should be no air pockets under the surface (between the gel coat and the first layer of reinforcement). Such pockets may be repaired as stated in 14.632. This semi-critical area should most certainly be followed within the intent of the topic 14.7.
- 14.644** If a split mandrel is used, the split must not be within the designated semi-critical or critical area of the duct.

14.645 Flanges -- Flanges shall be integrally attached to body of structure unless otherwise specified. All flanges shall be $\frac{3}{8}$ inch thick minimum. The length of the shear surface shall be no less than that calculated by the following formula.

$$L + \frac{TS}{1000}$$

Where L = Length of shear surface, inches

T = Wall thickness of duct, inches

S = tensile strength, psi (15,000 psi)

14.70 Construction Fabrication

14.71 Fabrication methods must be submitted to the Laboratory for approval. Methods may be hand lay-up, resin spray guns or press molding and then welding of the pieces together, etc.

14.72 Fabrication

14.721 In order to achieve a smooth interior surface of fabricated parts, the molds shall be constructed so that the outer surface of the mold will be the lay-up surface. Inside surface of laminate (gel coat) shall have at least a 35 micron finish.

14.722 Parts to be drilled or cut should be done with the use of high speed, carbide, or diamond tipped tooling.

14.723 Wherever possible, parts should be backed up to prevent delimitation and/or fraying.

14.724 Tools and procedures used shall be of the best standards to insure good workmanship.

14.725 All machined, cut, sanded, frayed edges, etc., shall be coated with a sealing coat of the resin used in the fabrication of the part. Holes and cracks that show up in the laminate from operations of cutting, etc. shall be filled in with resin, or a putty mix, to the level of the surrounding surface and the overall edge then coated with resins.

14.73 Thickness and make-up of the laminate -- Refer to Drawing No. MY-8545-A-3, "Typical Lay-up Sequence for Fiberglass Reinforced Plastic Laminates."

14.731 The thickness, Dimensions, make-up of the laminate, type of resin and other specific information for the laminated plastic materials shall be specified in drawings, specifications, or contracts for the parts. The

make-up of the laminate comprises the number of piles of the various fabrics, woven rovings, mat, their position and direction.

- 14.732 Expectations** – The laminate has been designed to meet particular needs. Thickness, dimensions, etc., are indicated in drawings and our specifications. This does not necessarily limit the fabricator technique, or where the fabricator feels additional strength is necessary. Any changes that may be necessary must be submitted to the Laboratory for approval.
- 14.733** The thickness of corners and edges where two or more sides come together must be, after cure, equal to or greater than the wall thickness of the adjacent part of the laminate. Additional plies of reinforcement as described in Drawing No. My-8545-A-3 must be added to overcome the shrinkage of the wall thickness due to the high stress applied during the cure in such areas.
- 14.74 Properties of FRP Laminates** – Physical, Mechanical, Flame Retardant. See Drawing No. MY-8545-A-4 for values.
- 14.75 Welds and Butt Joints** – See Drawing No. MY-85845-A-2. Space between joints to be filled and or covered over on inside with glass reinforcement impregnated. Enclosures fabricated by welding flat laminated together must be submitted to the Laboratory for prior approval; radii at corners must be maintained as required by drawing.
- 14.76 Warpage** -- The curing cycles and proper missing of the resin catalyst system should be such that no hot spots will develop or warpage caused by improper cures, etc., that are detrimental to use of the laminate.
- 14.77 Flatness** – The out of flatness of gasket grooves or gasket surface must not exceed:
- .02 inch in any 3 inches of length
 - .030 inch in any 13 inches of length
 - .050 inch in any 24 inches or greater length
- 14.78** If the fabricator feels that there is a need for greater strength in the laminate than that which the Laboratory has indicated on the drawings or in specifications, such information shall be immediately forwarded to the Laboratory for approval.
- 14.80 Inspection and Quality Control Provisions**
- 14.81 General** – The Vendor shall provide all reasonable facilities for testing of samples prepared for test by the vendor as requested by the Laboratory. All test data accumulated from quality control, inspection control, preproduction and production testing will be made available to the Laboratory upon request, and at the completion of the fabrication before final acceptance.

14.82 Inspection Control -- The Vendor shall provide certifications that all materials meet manufacturer's specification, and the glass reinforcement and resin materials meet the MIL-F-9084, MIL-F-9118, MIL-M-15617 and MIL-R-7575.

14.821 At the option of the Laboratory, all supplies shall be subject to inspection and test by the Laboratory at all times and places, including the period and place of manufacture and prior to final acceptance.

14.822 In case any supplies or lots of supplies are defective in material or workmanship or otherwise not in conformity with the requirements of specifications, the Laboratory shall have the right to reject them (with or without instructions as to their disposition) or to require their correction. Supplies or lots of supplies which have been rejected, or required to be corrected, shall be removed or corrected in place, by and at the sole expense of Vendor.

14.823 Immediately prior to impregnation, the glass material shall be visually checked to insure that the material is free of permanent wrinkles, creases and other distortions shall be free of tears, greases, oils and shall be uniform in color.

14.83 Quality Control -- The Vendor shall provide certification test data that all the laminated material will meet the physical property requirements of 14.74.

14.831 At the option of the Laboratory, all laminated parts shall be subject to inspection and testing by the Laboratory at all times and places, including the period and place of manufacture and prior to final acceptance.

14.832 In case any laminate parts are defective or otherwise not in conformity with the requirements of specifications, the Laboratory shall have the right to reject them (with or without instructions as to their disposition) or to require their correction. Laminated parts, which have been rejected, or required to be corrected, shall be removed or corrected in place, by and at the sole expense of the Vendor.

14.90 Test Methods

14.91 Physical Properties -- The physical property may be determined by either the ASTM method or the Federal Specification MY-8545-A-4.

14.911 Specific gravity will be determined in accordance with method 5011 or 5012, of Specification L-P-406. Purpose -- to determine the quantity of air pocketing in the laminate and inspection control of the resin.

14.912 Glass Content – The glass content shall be determined by the following procedure:

1. At least three specimens, 1 inch by 1 inch by the thickness of the sample shall cut from the laminate.
2. All loose particles and projecting fibers shall be cleaned off the specimens.
3. Each specimen shall be weighed on an analytical balance in a previously weighed crucible.
4. Crucible and specimen shall then be placed in a cold muffle furnace and ignited to a constant weight at 1000 to 1100°F. Higher temperatures shall be avoided to prevent fusion of the glass and the entrapment of unburned carbon particles. The ignition at 1000°F. required from 2 to 6 hours.

At the conclusion of the ignition, the glass fabric residue shall be entirely white as contrasted to various degrees of gray when all the carbon is not removed. The glass residue shall show no sign of fusion. The residue and crucible shall be allowed to cool to room temperature in a desiccator and reweighed on an analytical balance.

Glass content, by weight, percent

$$= \frac{\text{Residue weight} \times 100}{\text{Original weight of specimen}}$$

14.913 Barcol Hardness – The hardness shall be obtained by direct reading on the Barcol impresser. Tests should be made after the area has been lightly sanded with steel wool or fine sand paper to remove any surface film. A test of the laminate must not be made when the point of the needle may penetrate the laminate to a depth that may be detrimental to the laminate for the purpose it was intended. Barcol test shall be taken on gel coat surfaces of laminate pieces making up parts, or components, of the enclosure.

14.92 Mechanical Properties – The mechanical properties may be determined by either the ASTM or the Federal Specification method number (see L-P-406) as given in the table of 14.74. Values will be obtained for the ultimate tensile strength, ultimate flexural strength and ultimate flexural modules of elasticity. The flexural properties will be determined from the piece in the flatwise direction with the resin rich (gel coat) surface in tension.

14.93 Test Facilities and Conditions -- Test facilities will be available for the use of the Laboratory upon request to perform the testing of the supplies or the laminated material by any one of the test methods called for to obtain the results necessary to determine and control inspection, quality and acceptance.

14.931 Test conditions – Standard conditions shall be 23°C plus or minus 1°C (73.4°F plus or minus 2°F) and 50 plus or minus 4 percent relative humidity. Specimens shall be tested after being exposed for 4 days to this temperature and humidity. Specimens may be tested without the 4 day exposure of standard conditions except where there is a doubt that the materials will meet the requirements when the standard condition as specified is followed.

14.100 Sampling

14.101 The materials used will be sampled by the procedure used in 4.22 of MIL-P-8013-C upon request by the Laboratory.

14.102 Laminated Parts – For quality control of the lamination, samples may be prepared by making up of flat sheets following the lay-up sequence of materials used in the production items and procedures for the impregnation of the production item.

14.1021 Preproduction and production items will be sampled by taking the sample directly from the part fabricated and performing tests to determine if the properties of the laminate will meet the values in the property chart of 14.74.

14.1022 Prior to production of parts a preproduction sample of flat sheet to correspond with rectangular FRP laminates and a sample of round to correspond to round FRP laminates must be submitted to tests. The fabrication of the preproduction laminate must follow the typical lay-up sequence and the procedures to be used for the type part corresponding to production. Tests of preproduction samples shall consist of all tests described under 14.90.

14.1023 A sample flat sheet must be made of each new lot of resin and an intermittent flame test must be performed to determine the rating, and therefore acceptance of subsequent parts made from this resin lot. The sample of resin taken from the lot must be formulated in the same manner as the resin used in production. A part of this sample flat sheet must be sent to the Laboratory for testing. Certification by the supplier of each resin lot, that the resin meets the Flame Retardance ASTM D635-44 rating of self-extinguishing, must be provided.

14.103 The size of the sample will be governed by the type tests and the number of tests to made of the part in question.

14.104 Rejection and Retest - In case of failure of the sample to meet the specific tests, an additional sample representative of the same lot shall be tested. If this sample fails the specified tests, the material shall not be used in the part or if a part of the laminate than that part may not be accepted.

Corrosive Exhaust Ductwork

15.0 Scope of Work

The work covered by this division of the specifications defines the processes and materials to be employed in the fabrication of fiberglass reinforced polyester resin (FPR) laminates for a corrosive fume system.

15.1 Materials

15.1.1 Resins – Resins approved under Military Specification MIL-R-7575, resins, low pressure laminating, for Type I, shall be used unless otherwise approved by the Commission. Whenever the specification refers to resin, it shall be understood to mean Hetron 92, Hetron 92TG (Ashland Chemical Company) or an approved equal in self-extinguishing and fire resisting properties. The polyester resin must contain 5 to 7% antimony trioxide (Harshaw's KR Grade or Metal and Thermit Thermoguard L Grade) any may be diluted with up to 5% styrene by weight. Only pigment may be used and it shall be limited to 0.25% of resin by weight. Ten per cent by weight of graphite shall be added to the resin used for the gel coat. Samples of the graphite to be used must be submitted to the Commission for approval. No other additives shall be added to the resin other than those indicated above. Putty mixes for filling of voids may be used only upon approval of the Commission.

15.1.2 Glass Material – Glass fabric base material shall conform to Military Specification MIL-F-9084, "Fabric, Woven Glass, Finished for Plastic Laminates." Glass mat shall have a special binder or size and shall have a high wet strength retention when fabricated into a laminate and shall conform to Military Specification MIL-M-15617, "Mats, Fibrous Glass, for Reinforced Plastics." Reinforcement material to have a finish as required by MIL-F-9118. All glass fabric shall have a Volan "A" finish. Chopped-strand mat must have a polyester binder conforming to MIL-M-125617. Any chopped-strand fiberglass mat used as reinforcement shall be limited to 2 oz. per square foot per layer of mat and shall be Volan "A", Silane, or Garan finish or an approved equal. Any woven roving used shall be 18 oz. per square yard minimum conforming to MIL-C-19663, "Ships Woven Roving."

Fabric layer shall be 1 to 1 glass by weight; woven roving layer shall be 40% glass by weight and mat content shall be 25% glass by weight.

15.1.3 Catalysts -- The catalysts shall be:

- (1) Benzoyl Peroxide Paste (50% Benzoyl Peroxide and 50% Tri-Cresyl Phosphate) or BPO power mixed with styrene.
- (2) Cumene Hydroperoxide.
- (3) Methyl Ethyl Ketone Peroxide.

15.1.4 Accelerators -- Accelerators shall be:

- (1) Cobalt Napthenate conforming to Federal Specification TT-D-643, Type II, 100°F flash point.
- (2) American Cyanamid No. 400 promoter.

15.1.5 Parting Agents -- Cellophane wrap for release agent cannot be used. Mylar as release agent must have Laboratory approval. Silicones, oils, and other similar materials shall not be used as parting agents on the any side of the part. Type of release agent must be approved by the Commission.

15.1.6 Pigment -- light gray. The Laboratory will supply a sample for color match. No more than, 25% to be added.

15.2 SAMPLING

15.2.1 A minimum 12 inch round diameter pipe by 12 inches long sample shall be submitted to the Commission to indicate surface finish, thickness, material build-up, etc. This sample shall be an actual lay up as employed in production. Production samples shall also be submitted at the request of the Commission and these shall be of 12 inch x 12 inch size of thickness specified for flat duct and a 12 inch diameter by 12 inches long pipe section. One flange section (of 6" to 12" diameter) must be submitted to indicate the surface, finish, thickness of material build-up. The length should be long enough to show the method of welding flange to duct.

15.2.2 Unless otherwise specified by the Commission, from each lot of resin and reinforcement to be used in the fabrication of parts, at least two sample flat sheets of glass-fabric-base, low-pressure laminated plastic materials shall be made-up, in accordance with the process specification, and these sheets shall be tested for resin content, specific gravity, Barcol Hardness or Rockwell M and flexural strength in both the dry condition and the wet condition after two hours in boiling water. The sample of fiberglass sected for making the panel shall be inspected for conformance to the requirements of Specification MIL-P-8013-C, "Plastic Materials, Low Pressure Laminated, Glass Fiber Base, Polyester Resin." The sample sheets made up for test purposed shall be of the thickness designated on the drawing. A lot of resin or fabric shall be defined as all resin or fabric representative of the same manufacturer's batch or

shipment. Samples will be tested in accordance with L-P-406B. Self-extinguishing tests will be screened by "Intermittent Flame Test" (Hooker Electro-Chemical Company Bulletin) to yield a rating of 100, with the exception that the sample bars will be:

- (1) The piece will be of the thickness of the duct.
- (2) The piece will be of the typical construction make-up.

15.3 Catalyzing of the Resin

The resin used shall be catalyzed as recommended by the resin manufacturer and according to good practices which will result in parts that will comply to MIL-P-8013-C requirements. Catalyst formulation must be submitted to the Laboratory for approval. In addition, the amount of any catalyst used will also be governed by the size and thickness of the part and the atmospheric conditions prevailing at the time of manufacturing. Introduction of the catalyst into the resin for use shall not take place until the resin has reached room temperature. All catalyzed resining shall be allowed to stand a required time before use to allow entrapped air to escape. Approved pre-impregnated "B" state polyester cloth requires no further treatment before use, and may be used for parts having sharp and difficult changes in cross-section thicknesses. All pre-impregnated lets shall be evaluated for proper resin flow, resin content, specific gravity and the laminate made from such shall meet the requirements of MIL-P-8013-C. Catalyzed resin shall be intermittently checked for gelatin in the container and shall not be used under this specification when such a condition exists. Catalyzed resin may be kept for extended periods of time under proper refrigeration, except D.D.M. promoted. (Approval must be obtained from the Commission.)

15.4 Lay-up Procedure

15.4.1 The mold shall be checked for any condition which will affect the surface of the laminated part. Precautions shall be exercised to ensure that the fabric is maintained clean and free of contamination, dirt, and resin. The fabric or mat shall be applied to the form without distortion and tailored to fit so that the lap widths 1 1/2 inch minimum, are maintained; no two laps are to be superimposed upon each other and no gaps shall be allowed. These requirements will be observed unless otherwise specified.

A detailed description of the manufacturing and fabricating process and methods of control of manufacturing variables in the form of a titled, numbered, and dated process specification shall be submitted by the Contractor to the Commission for approval in conformance to Specification MIL-P-9400 and this specification. After approval, the processes in preproduction shall conform to the requirements of the process specification, in addition to this specification, and shall not be

changed in production without approval of a new superseding process specification.

Approval of the fabricator's process specification shall constitute compliance only with minimum acceptable requirements of this specification and MIL-P-9400 and does not obviate any additional requirements as may be specified in any specific procurement of laminated FRP. Additional requirements are specified in the contract, drawings, or detail specifications.

- 15.4.2** A detailed description of the manufacturing and fabricating process shall be submitted to the commission for approval of they lay-up method, overlapping of the various layers of reinforcement for developing strength of the laminate, type of mandrel (solid or split) to be used. If split mandrel is used on rectangular duct, the split must not be on a right angle break or corner edge, or within the designated semi-critical area of the duct. Where a break occurs, the material must be built up on the outside of the woven roving with extra mat to specified thickness. No split mandrel to be used on round duct. Split of the duct should be installed on the job on the vertical side.

15.5 Fabrication Notes

- 15.5.1** In order to achieve a smooth surface for the interior surfaces of the fabricated parts, the molds shall be constructed so that the outer surface of the mold shall be the lay-up surface. Inside surface of laminate (Gel Coat) shall have at least a 35 micron finish. (RMS)
- 15.5.2** Powered benzoyl peroxide or its equivalent may be dissolved in an equal amount of styrene monomer. This solution should be made just prior to usage.
- 15.5.3** Mixing of resin and catalyst shall be done when the materials are at room temperature. The containers shall not be opened until they have warmed up to room temperatures. Antimony Trioxide should be stirred in just prior to or restirred before using to avoid settling.
- 15.5.4** Parts shall be drilled with high speed, carbide, or diamond tipped drills.
- 15.5.5** Cutting should be done with diamond, carbide tipped, or high speed tools.
- 15.5.6** Wherever possible, parts should be backed up to prevent delamination and/or fraying.
- 15.5.7** Tools and procedures used shall be of the best standards to insure good workmanship.

- 15.5.8** Machined, cut, drilled or frayed edges of parts **must** be coated with a sealing coat of resin used in the fabrication of the part to eliminate moisture absorption and leakage due to capillary action. Holes and cracks that occur from cutting operations shall be filled with resin to the level of the surrounding surfaces then given a final coat of resin.
- 15.5.9** **Foreign Materials** – No staples may be used. No paper tape nor other foreign materials which produce a deleterious effect on the properties of the part shall remain in the finished laminate.
- 15.5.10** Outside surface contamination of parts shall be cleaned and removed of any waxes, release agents, etc. that adversely affect adhesion of a coating.
- 15.5.11** Silicone or cellophane must not be used or incorporated in a release agent or in a wax.
- 15.5.12** Putties may be used for filling of voids. If the laminate is colored the putty should be of the same shade in color. Resin in putty must be as hereinafter described.
- 15.5.13** **Gaps** -- Unless otherwise approved by the Commission there shall be no gaps between one piece of reinforcement and a previous piece as they are laid up.
- 15.5.14** **Laps** -- Where necessary, they shall be laid up with a lap width of at least $1\frac{1}{2}$ inch on spiral wrapping and $1\frac{1}{2}$ inch on longitudinal wrap. No two laps shall be superimposed upon each other unless they are crossing in direction.

15.6 **Defects**

- 15.6.1** Allowable defects shall consist of the following: Defects greater than those listed and not covered by repairable defects shall be reason for rejecting the laminate. Any area of the part which has been designated as a "critical area" shall be free of all defects herein described. Critical areas are all flanges and gasket surfaces.
- 15.6.2.** **Excess Resin** -- On interior or exterior surfaces of the part and adjacent to sharp changes in the contour excess resin thickness up to 0.025 inch is allowed. There shall be not resin pockets which will produce unserviceability of the part.
- 15.5.3.** **Starved Area** -- There shall be no starved areas. Starved areas are considered as an area in which the reinforcement is not impregnated with resin. Crowfeet shall not be defined as starved area.

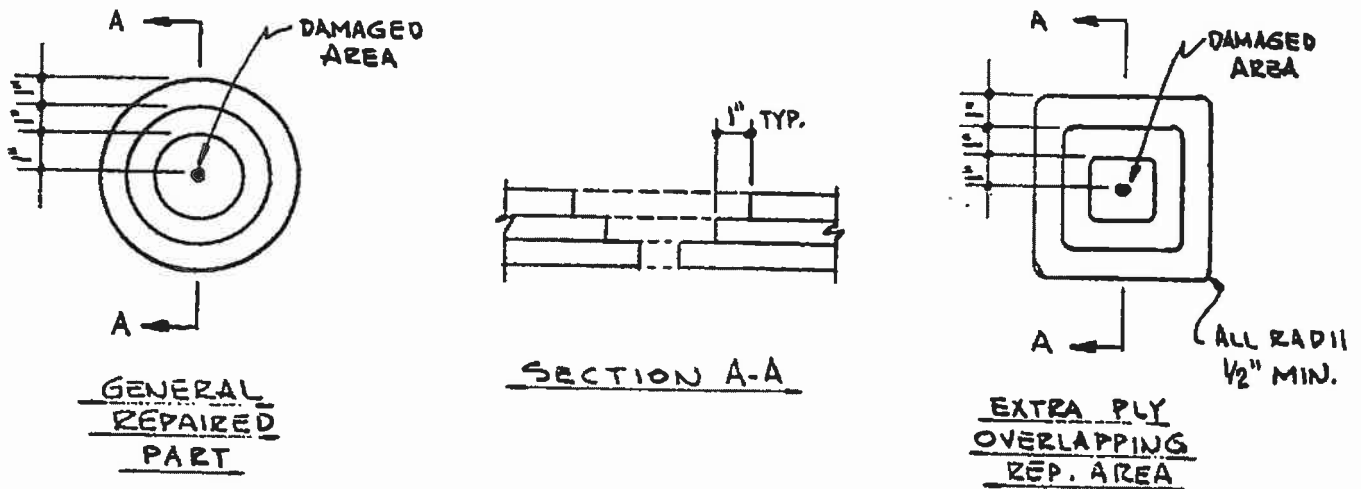
- 15.5.4** The bottom half of all round and rectangular duct, elbows, tees and any other piece used in the horizontal duct system shall be considered as a semi-critical area and shall have an unbroken surface gel coat free from air pockets under the surface (between the gel coat and the first layer of reinforcement). Such pockets may be repaired as stated in herein.
- 15.5.5** **Delamination** -- Delamination is defined as a separation of the lay-up piles and is not permitted except around drilled holes and sheared edges where only $1/32$ inch delamination is permissible. These areas shall be coated and cured with a dilute solution of the parent resin prior to shipment, as defined in paragraph 52-06f.
- 15.5.6** **Tackiness** -- The laminate surface shall be free of tackiness on both sides which when tested with a Barcol Hardness machine will render an average of 45 or more outside. Inside surface must reach a Rockwell "M" of 95.
- 15.5.7** **Voids** -- Internal voids shall not be larger than .03" in diameter and shall not materially effect the transparency, mechanical and electrical properties of the laminates.
- 15.5.8** **Pitted or Porous Surfaces** -- Pits or pores shall not exceed .01" in diameter on interior surfaces and .05" in diameter on exterior surfaces. The maximum allowable pitted area for either surface shall be limited to .001% of the total area (approximately 1 hole per 10 sq. inches).
- 15.5.9** **Gasket Surfaces** -- All gasket surfaces shall be free from nicks, scratches, burrs, cavities, pits, and bubbles, and shall have a level and true molded surface.
- 15.5.10** **Laps** -- Each layer of glass shall overlap unless otherwise specified, with a lap width of $1\ 1/2$ " minimum to form a continuous layer. No two laps shall be superimposed upon each other.
- 15.5.11** **Holes** -- There shall be no holes which penetrate the gel coat.
- 15.5.12** **Blisters** -- There shall be no blisters in any part of the laminate.
- 15.5.13** **Cracks** -- There shall be no cracks in any part of the laminate.
- 15.5.14** **Unbonded Areas** -- There shall be no unbonded areas in any part of the laminate.

15.7 Repairable Defects

Defects other than those indicated above may satisfactorily be repaired by following the procedures hereinafter specified, or by submitting the method of repair for approval by the Commission.

All repairs should be brought to the attention of the Commission.

15.7.1 Mark off on all sides with a pencil or scribe and a compass or straight edge, a square or rectangle or circle larger than the damaged area by 1" for each ply of material to be removed minus one. With a sharp tool, cut along the penciled or scribed outline with great care through the first layer. Removed the layer by inserting a sharp knife or point under this layer to effect delamination of this layer from the substrate layer. Move in 1" on all sides and repeat the above procedures until all piles to be removed are removed.



Dashed line (— — —) are replacement layers.

Solid line (—) are original layers.

Optimum structural repair (MIL-P-8013-C Type I).

- 15.7.2 The procedures and materials listed herein shall be used for the performance of the repair work. All replaced reinforcement and resins shall be the same as used for fabricating the part.
- 15.7.3 Repaired patches shall be butt jointed only when the engineering drawing so specifies.
- 15.7.4 Repaired patches shall have overlapped joints for normal MIL-P-8013-C type I requirements. However, if the engineering drawing designates the laminate structurally critical, the patches shall be overlapped joints, and in addition the entire repaired area will have an extra ply of fiberglass material (similar to the parent glass lay-up) superimposed unless

otherwise specified by the drawing. This repair method is defined as optimum structural repair.

- 15.7.5 Generally any laminate requiring fabric replacement for accomplishing repair will be brought to the attention of the Commission for proper repair procedures.
- 15.7.6 A sander or an equivalent tool shall be used to remove the respective number of piles in order to completely eliminate all traces of the damaged area. This procedure shall produce a uniform concave shape and shall allow for repairs as outlines above, 52-80a.
- 15.7.7 All other repairable defects of less extent or significance shall be accomplished by light sanding, with care being taken not to injure the glass fabric. Lightly coat the sanded area with the parent resin.

15.8 Inspection Control

- 15.8.1 At the option of the Commission, all supplies shall be subject to inspection and test by the Commission at all times and places, including the period and place of manufacture and prior to final acceptance.
- 15.8.2 In case any supplies or lots of supplies are defective in material or workmanship or otherwise not in conformity with the requirements of specifications, the Commission shall have the right to reject them (with or without instructions as to their disposition) or to require their correction. Supplies or lots of supplies which have been rejected, or required to be corrected, shall be removed or corrected in place, by and at the sole expense of the Contractor.
- 15.8.3 Contractor shall provide all reasonable facilities or tests to be made by the Commission at place of manufacture.

Each lot of resin shall be certified in writing to meet the requirements of MIL-R-7575.
- 15.8.4 From each lot of resin an amount shall be removed from the fabrication of MIL-P-8013-C panel using approved fiberglass reinforcement as shown in the drawings for the flat duct. See 523-03b.
- 15.8.5 Written certification of tests of fiberglass materials shall be furnished showing the delivered rolls of fiberglass fabric or mat meet the requirements of MIL-F-9084, MIL-P-8013-C, MIL-C-19663, and MIL-M-15617, as applicable.
- 15.8.6 Immediately prior to impregnation, the glass material will be visually checked to insure that the material is free of permanent wrinkles,

creases, and other distortions and shall be free of tears, greases, oils, and shall be uniform in color.








15.9 Construction of Duct Material Lay-up

15.9.1 Fabrication – Fabrication shall be accomplished by hand lay-up press molding, or resin spray gun. Use of glass delivery proved prior to fabrication by the Commission.

15.9.2 Material Thickness Table –

(1)	Circular Cross Section I.D. $\pm 1/16"$ 1" to 14" incl. 15" to 28" incl.	Wall Thickness 3/32" minimum 1/8" minimum
(2)	Rectangular Cross Section All sizes	3/16" minimum
(3)	Flanges All sizes	3/8" minimum
(4)	Length of Shear Surface All thicknesses	2 3/4" minimum

15.9.3 Typical Lay-up of Material

(1)	 Gel Coat (Finish on inner surface shall be 35 microns with 10% graphite)	15 - 20 mils
(2)	 6 - 10 Oz/sq. yd. fiberglass cloth	10 - 25 mils
(3)	 3/4 - 2 oz/sq. yd. fiberglass mat	30 - 60 mils
(4)	 18 - 25 oz/sq. yd. fiberglass woven roving	40 - mils
(5)	 3/4 - 2 oz/sq. fiberglass mat	30 - 60 mils
(6)	 1 layer of a compression glass cloth	
(7)	 Coat of resin (Hot Coat)	10 - 20 mils

The glass to resin ratio for the total laminate will be 25% or greater.
Glass reinforced cross section.

The glass content or glass to resin ratio will be determined from this section, the enumeration is -2,3,4,5 and 6.

- (1) Round duct – glass content to be 35 - 40%.
- (2) Rectangular duct – glass content to be 30 - 35%.

The wall thickness will be measurement of the glass reinforced cross section enumerated by 2 through 6 above.

Where drawings or specifications call for a thickness of the laminate or the glass reinforced cross section to be greater than indicated in this drawing; the difference of build up will be made after a section 5 or as a part of 5 as follows:

- (1) Fiberglass cloth or fabric.
- (2) Fiberglass woven roving.
- (3) Fiberglass mat (no layer greater than a 2 oz./sq. ft./ply)
- (4) Any combination of 1, 2 or 3.
- (5) Each ply of reinforcement must be impregnated with resin; before the next ply is overlaid.

Cross Section Thickness Table

Wall Thickness

Cylinder 1-14" diameter.....	$3/32+$
15- 28" diameter.....	$1/8$
Rectangular.....	$3/16$ minimum

Specification thicknesses are minimum and may be increased with the approval of the Commission.

15.9.4 Physical Properties – The plastic duct shall contain no metal staples, parting agents, tape or foreign materials. The laminate shall meet physical properties as follows:

	Fed. Spec.*		
(1) <u>At 73°F</u>	<u>Method No.</u>	<u>ASTM</u>	<u>Value</u>
(Minimum) ultimate tensile strength	1011	D638	15000 psi
(Minimum) flexural strength in tension of resin rich surface. First break on the curve.	1031	D790	16000 psi
(Minimum) flexural modulus	1031	D790	$8 - 1 \times 10^6$ psi

(Minimum) hardness	1081.1	D785	Barcol** 45 or Rockwell M95
Specific gravity	5011 or 5012		1.5 - 1.7
Intermittent flame test rating (Hooker Chemical Company)			100
Flame retardance rating		D635-44	Self-extinguishing

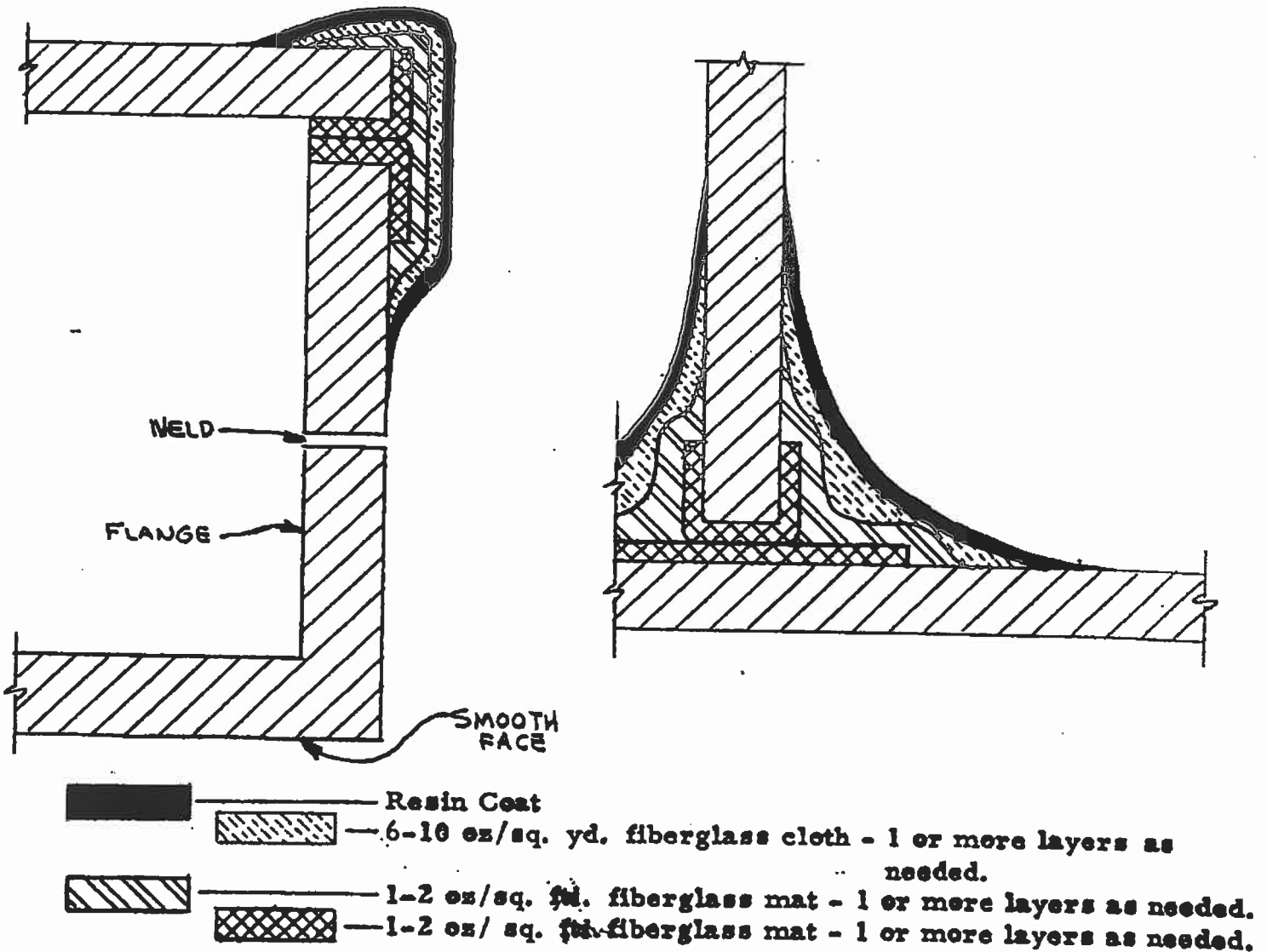
*Federal Specification Method Number may be found in Federal Specification L-P-406b.

**Barcol Tester No. 934.

- (2) Hardness tests shall be made on the cured samples of the resin rich surface and certifications furnished. Barcol tests shall not be made on inside surface of any piece that is used in job installation.
- (3) **Warpage** – The curing cycles and proper mixing of the resin catalyst system should be such that no hot spots will develop or warpage caused by improper cures or any action that is detrimental to our use of the laminate.
- (4) **Flatness** – The out of flatness of gasket grooves or gasket surfaces must not exceed:
 - .020" in any 3" of length
 - .030" in any 13" of length
 - .050" in any 24" of length
- (5) Flat and round duct will operate under a maximum of 5" of water negative. If the fabricator feels that there is a need for greater strength in the laminate than what the Commission has indicated in the drawings or specifications, this should be constructed and indicated to the Commission.
- (6) If external support or ribbing is needed, fabricator is responsible.

15.9.5 Welds -- Butt joint coat ends with putty mix of resin, place ends together and lap successive layers of mat, woven roving, mat and cloth. The welded strip shall extend 2" minimum beyond any joint or corner edge; final strip must overlap preceding strip or strips so that joint will be as strong or stronger than part joined. Appearance of joint shall be equivalent to that of duct. All edges shall be trimmed neatly. Strapping

edges must be sanded smooth before hot coat is applied so that no glass will remain that might cause injury during handling.



The welded joint must be equal to or greater in strength than the strength of the laminate.

- 15.9.6 **General** - Flat sections of exhaust duct components shall have a minimum thickness of $\frac{3}{16}$ ". The lay-up indicated for fabrication of round ducts shall be followed for rectangular ducts and the additional thickness shall be made up as required and as recommended by good trade practices. The outer layer shall be finished off with a final resin coat. Minimum glass content shall not be less than 30%. Flat sections shall be reinforced as required to prevent breathing or vibration when operating at pressures indicated on the drawings. The ductwork shall be fabricated to meet requirements as shown on the drawings. Positive methods shall be used to assure uniform total thickness of laminate and

uniform glass to resin ration . Laminates shall be designed without visible voids or dry spots and shall not be cracked or crazed. Corner edges of rectangular duct shall be built-up with additional material as above to retain minimum thickness after cure due to shrinkage. Flange fuse shall be made by itself and then welded or bonded to the duct as shown in the sketch above.

Fittings such as elbows, tees, reducers, and transitions, shall be made up to provide strengths equal or superior to the adjacent sections.

15.10 Erection of Plastic Ductwork

- 15.10.1** All field joints, connections, and supports shall be subject to approval of the Commission. Also see Division, "Sheet Metal."
- 15.10.2** Support of the ductwork shall be by external means, using an angle iron trapeze or similar type support. Drilling, tapping, or other means of penetrating the ductwork is prohibited.
- 15.10.3** Extreme care must be employed in installing plastic ductwork in concrete to preclude and prevent any damage to the ductwork from tools, vibrators, excessive pressure of wet concrete any and all other operations.
- 15.10.4** Plastic ductwork shall not be installed where welding is required if the ambient temperature is below 60°F. Welding can be accomplished provided special precautions are taken to hold temperatures at the weld area at 60°F or higher.

15.11 Inspection & Quality Control Provisions

- 15.11.1 General** – The Contractor shall provide all reasonable facilities for testing. All test data accumulated from quality control, inspection control, preproduction and production testing will be made available to the Commission upon request or at the completion of the fabrication before final acceptance.
- 15.11.2 Inspections Control** – The Contractor shall provide certifications that all materials meet manufacturers specifications and the glass reinforcement and resin materials meet the MIL-F-9084, MIL-F-9118, MIL-M-15617, MIL-C-19663, and MIL-4-7575.
- 15.11.3** In addition to tests made by the Contractor, and at the option of the Commission, all supplies shall be subject to inspection and test by the Commission at all times and places, including the period and place of manufacture and prior to final acceptance.

- 15.11.4 Immediately prior to impregnation, the glass material will be visually checked to insure that the material is free of permanent wrinkles, creases and other distortions and shall be free of tears, greases, oils and shall be uniform in color.
- 15.11.5 The Contractor shall provide certification that all the laminated material shall meet the physical property requirements herein specified with test data to substantiate the certification.
- 15.11.6 At the option of the Commission, all laminated parts shall be subject to inspection and testing by the Commission at all times and places, including the period and place of manufacture and prior to final acceptance.
- 15.11.7 In case any laminated parts, supplies or lots of supplies are defective or otherwise not in conformity with the requirements of specifications, the Commission shall have the right to reject them (with or without instructions as to their disposition) or to require their correction. Items which have been rejected, or required to be corrected, shall be removed or corrected in place, by and at the sole expense of the Contractor.

15.12 Tests

- 15.12.1 **Glass Content** The glass content shall be determined by the following procedure: at least three specimens, 1" by 1" inch by the thickness of the sample, shall be cut from the laminate. All loose particles and projecting fibers shall be cleaned off the specimens. Each specimen shall be weighed on an analytical balance in a previously weighed crucible and specimen shall then be placed in a cold muffle furnace and ignited to a constant weight at 1000 to 1100°F. Higher temperatures shall be avoided to prevent fusion of the glass and the entrapment of unburned carbon particles. The ignition at 1000°F requires from 2-6 hours. At the conclusion of the ignition, the glass fabric residue shall be entirely white as contrasted to various degrees of gray when all the carbon is not removed. The glass residue shall show no sign of fusion. The residue and crucible shall be allowed to cool to room temperature in a desiccator and reweighed on an analytical balance.

$$\text{Glass content, by weight, \%} = \frac{\text{Residue Weight} \times 100}{\text{Original weight of specimen}}$$

- 15.12.2 **Barcol Hardness** – The hardness shall be obtained by direct reading on the Barcol impresser no. 934. Tests should be made after the area has been lightly sanded with steel wool or fine sand paper to remove any surface film. A test of the laminate must not be made when the point of the needle may penetrate the laminate to a depth intended, if the piece is to be used as part of the job.

- 15.12.3 Mechanical Properties** -- The mechanical properties may be determined by either the ASTM or the Federal Specification method number (herinbefore specified). Values will be obtained for the ultimate tensile strength, ultimate flexural strength and ultimate flexural modulus of elasticity. The fexural properties will be determined from the piece in the flatwise direction with the resin rich (gel coat) surface in tension.
- 15.12.4 Test Facilities & Conditions** -- Test facilities shall be available for use of the Commission upon request to perform the testing of the supplies or the laminated material by any one of the test methods called for to obtain the results necessary to determine and control inspection, quality and acceptance.
- 15.12.5 Test Conditions** -- Standard conditions shall be 23°C+ of -1°C (73.4°F+ or -2°F) and 50 + or - 4% relative humidity. Specimens shall be tested after being exposed for 4 days to this temperature and humidity. Specimens may be tested without 4 day exposure of standard conditions, except where there is a doubt that the materials will meet the requirements when the standard condition as specified is followed.
- 15.12.6 Laminated Parts** -- For quality control of the lamination samples may be prepared by marking up flat sheets following by lay-up sequence of materials used in the production items and procedures for the impregnation of the production item.
- 15.12.7 Preproduction and production items** will be sampled by taking the sample directly from the part fabricated and performing tests to determine if the properties of the laminate will meet the values hereinfefore specified. Sampling of both rectangular and round FRP laminates will be subjected to tests.
- 15.12.8** Prior to production of parts a preproduction sample of flat sheet to corresponds with rectangular FRP laminates and a sample round to correspond to round FRP laminated must be submitted to tests. The fabrication of the preproduction laminate must follow the typical lay-up sequence and the procedures to be used for the type part corresponding to production. Tests of production samples shall consist of all tests described under this division.
- 15.12.9** A sample flat sheet must be made of each new lot of resin and an intermittent flame test must be performed to determine the rating, and therefore acceptance of subsequent parts made from this resin lot. The sample of resin taken from the lot must be formulated in the same manner as the resin used in production. A part of this sample flat sheet must be sent to the Commission for testing. Certification by the supplier

of each resin lot, that the resin meets the Flame Retardance ASTM D635-44 rating of self extinguishing, must be provided.

15.12.10 The size of the sample will be governed by the type tests and the number of tests to be made of the part in question.

15.12.11 Rejection & Retest -- In case of failure of the sample to meet the specific tests, an additional sample representative of the same lot shall be tested. If this sample fails the specified tests, the material shall not be used in part or if a part of the laminate then that part will not be accepted.

15.12.12 Pressure Test -- The assembled ductwork and plenum system shall be subjected to a 3"W.G. static air pressure test. All joints shall be checked with soap bubbles for leaks.

15.13 Reference Documents

The following specifications and standards of the latest issue shall form a part of this specification:

MIL-R-7575	"Resin, Low Pressure Laminating"
MIL-P-8013-C	"Plastic Materials, Low Pressure Laminated, Glass Fiber Base, Polyester Resin"
MIL-P-9400	"Plastic Materials, Glass Fiber Base, Low Pressure Laminated, Aircraft Structural Process and Inspection Requirements"
MIL-F-9084	"Fabrics, Woven Glass, Finished, for Plastic Laminates"
MIL-M-15617	"Mats, Fibrous Glass, for Reinforced Plastic"
MIL-F-9118	"Finish, for Glass Fabric"
L-P-406b	"Plastics, Organic, General Specification Tests Methods"
MIL-STD-105	"Sampling Procedures and Tables for Inspection by Attributes"
ANL-CH-12	"Standard Chemical Comparison Test"
MIL-C-19663	"Ships - Woven Roving"
MY85-45-A	"Argonne National Laboratory" (5 sheet)

15.14 Shop Drawings --

Shall be submitted in accordance with Division "Special Conditions and Miscellaneous Work."

15.15 Protection of Surfaces

All surfaces and flanges shall be protected by adequate packaging and crating to insure against damage.

