METRIC

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MILITARY STANDARD

GLASS REINFORCED PLASTIC COVERINGS FOR PROPELLER SHAFTING (METRIC)

AMSC N/A

FSC 9330

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1. This Military Standard is approved for use by the Naval Sea Systems Command, Department of the Navy, and is available for use by all departments and agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Sea Systems Command, SEA 55Z3, Department of the Navy, Washington, DC 20362-5101 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

3. Glass reinforced plastic (GRP) coverings as described in this standard, and vulcanized rubber coatings conforming to MIL-R-15058, type II are specified as alternative corrosion prevention materials for waterborne propulsion shafting on Naval ships.

4. This standard provides requirements and guidance in application procedures in sufficient detail to allow personnel with limited experience to apply an effective GRP shaft covering.

5. This standard is intended for the use of contractor, shipyard, and ships' force personnel who install or repair propeller shaft coverings on Naval ships.

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1. SCOPE

1.1 Scope. This standard defines requirements for the materials to be used and provides detailed instructions for guidance on surface preparation, resin preparation, and application of fiberglass reinforced plastic coverings on waterborne propulsion shafting.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications. The following specifications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

FEDERAL

O-T-620	1,1,1-Trichloroethane, Technical, Inhibited (Methyl Chloroform)
P-D-680	Dry Cleaning and Degreasing Solvent

MILITARY

MIL-C-9084	Cloth, Glass, Finished, for Resin Laminates
MIL-R-17882	Repair Kits, Metallic Pipe and General Purpose, Damage Control
MIL-P-23236	Paint Coating Systems, Fuel and Saltwater Ballast; (Metric)
MIL-R-23461	Resin Compound, Thermosetting, Room Temperature Curing, For Metal Coating
DOD-C-24176	Cement, Epoxy, Metal Repair and Hull Smoothing; (Metric)

(Unless otherwise indicated, copies of federal and military specifications and standards are available from the Naval Publications and Forms Center, (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

2.1.2 **Other Government drawing and publications.** The following other Government drawing and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

DRAWING

NAVAL SEA SYSTEMS COMMAND (NAVSEA)

NAVSHIPS 803-2145807 Shafting, Propulsion and Components

PUBLICATIONS

NAVSEA

090-LP-430-0012	NSTM Chapter 9430, Shafting, Bearings and Seals
0943-LP-017-1010	Submarine Propulsion Shafting Main Technical Repair Standard
0943-LP-017-2010	Propulsion Main Shafting for Surface Ships, Technical Repair Standard
S9086-VD-STM-000, Chapter 631	Preservation of Ship in Service (Surface Preparation and Painting)
S9086-VG-STM-000, Chapter 634	Deck Coverings

(Application for copies should be addressed to the Naval Publications and Forms Center, (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

2.2 **Non-Government publications.** The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DOD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

AMS 3824 Cloth, Glass Finished for Resin Laminates; (DOD adopted)

(Application for copies should be addressed to the Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

D 2583 Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor; (DOD adopted)

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 **Order of precedence.** In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 **Abrasive-blasting.** Abrasive-blasting is a more all-inclusive term for the procedure known as sandblasting. Many abrasive materials other than sand are often used and are suitable for shaft surface preparation. In fact use of sand may not be permitted by some local environmental and safety regulations.

3.2 **Accelerator (promoter).** An additive for polyester resins which promotes curing of the resin at room temperature.

3.3 **Air-inhibited (air-inhibited resin).** A characteristic of some types of polyester resin which results in incomplete cure of the surface which is in contact with air; the surface remains tacky.

3.4 **BARCOL (BARCOL hardness).** A measure of surface hardness of a covering system and used to indicate the degree of cure. The method involves applying a hand-held impressor to the surface, following for the procedure and the instrument.

3.5 **Catalyst.** An organic peroxide additive for polyester resin which initiates the curing of the resin and accelerator mixture at room temperature (see 5.3.2).

3.6 **Cure (or Curing).** The chemical reaction process by which epoxy and polyester resins change from a liquid to a solid mass having characteristic properties. Cure implies more than solidification alone. Cure continues for a period of time after initial solidification and results in the final physical and mechanical properties of the reacted resin.

3.7 Fair. The condition of a surface, either flat or curved, when it is smooth and free of irregularity, unevenness or abrupt change in curvature. It is the condition in which the ends of the glass reinforced plastic (GRP) covering blend smoothly into the shaft or sleeve without roughness, projection or abrupt change in thickness or curvature.

3.8 Gel. A step in the cure cycle in which the resin thickens to a semi-solid consistency. This thickening progresses to such a degree that the resin can no longer be applied effectively.

3.9 Glass reinforced plastic (GRP). Fiberglass reinforced epoxy or polyester resin.

3.10 Hardener. An additive component which for epoxy resin causes the curing of the resin.

3.11 Infusible. The condition in which the cured, solid resin-coating will not melt under application of heat.

3.12 Insoluble. The condition in which the cured, solid resin-coating will not dissolve or soften in a solvent (such as water).

3.13 Milled glass fiber. An additive, composed of short lengths of glass fiber (approximately 1.6 millimeters (mm) (1/16 inches), which thickens resin.

3.14 Pot life (working life). The length of time that the mixed resin is of the workable consistency required for proper application. It is the length of time after the catalyst or hardener has been added, to the point that gelling or thickening of the resin has progressed to the degree it can no longer be applied effectively to the shaft.

3.15 Resin. A liquid epoxy or polyester type of plastic which may be cured to an infusible, insoluble solid.

3.16 Sleeve. In most cases as used herein a (copper-nickel) cylindrical tube or band secured to the shaft by shrink-fit and used in way of bearings, coupling covers, and fairwaters.

3.17 Tacky. The condition of a coated surface which remains sticky to the touch.

3.18 Thixotropic. A characteristic of resins to which a finely divided silica (fumed silica) has been added, which thickens resin to the degree that it will not flow or move unless spread by hand or brush.

3.19 Viscous. A term describing the resistance of a liquid to flow. The thick, syrupy, consistency of resin would be a relatively high viscosity.

3.20 Wet-out. The ability of a resin to "wet" or saturate the reinforcing fibers. Good wet-out implies complete wetting. Also, the process of applying resin to reinforcement.

4. GENERAL REQUIREMENTS

4.1 Personnel. Before being assigned the task of applying a glass reinforced plastic propeller shaft covering, personnel shall have background and experience with regard to the following:

a. *Materials.* General knowledge of the characteristics of the particular resin system being used, determining the mass of proper proportions of resin, accelerator, catalyst or hardener, and mixing the components thoroughly without entrapping air.

b. *Shaft and sleeve preparation.* An understanding of the need for the proper shaft and sleeve surface preparation, including abrasive blasting and degreasing, for obtaining acceptable resin adhesive bond.

c. *Covering application.* The skill required for uniformly applying fiberglass tape and resin to the shaft, detecting and eliminating air entrapment, and thoroughly wetting-out the tape with resin.

d. *Quality control and inspection.* Experience in determining, by visual inspection and the tests specified herein, whether the covering has been properly applied, is void free, and has continuous adhesive bond to the shaft and sleeve.

4.2 Facilities, tools, and equipment. Facilities are required to provide a clean, dry environment and the temperature range required in 5.4.6.1 of both the shaft and surroundings. To ensure the safe and proper application of the shaft covering as described herein, equipment and tools shall be required to perform the tasks of abrasive grit blasting, mixing and applying the resin, and performing specified tests.

5. DETAILED REQUIREMENTS

5.1 Basic materials. The basic materials as specified in 5.1.1 and 5.1.2 shall be used.

5.1.1 Resin. Resin shall be in accordance with MIL-R-23461, type I or III, as applicable (see 5.3).

5.1.2 Glass reinforcement. Glass reinforcement shall be woven fiberglass tape with a flat salvage on both sides to prevent fraying, in accordance with AMS 3824, style 7500 or MIL-C-9084, type XII A. The finish shall be compatible with the specific type of resin used (that is, for epoxy or polyester). The width of tape will depend on the diameter of the shaft. For shaft diameters greater than 20 centimeters (cm) (8 inches), the recommended width of tape is 15 cm (6 inches). Ten cm (4 inches) width tape is recommended for shaft diameters of 13 to 20 cm (5–8 inches). Narrower tape may be used on shafting of smaller diameter (see 5,6,2(f)(5)).

5.2 Auxiliary materials. The materials specified in 5.2.1 through 5.2.3 may be required.

5.2.1 Thixotropic filler (thickening agent). The addition of a small amount (2 to 4 percent by mass) of a thixotropic filler to the basic resin may be necessary to minimize or eliminate resin drainage. The amount required depends on the ambient temperature and resin viscosity. More filler will be required in warm temperatures when the resin flows more freely. Some manufacturers will provide the basic resin with the filler previously added, if required.

5.2.2 Fairing compound. One of the following thickened or paste type resin materials shall be used:

a. Hull smoothing cement in accordance with DOD-C-24176

b. Repair kit paste resin in accordance with MIL-R-17882 (sometimes preferred due to its fast cure time)

c. Basic resin thickened with milled glass fibers (see 3.13) (recommended for use with polyester type resins).

5.2.3 Coatings for flange coupling areas. Coating for flange coupling areas shall be coal tar epoxy conforming to MIL-P-23236, class 2, or the basic resin thickened with milled glass fibers and thixotropic filler (see 5.4.3.2).

5.3 Chemical types of resins. The resins which are used in the GRP coverings are viscous liquids which can be cured at room temperature into hard, insoluble, and infusible plastics by incorporation of curing agents (accelerator and catalyst or hardener). The type and quantity of curing agents shall be in accordance with recommendations of the resin manufacturer. The resin used shall meet the performance requirements of MIL-R-23461 which specifies either of two different types of resin systems; epoxy or polyester. Working characteristics of the two types of resin are described in 5.3.1 and 5.3.2.

5.3.1 Epoxy resins. Epoxy resins have been most widely used for shaft coverings because of their superior adhesive characteristics and this type of resin system is recommended. Epoxy resins are cured by the addition of a specific amount and type of curing agent or hardener. The amount of hardener added shall be in accordance with the recommendations of the epoxy resin manufacturer and shall not be varied over a wide range for pot life control. Pot life of an epoxy resin and associate hardener depends on the ambient temperature (see 5.3.3).

5.3.2 Polyester resins. Isophtalic-type polyester resins are generally preferred because of their improved toughness. Polyesters are cured by the addition of an accelerator (promoter) and an organic peroxide catalyst (in liquid or paste form) as required in 5.3.2.1 and 5.3.2.2. Pot life of the mixed resin is affected by ambient temperature and may be varied within limits by adjusting proportions of the accelerator and catalyst in accordance with the resin manufacturers instructions.

5.3.2.1 Polyester resin curing. An accelerator shall be mixed into the polyester resin either by the user or pre-mixed by the resin manufacturer; the curing reaction can then be activated by mixing in a small amount of an organic peroxide catalyst. The type and amounts of these materials shall be in accordance with the recommendations of the resin manufacturer. Caution shall be taken to ensure that the accelerator and catalyst are not directly mixed together as this will result in a violent reaction. It is common practice and very desirable to acquire the resin premixed with the accelerator to avoid this dangerous possibility.

CAUTION

NEVER MIX ACCELERATOR AND CATALYST TOGETHER DIRECTLY!!

5.3.2.1.1 Peroxide catalyst, handling and storing. Care shall be taken in handling and storing the organic peroxide catalyst. It is flammable in nature and will decompose violently under certain conditions. It should not be exposed to heat such as direct sunlight, steam pipes, open flames, or sparks. Consult the manufacturer's data sheet for specific details on safe handling and storage conditions.

5.3.2.2 Polyester resin classification. Polyester resins may be classified as "air-inhibited" or "non-air-inhibited" (resins which cure tack free). Some air-inhibited resins frequently contain an additive such as wax which enables the resin to cure to a tack-free surface. This type of resin shall not be used since the wax additive interfere with adhesion between plies of reinforcement. The resin supplier shall furnish either a resin that is naturally non-air-inhibited or an additive (preferably non-wax) which can be added to the resin for the final tack-free layer coating application.

5.3.3 Cure. Once the hardener or catalyst has been added, the resin will remain liquid for a limited period of time after which it will begin to gel or thicken and become unworkable. The resin should cure at room temperature (or according to the manufacturer's instructions). However, optimum properties can be developed in a shorter time by post curing or heating at moderate elevated temperatures. Infrared lamps and strip heaters are convenient sources of heat. Post curing may be used to obtain optimum cure particularly for coverings applied in cold weather or coverings that must be put in service as soon as possible.

5.3.4 Fillers. Resin flow from the freshly applied covering shall be minimized or eliminated by assuring the proper viscosity, or if necessary, increasing the resin's viscosity by the addition of thixotropic filler material (see 5.2.1). This will probably be necessary if the shaft cannot be rotated continuously during application and cure. The addition of filler may have the disadvantage of obscuring visual inspection for voids and trapped air. Clear, unfilled resin shall be used on shafts which are rotated during application.

5.4 Application procedures.

5.4.1 General description. After proper shaft surface preparation, a coat of resin is applied uniformly to the shaft. The first ply of glass tape is then wound spirally on the shaft, butting the edges. After working out entrapped air and ensuring that the glass tape is wet-out properly, a coat of resin is applied over this ply. A second ply of glass tape is then wound on the shaft, reversing the direction of the spiral wrap. This process is continued until four plies of tape have been applied. Safety precautions (see 5.4.5) shall be observed in the handling and application of these materials.

5.4.2 Preparation of shaft. The shaft surface shall be prepared immediately prior to application of the covering in accordance with the following procedures to ensure a maximum degree of adhesion:

a. The existing covering on shafts and sleeves which have been in service shall be removed by mechanical means.

b. Remove any oil or grease from the surface of the shaft by washing with suitable solvents (for example, petroleum distillate type solvent in accordance with P-D-680, type II), or trichloroethane in accordance with O-T-620. Washing shall include scrubbing action (as with a stiff bristled paint brush) followed by pouring clean solvent over the shaft surface such that it runs freely off the lower surface. The shaft should be rotating during washing. Appropriate safety precautions shall be observed when using these solvents.

c. Metal surfaces to be covered shall be abrasive blasted with clean abrasive grit to approximately 3 mil profile. (Experience has shown that a satisfactory covering can be applied to a freshly machined shaft (not abrasive blasted) if solvent washing procedures and time limitations herein are carefully followed. Covering freshly machined shafts is permitted though not encouraged. Abrasive blasting is a more reliable method of surface preparation).

d. Wash with solvent as required in 5.4.2(b) after abrasive blasting, assuring that no residue remains.

e. Pits or cracks in the shaft shall be treated as specified in NAVSEA 0943-LP-017-1010, NAVSEA 0943-LP-017-2010, NAVSEA 0901-LP-430-0012 Chapter 9430. Irregular surfaces may then be faired using paste resin (see 5.2.2). Also, this is a good time to fill and fair the shaft to sleeve junction as specified in 5.4.3. Cure of the paste resin can be accelerated by warming the repaired area with hot-air guns or infrared heat. When the filled-in areas are fully hardened they shall be sanded to conform to the contour of the shaft but left roughened for better adhesion of the covering. These areas and any affected surrounding areas shall be washed with solvent as specified in 5.4.2(b).

f. GRP covering of the shaft shall be started as soon as possible (within 8 hours) after the abrasive blasting, although shafts protected by plastic film or vapor phase inhibitor (VPI) paper can be held a maximum of 24 hours before coating. If covering of the shaft cannot be started within 24 hours, or if there is evidence of oxidation, the shaft shall be re-abrasive blasted.

5.4.3 Preparation for GRP shaft covering in way of shaft sleeve end and flange coupling. In cases where specific details of the covering are described on the shafting drawing, as on new construction, these details shall be followed in the application of the GRP covering. Similarly, requirements in accordance with NAVSEA 0943-LP-017-1010, NAVSEA 0943-LP-017-2010, NAVSEA 0901-LP-430-0012 Chapter 9430, whichever is applicable, shall be observed and shall govern in the case of conflict with this standard.

5.4.3.1 Sleeve. There are at least 13 different sleeve end details which may be encountered on Naval ships. Each of these details may require different preparation in order to provide a configuration which facilitates application of the shaft covering. Figure 1 shows the Navy current standard sleeve which is found on new construction and some older ships which have been modified. Figure 2 shows the configuration of a bearing sleeve used previously which has been modified to facilitate application of the GRP covering. Figure 3 shows a bearing sleeve with typical configuration which may be found on some older ships. Experience has indicated that application of the GRP covering is most critical in the area of the sleeve and at the junction between the sleeve and the shaft. Many failures seem to initiate in this area which could be due to improper preparation of the surface in way of the sleeve. Figures 1, 2, and 3 show some possible approaches to preparation of the shaft-sleeve junction and sleeve. As shown, any grooves, hollows, shoulders or steps on the sleeve or between the sleeve and shaft are filled out with paste resin (fairing compound (see 5.2.2) to form a smooth surface and a gradually tapered junction between shaft and sleeve. Fairing compound shall be mixed according to the instructions for the particular material and the surfaces prepared as specified in 5.4.2. As specified in 5.4.2(e) cure of the resin may be accelerated by warming and after cure the surface shall be sanded fair and solvent washed. The objective is to provide a firm, faired, clean, and roughened surface on which to apply the GRP covering. Care shall be taken to ensure that the steel shaft is protected by a watertight seal in this area.

5.4.3.2 Shaft flange. Since 1967, rotating coupling covers are required on all Navy multisection, waterborne shafting. Treatment of the shaft sleeve for the fair-water and coupling cover shall be as required in 5.4.3.1. For older Navy ships which may have exposed couplings, the flanged couplings, sides of sleeve couplings, as well as bearing sleeve areas and other discontinuities in the shafting (such as coupling bolts and nuts) which cannot properly be covered with glass tape shall be sanded or sandblasted, solvent cleaned and coated with two coats of a coal-tar epoxy conforming to MIL-P-23236, class 2 to a minimum dry film thickness of 15 mils or coated with resin formulation containing 10 percent by mass of milled glass fibers (the same resin that has been used to coat the straight runs of shafting is used) after the straight run coverings have been applied. Any resin remaining from the latter operation may be used or new batches of resin may be prepared. In the latter case, 10 percent milled glass fibers shall first be added to the resin followed by the addition of the curing system (accelerator and catalyst for polyesters and hardener for epoxies). A thixotropic filler (see 5.2.1) may also be added to limit resin drainage (up to 4 percent by mass depending on temperature). Four coats of resin may be sufficient but the total thickness shall not exceed 60 mils. Separate batches of resin shall be prepared for each coat since gelation (partial hardening) must occur before the next coat may be applied. In coating flanged couplings, care shall be exercised with regard to areas around and between bolts in order to avoid holidays or porosity.

5.4.4 Estimation and preparation of the basic materials required (see 5.1). This section covers the calculation of the amount of fiberglass tape and resin required for a four-layer (ply) covering and their preparation for application.

5.4.4.1 Fiberglass tape. The length of fiberglass tape shall be calculated using the following equation:

$$L = \frac{3.5\ DH}{W}$$

Where:

L = Length of tape required for each ply in meters (feet)
D = Diameter of the shaft in centimeters (inches)
H = Length of the section of straight run of shaft to be covered in meters (feet)
W = Width of the fiberglass tape in centimeters (inches).

The factor 3.5 in the above equation is used instead of the extract factor (π = 3.14) to allow for some excess tape and some overwrap at terminations.

5.4.4.1.1 **Example of calculation for fiberglass tape.** Calculate the length of 15.24 cm (6 inch) wide glass tape required for each ply of a covering for a 3.05 meter (10 feet long section of a 17.78 cm (7 inch) diameter shaft.

$$D = 17.78,\ H = 3.05,\ W = 15.24$$

$$L = \frac{3.5 \times 17.78 \times 3.05}{15.24} = \frac{189.8}{15.24} = 12.45 \text{ meters}$$

of tape for each ply. The length in feet can be similarly calculated by using the English dimensions given in parentheses. The total length of tape required for the four plies is equal to four times the length of a single ply as calculated above.

5.4.4.1.2 **Preparation of fiberglass tape.** Determine the amount of tape on each roll furnished to be sure there is sufficient material for accomplishing the task. The mass of all four plies of tape shall be determined to provide a basis for calculating the amount of resin required (see 5.4.4.2).

5.4.4.2 **Resin.** This section describes calculation of the mass of resin, thixotropic filler (see 5.2.1), and curing agents for typical polyester and epoxy resin coating formulations.

5.4.4.2.1 **Epoxy.** The total amount of resin (including hardener) required can be estimated by using the guide 1 liter of resin for every 2 square meters of tape (1 gallon for every 81.5 square feet) per layer of tape plus a finish coat (four layers of tape requires five layers of resin). The 2 square meters per liter is based on resin requirements per layer of fiberglass tape to provide thorough wet-out. The total amount of resin (including hardener) can also be estimated on a mass basis by multiplying the total mass of tape (all four plies, as determined in 5.4.4.1) by a factor of 2. This factor will provide an excess of mixed resin required for coating the shaft and thoroughly wetting-out the fiberglass tape.

5.4.4.2.1.1 Example, calculation for epoxy resin. Four 12.5 meter (41 feet) lengths of 15.24 cm (6 inch) tape would have a mass of approximately 2.52 kilograms (kg) (89 ounces (oz)).

Total mass of resin plus hardener = 2.52 kg x 2 = 5.04 kg
(89 oz x 2 = 178 oz or 11 pounds – 2 oz)

The mass of resin hardener (separately) may be estimated, but the proportion (percent) of resin and hardener required shall first be obtained from the resin manufacturer, since this can vary greatly, depending on the hardener used. Assuming that 60 percent of resin by total mass is required to be mixed with 40 percent of hardener then:

Mass of resin = 0.60 x 5.04 kg = 3.02 kg
(0.60 x 178 oz = 106.8 oz)

Mass of hardener = 0.40 x 5.04 kg = 2.02 kg
(0.40 x 178 oz = 71.2 oz)

Total mass (resin and hardener) = 5.04 kg (178 oz).

WARNING

The resin and hardener shall not be mixed together until immediately prior to use, since the mixture will have a limited working life.

5.4.4.2.1.2 Preparation of epoxy resins. Since epoxy resins have limited pot or working life, especially in warm temperatures, separate batches of resin may need to be prepared for each of the four layers of glass tape. The appropriate amount of hardener shall be added to each batch separately just before use. In warm weather the resin may be cooled to extend the pot life of the resin-hardener mixture. Pot life may also be extended by preparing the resin in the shade, avoiding direct exposure to the sun, and by keeping the mixed resin in a shallow pan to slow its heat buildup. Information on resin pot life may be obtained from the resin manufacturer. The mass of the resin and the hardener, each separately, shall be weighed out in four equal parts (for each ply of tape), and placed in separate metal or plastic containers. One part each of resin and hardener shall be thoroughly mixed prior to application of each ply, taking care not to beat or whip in any air.

5.4.4.2.2 Polyester. The amount of resin required is estimated as described in 5.4.4.2.1. Unlike epoxy resin, however, the amounts of accelerator and peroxide catalyst required are so small (on the order of 1 to 2 percent) they need not be considered as part of the total mass.

5.4.4.2.2.1 **Example, calculation for polyester resin.** Four 12.5 meter (41 foot) lengths of 15.24 cm (6 inch) tape would have a mass of approximately 2.52 kg (89 oz). Total mass of resin:

2.52 kg x 2 = 5.04 kg
(89 oz x 2 = 178 oz or 11 lbs – 2 oz)

Assuming that 1 percent of accelerator and 1-1/2 percent of peroxide catalyst by mass are required in order to obtain the desired working life, then:

Amount of accelerator = 0.01 x 5.04 kg = 50 grams
(0.01 x 178 oz = 1.78 oz)

Amount of catalyst = 0.015 x 5.04 kg = 75 grams
(0.015 x 178 oz = 2.67 oz)

The resin may be supplied with the accelerator premixed. The accelerator and catalyst shall not be directly mixed together. If the accelerator is supplied separately, it shall be thoroughly mixed into the resin first and then the catalyst shall be added to the resin and accelerator mixture immediately before use.

5.4.4.2.2.2 **Preparation of polyester resin.** As discussed previously (see 5.3.2), the working life of a polyester resin depends on the percentages of catalyst and accelerator in the resin and the ambient temperature. Catalyst and accelerator percentages may be adjusted to permit enough time for the coating operation before the resin gels. Information on the specific resin shall be obtained from the manufacturer. The required quantity of resin (with accelerator) and catalyst shall be mixed thoroughly, immediately prior to use, taking care not to beat or whip in any air. A gel time (pot life) of 2 to 3 hours should be sufficient to permit three people to apply a four-ply covering on a 3 meter (10 feet) length of 20 cm (8 inch) shafting. Two people can typically cover a 6 meter (20 feet) length of 50 cm (20 inch) shafting with one ply in 15 minutes.

5.4.4.2.3 **Thixotropic filler.** Refer to 5.2.1 and 5.3.4 for use information. The amount of filler added to the resin shall be determined based on prior experience, trail, or the recommendation of the resin manufacturer. Particular care shall be taken to avoid beating air into the resin.

5.4.5 **Safety precautions.**

5.4.5.1 **General.** Caution must be observed when handling any chemicals or solvents. The application of the GRP shaft covering is no exception. When applying the covering, the following general precautions shall be observed:

a. The working area shall be properly and adequately ventilated to draw fumes away from the worker.

b. Avoid direct contact with the solvents, resins, and associated hardeners and catalysts

c. Keep chemical containers clearly labeled, tightly covered when not in use, and stored in a cool, dry area

d. Do not work near hot surfaces or open flames. Do not smoke on the job or when handling chemicals.

e. Review the manufacturer's Material Safety Data Sheet for the specific resin system to be used

f. For further guidance on related safety procedures and equipment, refer to NAVSEA S9086-VD-STM-000, chapter 631.

5.4.5.2 Specific precautions. The following specific precautions shall be observed:

a. Wear disposable plastic gloves, protective clothing and goggles. The use of barrier cream on exposed skin which contact resiner hardeners is encouraged.

b. Wear a dust respirator when handling the finely divided thixotropic filter.

c. Avoid contact of resins and associated chemicals with eyes, skin or clothing. Absorption through the skin may be harmful. In case of contact with the skin, immediately wash with soap and water and flush with plenty of water for at least 15 minutes. If the eyes are involved flush with water immediately and for at least 15 minutes. Medical attention must be obtained as soon as possible.

d. Avoid prolonged or repeated breathing of vapors. If ventilation is not adequate, wear and organic vapor respirator.

e. If clothes or shoes become contaminated, remove at once and clean thoroughly before reuse.

f. Always wash exposed skin areas thoroughly after completing the job.

5.4.6 Application of covering. Typical details of waterborne propulsion shafting and components for Navy ships are shown on Drawing 803-2145807.

5.4.6.1 Temperature. During the covering operation, the temperature of the shaft and the immediate environment ideally should be about 23 degrees Celsius (°C) (73 degrees Fahrenheit (°F)). Covering shall not be attempted at temperatures below 16 °C (60 °F) since both cure of the resin and wet out of the fiberglass will be adversely affected. Covering may be done at environmental temperatures below 16 °C (60 °F) if a suitable heat controllable enclosure is used which enables all areas of the shaft to be covered and the covering to be maintained above 16 °C (60 °F). At higher temperatures (for example, 24 to 32 °C (80 to 90 °F)), the gel time (pot life or working life) of the resin will be significantly reduced. The resin system may have a gel time of anywhere from 30 minutes to 6 hours at 23 °C (73 °F) and 18 minutes, minimum, at 32 °C (90 °F) as permitted in accordance with MIL-R-23461 (see 5.1.1). The manufacturer's instructions shall be consulted for gel time or working life details for the specific resin system to be used. The required work shall be performed within the gel time limits for that resin system (see 5.5.1).

5.4.6.1.1 Humidity. High humidity can have an adverse effect on resin curing and also on resin wet-out of the fiberglass tape. The effects may vary the specific resin and tape combination to be used. In general, humidity conditions above 85 percent relative humidity should be avoided unless a trail application shows that the materials to be used will perform satisfactorily under the specific conditions.

5.4.6.2 Detailed procedure. The application of fiberglass tape and resin on the shaft shall be as follows:

a. Start the application as soon as possible and within 24 hours after shaft preparation (see 5.4.2 and 5.4.3). If shaft has been wrapped with VPI paper, it shall be allowed to air for 1 hour or more to dissipate any inhibitor vapor.

b. Review and observe the safety precautions (see 5.4.5).

c. Prepare the required quantities of materials (see 5.4.4).

d. Pour or brush mixed resin on top of the shaft as it rotates (see figure 4). See 5.3.4 for application to stationary shaft. It should be noted that the preferred method of application of the covering is to a rotating shaft. Resin drainage is usually not a problem and overall quality is better. Recommended speed of the shaft rotation, in revolutions per minute (r/min) may be determined as follows: When shaft diameter (d) is in centimeters then 450 divided by d equals r/min (when d is in inches then 180 divided by d equals r/min). For a 25 cm (10 inch) diameter the speed would be:

$$450/25\ (180/10) = 18\ \text{r/min}.$$

Spread the resin with gloved hands, brush or roller, to completely wet-out the shaft and sleeve surfaces and to provide a resin base to impregnate the first ply of the tape to be applied.

e. To start the wrap, wind one complete circumferential turn of tape around the shaft to completely cover the tape end. Then gradually, in two or three turns, decrease the tape overlap and work into a spiral with edges of the tape continuously butted as closely as possible to avoid gaps in coverage (see figures 5 and 6). On rotating shafts, two people are generally required to handle a roll of tape; one holds and feeds the tape from the roll to the second person who guides the tape onto the rotating resin-coated shaft. The preferred method of application is to a rotating shaft. On a stationary shaft, this operation may be accomplished with two people, one on each side of the shaft, who pass the roll of tape to each other over and under the shaft. The tape shall be carefully butted and applied with some tension so that the wrap is fairly tight, but not so tight as to pucker or distort the tape. Apply additional resin to the surface, if needed to completely impregnate the tape. Effort should be made to apply enough resin initially to impregnate the tape without the need to apply additional resin on top of the tape. The glass tape shall be coated uniformly and thoroughly so that good wetting of the glass fibers is obtained. After allowing some time for wetting by the resin, work out entrapped air with a roller, squeegee or other convenient method.

f. If there is a flange, each ply of tape shall be started or ended by butting as close to the flange as possible. To provide complete shaft coverage, the tape, which is spiral wound around the shaft, shall end up normal (90 degrees) to the shaft axis at both ends of the coated length (see figure 5). Several tape widths from the end, begin reducing the spiral angle to achieve and increasing overlap, minimize wrinkles, and end with a circumferential turn.

g. If a ply begins at a tapered sleeve (see figures 1, 2, and 3), start spiral winding the tape with edges closely butted (see figure 5), approximately 0.6 meter (2 feet) from the sleeve and wind toward the sleeve. The first turn may overlap to help hold the tape in place. Tapered ends of sleeves are always wrapped proceeding from the shaft up onto the sleeve taper. To end the wrap, the last several turns are taken with decreasing spiral and increasing overlap so that the final turn on the sleeve will end up normal (90 degrees) to the shaft axis (see figure 5). It may be necessary to use a narrower tape or to slash the tape to eliminate wrinkles and air pockets. Additional plies of tape may be interspersed with each ply of shaft covering as necessary to fair the covering and sleeve surfaces, as shown on figures 1, 2, and 3. After completing this short section, complete the application of the first ply. This is done by going back to the starting point, applying a turn of tape over the first turn which had been previously applied and proceeding to the opposite end of the shaft. (To maintain the same spiral for the continuation of the wrap, the shaft rotation must be reversed.) The tape is applied by spiral winding with edges butted as closely as possible to avoid gaps in coverage. As described previously, the wrap at the end shall begin to overlap on the last few turns and end up normal to the shaft axis.

h. On larger diameter shafting, the roll of tape may not be long enough to cover the entire shaft. In this event, cut the end of the tape square and start winding a second roll of tape. The first turn of the new roll shall overlap the last turn previously applied on the shaft. Some edge overlap may be used to ensure that the tape ends are held in place. Alternatively, lengths of tape may be measured out in advance and splicing as necessary may be done by overlapping tape ends 8 to 10 cm (3 to 4 inches) and securely stitching them together with fiberglass yarn. This procedure also has the advantage of permitting location and removal of any defects in the tape in advance of the winding operation.

i. After completing the first ply, allow the shaft to continue rotating while the fiberglass wets through which may take several minutes. The tape will be transparent and essentially invisible when properly wet-out. Work the resin through the tape and smooth any wrinkles with gloved hand, roller or squeegee. Add additional resin if needed to assure thorough wetting of the glass tape. Wrinkles and trapped air shall be removed.

j. Continue by pouring more resin over the shaft as needed to provide a reservoir of resin to wet out the second ply. Apply the second ply in a similar manner, except begin at the opposite end of the shaft, using a reversed direction of spiral so that edges of this ply cross the first ply (see figure 5). Add additional resin as needed for complete wetting of the tape.

k. Work out entrapped air and wrinkles and proceed with two additional plies of resin and tape alternately reversing the direction of spiral wrap. Upon completion of the four ply wrap, one or two circumferential turns may be applied at each end to "tie down" the covering, although this usually will not be necessary.

l. After fourth ply, the entire surface shall be coated with additional resin to ensure complete wetting of the glass tape and to provide a smooth, resin-rich and glossy surface with no evidence of dry glass tape or protruding glass fibers. The surface shall be brushed smooth and excess resin droplets or runs shall be removed before the resin gels.

5.4.6.3 Cure (hardening). The shaft shall continue to rotate during the curing period until the resin has gelled to prevent the resin from draining and forming runs or globules on the lower part of the shaft. If the shaft cannot be rotated continuously, even periodic 180 degree turns will be helpful to prevent runs and drainage. If the shaft cannot be rotated, any globules of resin on the underside of the shaft shall be removed periodically, until the resin has gelled. Cure time for some resins will be approximately 24 hours at 23 °C (73 °F) but the resin manufacturer should be consulted for a specific resin's cure characteristics. A longer cure time will be required at 16 °C (60 °F). Cure time may be shortened appreciably by raising the temperature of shaft and environment to 38 to 52 °C (100 to 125 °F). Temperature should not exceed 52 °C (125 °F) to avoid too rapid a cure or excessive thermal expansions. The cured covering shall be smooth, hard, and tack free. If there is any doubt of completeness of cure, BARCOL harness measurements (see 3.4) can be taken and compared to the manufacturer's values for specific resin system. After hardening, if the shaft is to be moved or stored it shall be wrapped in plastic and with heavy paper or canvas to protect the coating from being scratched or scored. If the shaft is not scheduled for immediate installation it shall be painted prior to wrapping in plastic and heavy paper or canvas, to provide additional protection. The shaft shall be stored in a sheltered area.

5.4.6.4 Painting. The covered shaft and couplings and covered areas of the sleeve shall be lightly sanded (preferably by hand) and painted with a tack coat of formula 150. While the formula 150 is still tacky, anti-fouling paint, of the type and number of coats specified for the hull bottom, shall be applied. It is important that the formula 150 still be tacky when the anti-fouling coat is applied. Anti-corrosion paint shall not be applied. Refer to NAVSEA S9086-VD-STM-000, chapter 631 for specific details on paint formulas, their application, and the type and number of coats of anti-fouling paint to be used.

5.5 Quality control. Correcting defects, once the GRP covering has cured, is costly and time consuming. To provide for quality control in the process, the following steps shall be observed:

a. Select proper materials as specified (see 5.1)

b. Check shelf life to ensure that the resin system components are not over age.

c. Provide proper environmental conditions (see 5.4.6.1)

d. Prepare and clean shaft (see 5.4.2)

e. Proportion, determine the mass, and mix resin (see 5.4.4.2)

f. Work out resin and fiberglass to thoroughly wet-out the fiberglass, eliminate wrinkles and air entrapment, and provide intimate contact with the shaft (see 5.4.6.2)

g. Permit GRP covering to cure before handling (see 5.4.6.3).

5.5.1 Gel time. When using a particular resin system for the first time or applying the GRP covering at the low or high range of permissible temperature (see 5.4.6.1), the pot life (working life) of the catalyzed (mixed) resin shall be checked. This may be simply done by checking the time to gel a container of 120 to 240 milliliters (mL) (4 to 8 oz) of catalyzed resin which is at the working temperature. The resin and all curing agents shall be at the working temperature before they are mixed. Timing shall be started when the mixing is started. Every 2 to 3 minutes, the resin shall be stirred with a wooden applicator stick. Gel is considered to have occurred when the resin has thickened to the point that it can no longer be stirred. Gel time is the elapsed time from start of mixing until gelling occurs. It should be understood that the gel time of a large container of catalyzed resin may be significantly shorter than as determined above and the gel time of the comparatively thin GRP covering will be considerably longer. This is because the catalyzed resin begins to generate heat within its volume and the warmer it gets the faster it reacts. A larger volume tends to retain the heat (unless it is in a shallow pan) and react faster. Conversely, when applied to the shaft, the thin covering dissipates heat much more readily and the reaction is slower.

5.6 Inspection. The shaft covering shall be inspected after application (before painting) and at each drydocking.

5.6.1 After application. The following step-by-step inspection and corrective procedures shall be required after the covering has hardened:

a. Visually inspect the shaft covering and particularly the sleeve, sleeve-shaft junction, and flange coating areas. Look for discoloration which may be evidence of overheating during cure, white laminate which indicated poor wet-out, air bubbles, pimples, or rough spots.

b. Tap suspicious looking areas with a coin. A dull or hollow sound indicates trapped air on debonded area (see 5.6.2(b)).

c. Slowly pass a high voltage spark tester over the entire coated area, with particular attention paid to the suspicious areas. Pinholes are evidenced by bright sparks which can be clearly distinguished from the purplish corona. (A suitable spark tester is shown in NAVSEA S9086-VG-STM-000, chapter 634.)

5.6.1.1 Corrective action. Surface defects such as areas containing isolated or scattered pinholes, pimples, and rough spots shall be sanded smooth and recoated with resin as was used for the covering. Widespread areas of air bubbles or pinholes shall be repaired by sanding the covering surface completely around the circumference and applying an additional ply of tape and resin (see 5.4.6) to cover the defective area. Areas which appear to be debonded or areas of white laminate shall be repaired by removing the fiberglass tape and resin, circumferentially, using a chisel or belt sander, down to the shaft surface, being careful not to damage the shaft surface. The covering on both sides of this removed area shall be beveled 2.5 to 5 cm (1 to 2 inches) and the tape and resin shall be reapplied (see 5.4.6). A final surface coat shall be applied. After cure, these areas shall be reinspected with the spark tester.

5.6.2 **Drydock inspection and repair.** Propeller shaft coverings shall be inspected when the ship comes into drydock for overhaul or repair work. GRP coverings that have been in service shall be inspected and repaired by the following procedure:

a. Remove marine growth of loose paint from the plastic covering including couplings and other coated areas, by scraping carefully, so as not to score or damage the covering

b. Conduct at close range a careful visual inspection of the full length of all the accessible reinforced plastic covering for evidence of deterioration, physical damage, lack of adhesion or other defects. Evidence of loss of adhesion of shaft covering is characterized by one or more of the following:

(1) Loss of covering as a whole or in part

(2) Rust stains where rust has leaked through the covering in the vicinity of a cut, joint, patch, or flaws, such as pinholes or porosity.

Evidence of loss of adhesion is generally difficult to detect. However, detecting lack of bond of plastic covering has been successful by tapping the covering at regular intervals of about 45 cm (18 inches) along the length of the covering with a light hammer rap while holding the palm of one hand against the covering on the other side of the shaft. Discernible vibration, movement of the covering, or audible hollow sound is evidence of probable loose bond and shall be explored or further examined (see 5.6.1(b)).

c. Carefully inspect the entire covering for developed porosity with a high frequency spark tester. Particular attention shall be given to the joining line between sleeve couplings, bearings sleeves, and the shaft. Mark all areas of porosity with chalk (do not use crayon).

d. Particular attention shall be given to the detection of breaks in the covering or leakage in the joint where the covering joins or laps on the shaft sleeve. Sleeve ends are the most vulnerable areas of waterborne shafting. The shaft at the forward end as well as the after end of the aftermost bearing sleeve are the locations of nearly all propulsion shaft failures. Therefore, special attention shall be given to the detection of breaks in the covering or leakage in the joint in these critical areas. Where evidence is found of deterioration, physical damage, lack of adhesion, or sea water penetration at the joint at ends of sleeves, remove the covering for a distance of at least 25 cm (10 inches) beyond the maximum extent of water penetration. Consult NAVSEA 0901-LP-430-0012 (chapter 9430) for corrective procedures with regard to the shaft and sleeve. After the inspection and repair have been completed, replace the GRP covering as required in 5.6.2(f)).

e. When the GRP covering contains scattered, isolated pinholes, the entire shaft shall be coated with resin as follows:

(1) Sand the shaft covering lightly or abrasive blast lightly around the entire circumference of the shaft. If the covering had been treated with anti-fouling paint, abrasive blasting may be necessary to remove the paint. When abrasive blasting precautions shall be taken to avoid damage to the covering by abrasion deeper than just surface roughening. Use fine or medium grit and mild conditions (low air pressure, low grit velocity). Do not dwell at one spot excessively. Careless or indiscriminate abrasive blasting may damage the covering severely.

(2) Clean away all sanding or abrasive blasting grit or residue and apply one coat of resin to the entire surface. Particular attention shall be given to those areas showing porosity.

(3) After the coating has hardened, re-examine with spark tester for porosity.

(4) Apply an additional cost of resin if any porosity is indicated, then reinspect the area for porosity.

f. If the covering contains damaged areas or areas of excessive porosity, remove those sections of the covering down to the shaft surface and recover with glass tape and resin as follows:

(1) Remove a circumferential section of covering by means of chisel or disc sander. Use care so as not to damage the shaft surface.

(2) Bevel the edges of the adjacent remaining covering 2.5 to 5 cm (1 to 2 inches)

(3) Examine the exposed shafting for any defects in accordance with NAVSEA 0943-LP-017-1010, NAVSEA 0943-LP-017-2010 or NAVSEA 0901-LP-430-0012 (chapter 9430), whichever is applicable and repair as necessary. If the shaft is in good condition, proceed with coating operation.

(4) Abrasive blast the exposed shafting, taking care not to abrade areas of covering which will not be recoated. Sand or lightly abrasive blast the remainder of the covering if a complete wrap is to be applied. Solvent wash the area as described in 5.4.2(b).

(5) Prepare a length of glass tape sufficient to provide a four-ply covering for each section to be repaired (see 5.4.4). For narrow repair sections, use 5 to 10 cm (2 to 4 inch) wide glass tape.

(6) Prepare the resin (see 5.4.4.2)

(7) Paint the exposed shaft and bevel with a coat of resin

(8) Apply tape and resin (see 5.4.6) to the cut out section and over the bevelled edges of the sound covering

(9) After the patch has hardened, fair excess material to a smooth contour with a disk sander, if necessary.

(10) Apply one wrap of glass tape and resin over the entire straight run of shafting if several section of the shaft have been repaired. Sand or lightly abrasive blast the entire shaft covering before application.

(11) After the covering has gelled, apply an additional coat of resin.

(12) Examine the covering for porosity as described in 5.6.1. Apply an additional coat of resin if there is evidence of porosity and reinspect the area.

g. Areas of the shaft that have been coated with resin (flanged couplings, sides of sleeve couplings, bearing sleeve areas, and so forth) and which show damage or excessive porosity shall be repaired by removal of the covering and reapplication as described in 5.4.3.2.

h. If the covering is so severely damaged as to preclude repair, the entire covering shall be removed and the shafting recovered as a new installation by the procedures described herein. The covering may be removed conveniently by chiseling through on opposite sides of the shaft. Do not damage the shaft surface.

5.7 **Reports.** Comments on the results of the in-service inspection (see 5.6.2) shall be forwarded with the initial inspection report specified in (chapter 9430), whichever is applicable. A brief description of corrective repairs which may be necessary shall be forwarded with the final inspection report required (see 6.2).

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. This standard describes detailed instructions for the preparation of glass reinforced plastic coverings. Preparation of plastic coverings should take place in a clean, dry environment with the appropriate temperature range to avoid unsafe application.

6.2 Issue of DODISS. When this standard is used in acquisition, the applicable issue of the DODISS must be cited in the solicitation (see 2.1.1 and 2.2).

6.3 Data requirements. The following Data Item Descriptions (DID's) must be listed, as applicable, on the Contract Data Requirements List (DD Form 1423) when this standard is applied on a contract, in order to obtain the data, except where DOD FAR Supplement 27.475-1 exempts the requirement for a DD Form 1423.

Reference paragraph	DID number	DID title	Suggested tailoring
5.7	DI-T-5329	Inspection and Test Report	–

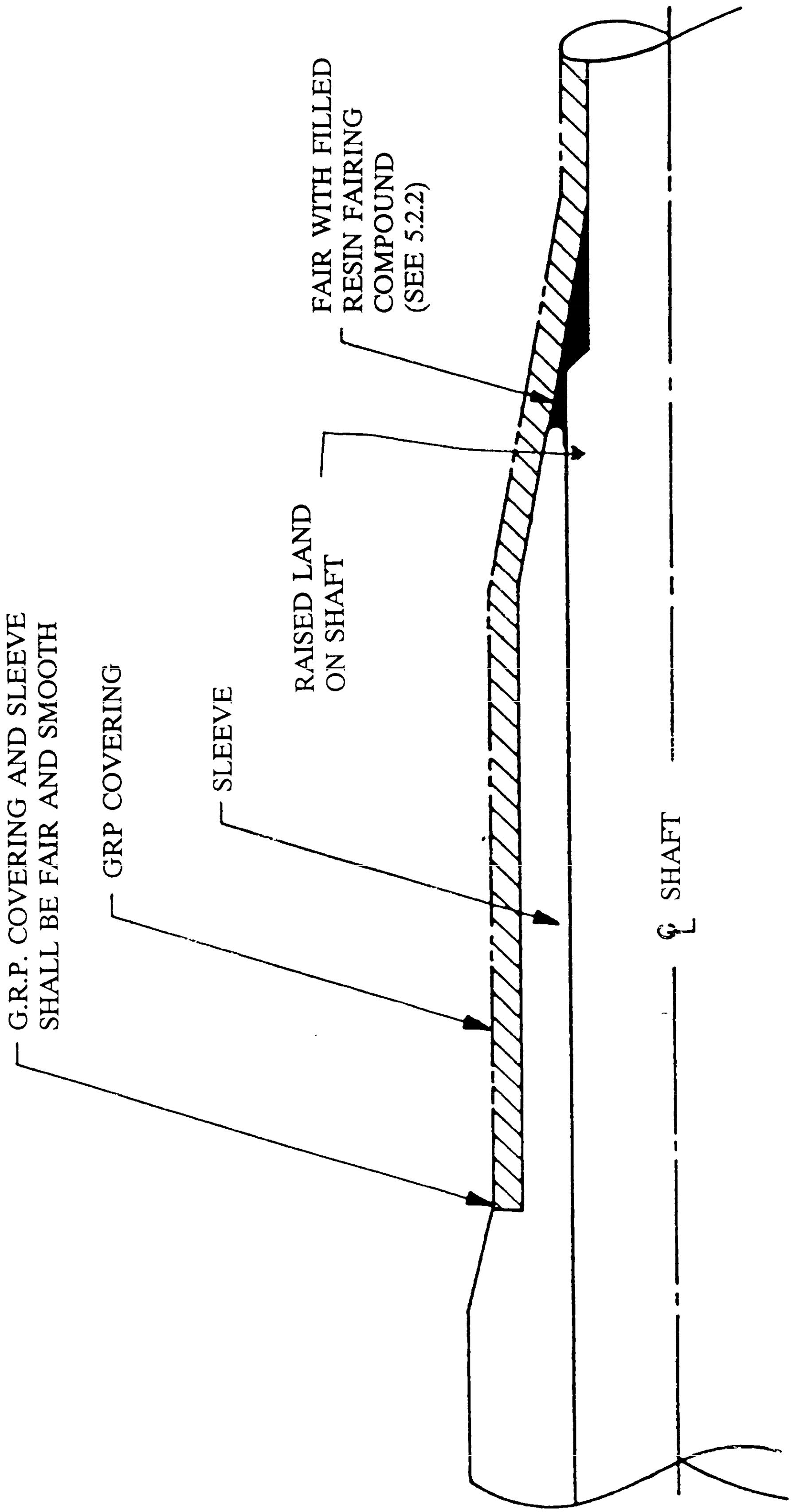
The above DID's were those cleared as of the date of this standard. The current issue of DOD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL), must be researched to ensure that only current, cleared DID's are cited on the DD Form 1423.

6.4 Subject term (key word) listing.

Epoxy
Polyester resin
Thixotropic filler
Woven fiberglass

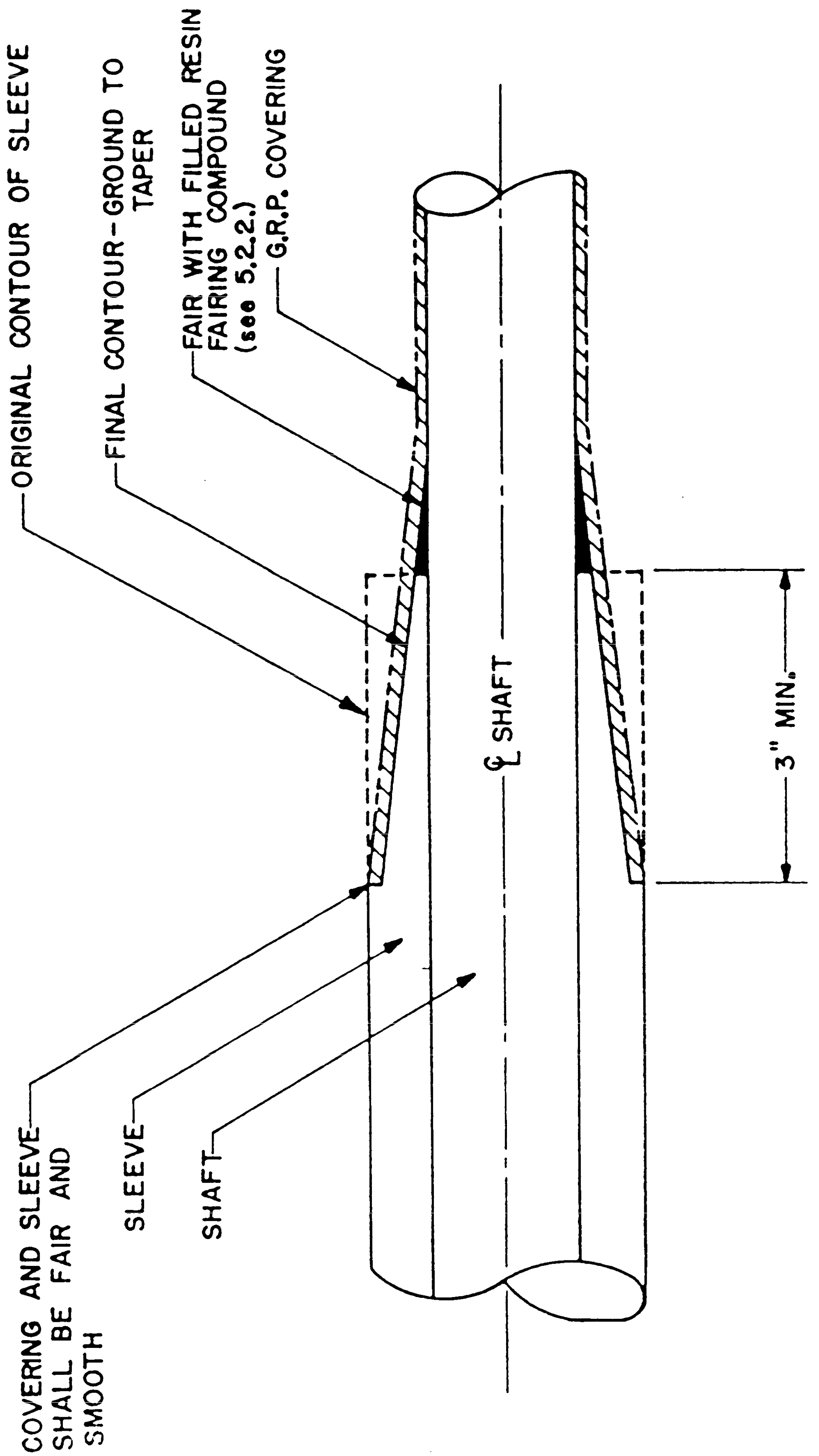
6.5 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Preparing activity:
Navy – SH
(Project 9330-NB03)



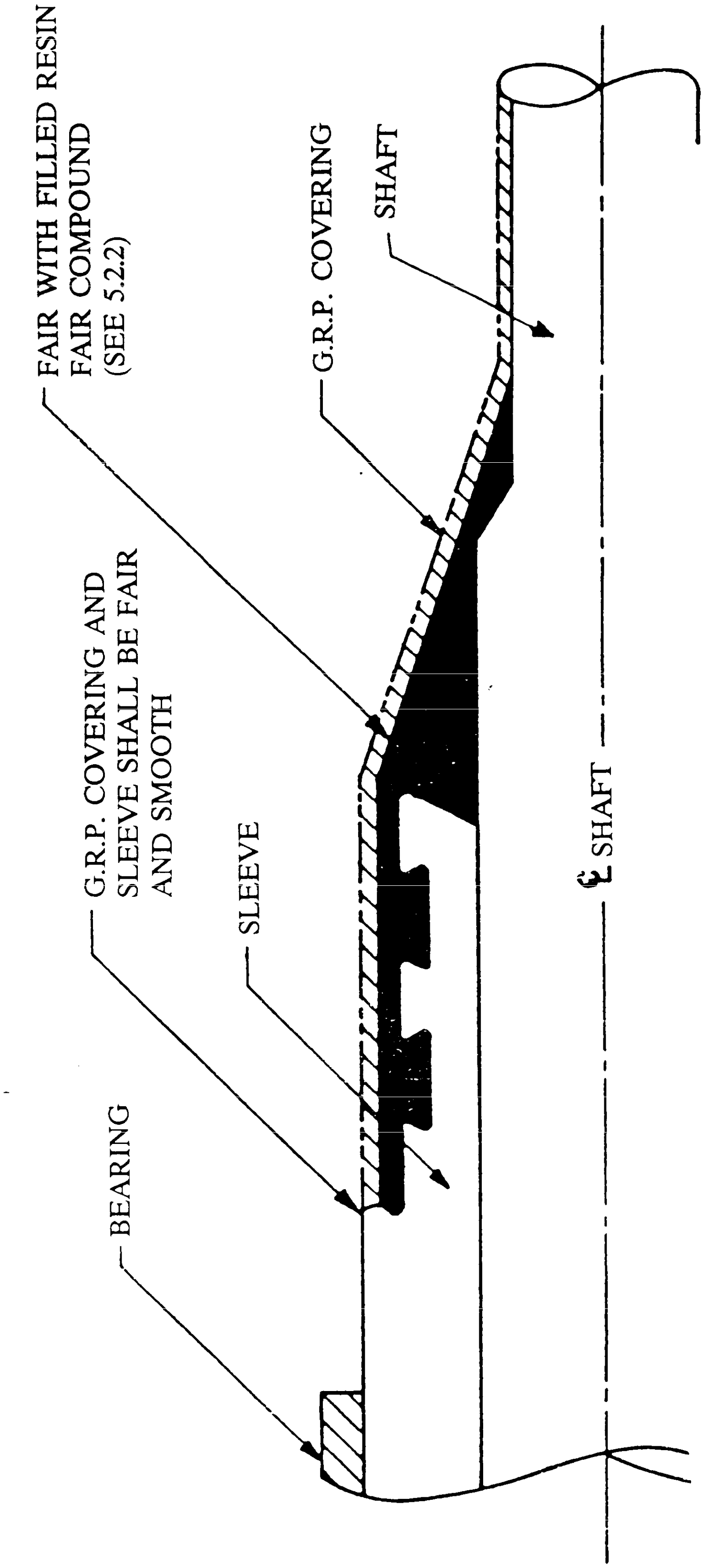
SH 131356

FIGURE 1. *Navy current standard sleeve – suggested resin fairing detail (see 5.4.3.1).*



SH 131357

FIGURE 2. *Bearing sleeve (modified) – suggested resin fairing detail on some older ships (see 5.4.3.1).*

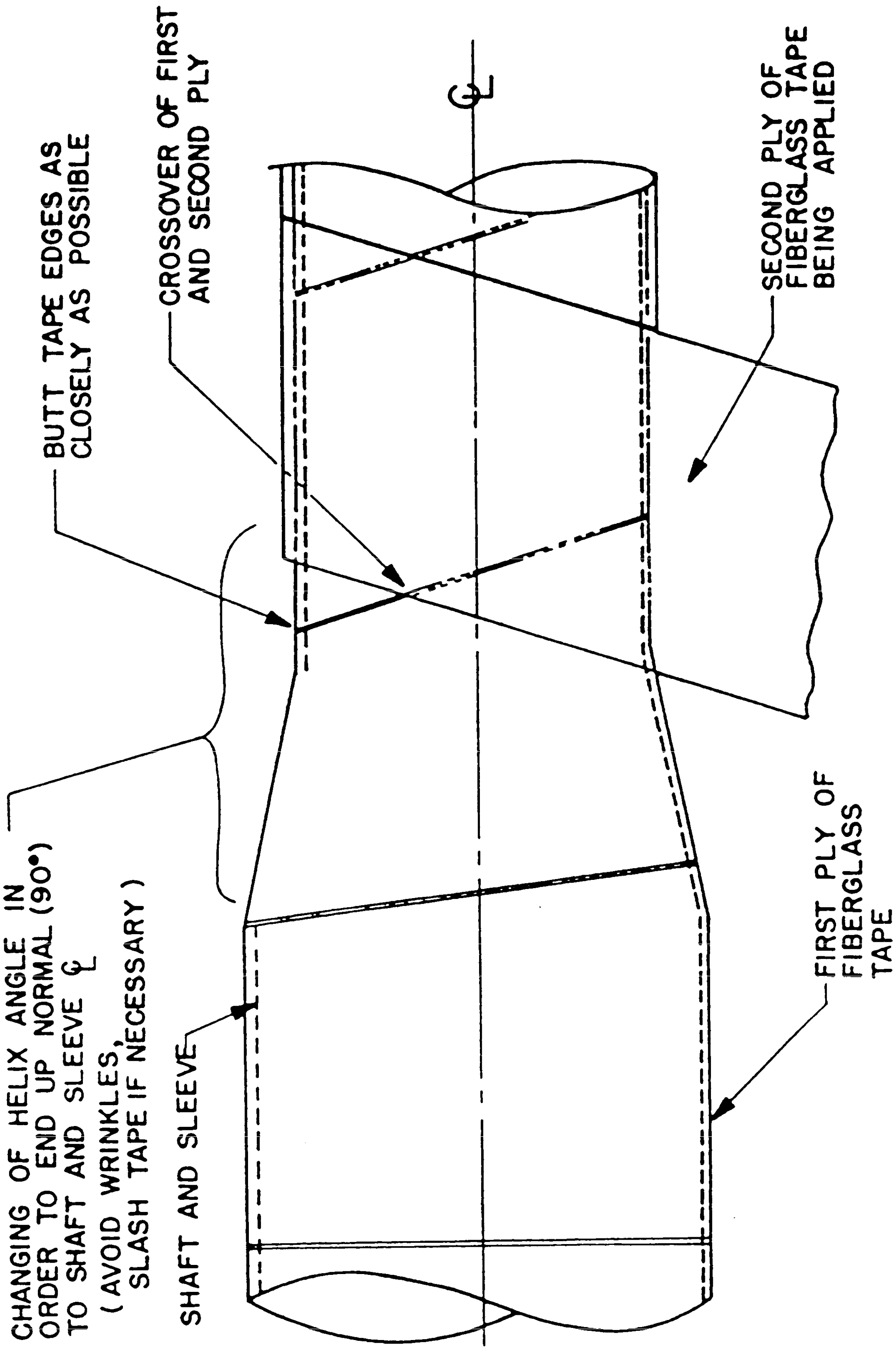


SH 131358

FIGURE 3. *Bearing sleeve (typical configuration) – suggested resin fairing detail on some older ships (see 5.4.3.1)*

SH131359

FIGURE 4. *Resin being applied to shaft.*



SH 131360

FIGURE 5. *Schematic of tape wrap.*

SH 131361

FIGURE 6. *Fiberglass tape being applied to shaft.*