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NAVIGATION AND VESSEL INSPECTION CIRCULAR NO. 8-87 With Change 1
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Subj: Notes on Design, Construction, Inspection and Repair of Fiber Reinforced Plastic (FRP) Vessels

1. PURPOSE. The purpose of this circular is to disseminate to vessel designers, owners and shipyards general information relating to good marine practice when dealing with FRP vessels. It is intended to provide guidance on various aspects of the design, construction, inspection and repair of FRP vessels and amplify certain sections of classification society rules. This circular is based on information from many sources.

2. PERIODICALS AFFECTED. Navigation and Vessel Inspection Circular No. 3-80 is canceled.

3. BACKGROUND.
   a. Compared to steel and traditional wood construction, fiber reinforced plastics have not been in use for a long period of time as a common boat building material. The popularity and variety of FRP has caused the development to exceed the amount of proper guidance on its use. Much of the existing Coast Guard guidance applies only to one aspect of construction or repair, e.g., single-skin displacement hulls with glassed over wood stiffeners.
   b. Traditional small passenger vessel construction has been relatively basic, so that plan review, construction and inspection are customary events. However, many current designs are for complex vessels with various design features, such as sandwich hulls, combination aluminum and FRP structures, hydrofoils and localized use of high strength materials, such as kevlar and carbon fiber. Furthermore, the classification society rules of the American Bureau of Shipping (ABS) and Lloyd's Register of Shipping (Lloyd's) were developed to be used by those societies' specialized technical experts and surveyors, and may be difficult to follow for a traditional yacht builder faced with building a complex vessel or an inspector faced with certificating it.
   c. Repair methods can vary widely but still return a vessel to original strength. However, there is little formal guidance on Raking reliable repairs. To achieve the level of safety desired by the Coast Guard, the best methods were investigated and included in this circular.

4. DISCUSSION.
   a. Regulations for small passenger vessel construction are found in Title 46, Code of Federal Regulations (CFR), Subchapter T, Part 177. This part prescribes the rules of ABS and Lloyd's as acceptable for the structural design and construction of certificated FRP vessels. Regulations for cargo and miscellaneous vessel construction are found in 46 CFR, Subchapter I, Part 92. Owners of uncertificated vessels may find these regulations and this guide useful as a safety reference.

b. In addition to ABS and Lloyd's Rules, there are many other classification society standards, other design standards and existing proven designs. This circular may be used as a guide to present a vessel for certification which has been designed and built to one of those other standards. It also covers aspects of survey and repair unique to FRP vessels.

c. Enclosure (1) is divided into six chapters:

(1) Chapter 1., "Structural Design Considerations," discusses the use of the ABS and Lloyd's rules, methods for gaining approval of designs based on "the five year rule" of successful operation, other standards, and designs based on detail calculations.

(2) Chapter 2., "Plan Submittal Guide," covers submitting plans to the Coast Guard for approval and discusses many acceptable design details not found in the rules.

(3) Chapter 3., "Preliminary Construction Tasks," has information on quality assurance, material property tests, production and inspection personnel safety.

(4) Chapter 4., "Vessel Fabrication, discusses the actual formation of many components into a finished vessel.

(5) Chapter 5., "In-Service Inspections," is information collected from Coast Guard and industry sources about in-service inspections explaining various fault conditions, types of deterioration and ways of surveying collisions.

(6) Chapter 6., "Repairs," discusses many acceptable methods of repair.

5. IMPLEMENTATION. Owners, operators, surveyors and builders are encouraged to follow the guidelines set forth in this circular. Although developed with input from industry, classification societies and experienced inspectors, the Coast Guard realizes that this guide will require occasional revision to keep pace with industry, and welcomes comments from any source on the usefulness, adequacy and applicability of this guide. Send comments to Commandant (G-MTH-3), United States Coast Guard, Washington, DC 20593-0001.

J. W. Kime

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End: (1) Notes on Design, Construction, Inspection and Repair of Fiber Reinforced Plastic (FRP) Vessels

NOTES ON DESIGN, CONSTRUCTION, INSPECTION AND REPAIR OF FIBER REINFORCED PLASTIC VESSELS

GLOSSARY

Aerosol - A term used to describe a broad range of suspensions of solid or liquid particles in air (or in some special cases other gases). The term includes many other more commonly used and misused terms, such as dusts, fumes, smokes, mists, and fogs. Small glass fibers which can remain suspended in air for long periods of times might be referred to as an aerosol. Aerosols do not include gases or vapors.

ACGIH - American Conference of Governmental Industrial Hygienists. A professional society of industrial hygienists formed in 1938. Although primarily composed of persons associated with the government, it is not an official government agency. ACGIH recommendations do not carry the weight of law unless adopted through official rule making.

American Conference of Governmental Industrial Hygienists
6500 Glenward Ave, Bldg. D-7
Cincinnati, OH 45211-4438

Air Inhibited Resin - A resin that will not fully cure on the surface when exposed to air. These resins may have wax introduced into the resin which will migrate to the surface, seal the surface and allow the resin to cure.

ANSI - American National Standards Institute. ANSI is a nonprofit organization whose bylaws provide for membership from national trade, technical, professional and labor groups, firms from commerce and industry, government, consumer groups and similar organizations. It is a national clearing house for standards supported by a national consensus.

American National Standards Institute
1430 Broadway
New York, NY 10018

Approving Authority - For a vessel certificated by the Coast Guard to carry more than six passengers, this will be the cognizant OCMI, the Marine Safety Center or Commandant who approves the design of a vessel.

ASTM - American Society for Testing Materials. ASTM is a scientific and technical organization formed for the development of standards on characteristics and performance of materials, products, systems and services, and the promotion of related knowledge. The ASTM address is:

American Society for Testing Materials
1916 Race Street
Philadelphia, PA 19103

Bedding Compound - White lead or one of a number of commercially available resin compounds used to form a flexible, waterproof base to set fittings.

Bonding Angles - An additional FRP laminate, or an extension of the laminate used to make up the joined member) which extends onto the existing laminate to attach additional items such as framing, bulkheads and shelves to the shell or to each other.

Cabin Sole - See Hull Liner.

Ceiling Concentrations - OSHA Ceiling concentrations, found in 29 CFR 1910.1000, are concentrations which, in addition to the PEL are not to be exceeded during the work shift even for a brief period. For a few chemicals (including styrene) the ceiling can be exceeded up to a "peak" value. The duration of excursions to these peak values are strictly limited and the daily exposure must still be within the PEL average.

Chain Plates - The metallic plates, embedded in or attached to the hull, used to evenly distribute loads from shrouds and stays to the hull of sailing vessels.

Chemical Bond - A bond formed by the chemical cross-linking of the resin polymer during its cure. A primary bond between laminates is a chemical bond. A secondary bond is an adhesive bond to an already cured laminate where the resin has cured to the degree that polymer cross-linking is no longer possible when the next laminate is applied.

Chopped Strand Mat - Fiber reinforcement of short randomly oriented fibers to achieve strength in all directions of a laminate as opposed to woven rovings, knitted or unidirectional fabrics which achieve maximum strength in discrete directions of a laminate.

Cored FRP - See Sandwich Construction.

Fire Retardant - Shipboard materials such as FRP, fabrics, paddings, and draperies, which have a considerably higher degree of flammability than noncombustible materials, yet maintain a degree of protection higher than that of non-fire retardant materials of similar construction.

FRP - Fiber Reinforced Plastics. FRP has been used alternatively to mean fiberglass reinforced plastics, fiber reinforced plastics and many other reinforced plastics. In this guide, it means plastics reinforced with fibers or strands of some other material.

Ganged Woven Ravings - An FRP laminate consisting of adjacent layers of woven rovings without the normally applied layer of chopped strand mat between layers.

Glass Tabbing - Same as Bonding Angles.

GRP - Glass Reinforced Plastic or fiberglass.

Hull Liner - A separate interior hull unit with bunks, berths, bulkheads, and other items of outfit preassembled then inserted into the hull shell. A liner can contribute varying degrees of stiffness to the hull through careful arrangement of the berths and bulkheads.

IDLH - 'Immediately Dangerous to life or Health - A maximum concentration of a hazardous substance to which a person could be exposed without suffering from "escape-impairing symptoms" or any irreversible health effects.

Knitted Fabrics - Fiber reinforcements arranged in layers then knitted together with lighter fibers to maintain shape during lamination. They can be arranged in various orientations to achieve high strength in the desired direction.

Marine Safety Center (MSC) - The single Coast Guard Headquarters it formed from the (now closed) field Merchant Marine Technical offices in the Third, Eighth, and Twelfth Coast Guard Districts. The NSC performs plan review for more complicated designs which are beyond the capability of the local OCMI to review. The MSC's address is:

Commanding Officer
USCG Marine Safety Center
2100 Second Street, SW
Washington, DC 20593-0100

Marine Safety Information System (MSIS) - The Coast Guard's nationwide computer network for managing information on vessels such as principal dimensions, certificates of inspection, unique construction features, violations, etc.

NIOSH - National Institute for Occupational Safety and Health. A research arm of the U.S. Department of Health and Human Services devoted to occupational health concerns.

Publications	Central Office
Public Health Service National Institute for Occupational Safety and Health Cincinnati, OH 45226	Hubert H. Humphrey Bldg, Km 7215 200 Independence Ave, SW Washington, DC 20201

OCMI - Officer in Charge, Marine Inspection - That Coast Guard officer having authority over the plan approval, inspection and certification of a certificated vessel.

OSHA - Occupational Safety and Health Administration - The branch of the Department of Labor responsible for governing safety in the workplace.

Occupational Safety and Health Administration
Headquarters Office
3rd and Constitution Ave, NW
Washington, DC 20210

Panel - The designation of a section of FRP shell plating, of either single-skin or sandwich construction, bounded by longitudinal and transverse stiffeners or other supporting structure.

Peak Exposure Value - An exposure concentration of limited duration as determined by OSHA, and promulgated in 29 CFR 1910.1000. In addition to giving a concentration, OSHA will also specify a duration of the exposure (usually peak exposure (usually several hours). For example styrene has a peak value of 600 ppm/3 min/3 hr. This means that in any given three hour work period, exposures up to a MAXIMUM of 600 ppm can be tolerated for a period not exceeding five minutes. The eight hour time weighted exposure average must still remain at or below the PEL.

Peel Ply - A layer of woven cloth, partially (resin) vetted then applied to the surface of a curing laminate as a surface preparation for a later laminate application. The cloth is peeled off just prior to applying the next layer to present a clean, wax free surface for the next layer.

PEL - Permissible Exposure Limit - The OSHA limit found in 29 CFR 1910.1000. These concentrations, like the ACGIH TLV-TWA, are work shift time weighted averages. Because a PEL is an averaged value it can include (over the workday) values greater than or less than the final average. To set some limit on these high and low excursion concentrations, OSHA sometimes sets ceiling and peak values in addition to the PEL.

ppm - Parts per Million - A measure of the density of a substance in a specified volume of air.
Plan Review - That function performed by the Coast Guard approving authority to check and approve design plans.

Primary Bond - See Chemical Bond.

Sandwich Construction - That type of FRP construction which uses a light weight core material bonded to both inner and outer skins to increase panel stiffness, carry shear loads and reduce weight.

Scantling - The size or weight dimensions of the members which make up the structure of a vessel.

Secondary Bond - See Chemical Bond.

Secondary Structure - Secondary structure is considered that which is not involved in primary bending of the hull girder, such as frames, girders, webs and bulkheads which are attached by secondary bonds.

Shell - The watertight boundary of a vessel's hull.

Skin - Generally, a term used to describe all of the hull shell. construction there is an inner and outer skin which together than the single-skin laminate that they replace.

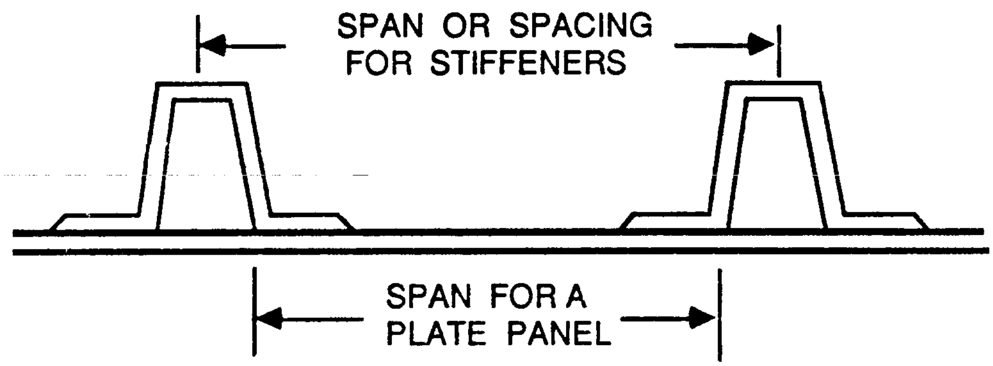
For sandwich are thinner

Skin Coat - A special layer of resin applied just under the gel coat to prevent blistering. It is sometimes applied with a layer of mat or light cloth.

Spacing (of stiffeners) - Stiffener spacing is measured from center to center on the stiffeners. This may not be the same dimension used for the effective width of plating considered along with the stiffener to determine section modulud. See Figure G-l and ABS Rules (3.4).

Span - The unsupported breadth of shell plate panel or the spacing (span) of the supporting stiffeners. The span of a panel is taken from the inboard side of a stiffener leg across the panel to the inboard side of the adjacent stiffener leg. See Figure G-l.

Figure G-1



Stiffener - A frame which supports a panel of the hull, a tank or a bulkhead.

Stringer Plates - Additional thickness of laminate required by ABS Rules (11.2.4) for additional stiffening in the deck in way of large openings for vessels over 100 FT.

T-boat - A small passenger vessel certificated by the Coast Guard under 46 CFR Subchapter T to carry more than six passengers for hire.

TLV-STEL - Threshold Limit Value - Short Term Exposure Limit - Same as TLV-TWA except that the short term safe exposure limit set by the ACGIH is determined for a period of 15 minutes.

TLV-TWA - Threshold Limit Value Time Weighted Average - A recommended exposure limit promulgated by the ACGIH. The ACGIH further defines it as "the time-weighted average concentration for a normal 8-hour per day workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect."

Unidirectional Fibers - Fiber reinforcement arranged primarily in one direction to achieve maximum strength in that direction.

CHAPTER 1. STRUCTURAL DESIGN CONSIDERATIONS

A. Introduction.

1. There are many methods by which a fiber reinforced plastic (FRP) vessel can become Coast Guard certificated. The American Bureau of Shipping (ABS) Rules for Building and Classing Reinforced Plastic Vessels, 1978 (ABS Rules) apply to vessels up to 200 feet in length of normal form, and require special consideration for vessels of unusual form or design features. Lloyd's Register of Shipping Rules and Regulations for the Classification of Yachts and Small Craft (Lloyd's Rules), Part 2, Chapter 2, Glass Reinforced Plastics, apply to vessels of not more than 30 meters (100 feet) in length. This chapter addresses the use of these and other acceptable design methods.

2. Many designs are based on existing vessels or extrapolated from smaller successful vessel designs. Builders whose results are based on experience with previous vessels may never have submitted a rule based design to the Coast Guard. This chapter should help to ensure that an adequate design is presented to the Coast Guard for approval, and discusses the design methods and features acceptable to the Coast Guard and allowed by the regulations as discussed below.

3. The process of certificating an FRP vessel to carry passengers under the United States flag is regulated by Title 46, Code of Federal Regulations (CFR), Subchapter T (T-boat regulations). FRP is prohibited as a construction material for vessels carrying 150 or more total passengers (46 CFR 177.l0-5(a-l)) or 50 or more passengers with overnight accommodations. FRP is also prohibited for carrying 13 or more passengers on international voyages covered by SOLAS (Chapter 11-2, Regulation 23.1 of SOLAS '74 as amended) unless equivalencies or exemption determinations have been granted by the cognizant OCMI. Regulations for cargo and miscellaneous vessel construction are found in 46 CFR, Subchapter I. Federal Regulations can be purchased from Superintendent of Documents, Government Printing Office, Washington DC 20402, (202) 783-3238. Regardless of the type of construction or rule basis, the design must be reviewed and approved by the cognizant OCMI or, for complicated designs, the Marine Safety Center (MSC). The designer must provide the Coast Guard with plans required by 46 CFR 177.05 or 91.55 and additional plans as necessary to show design features which meet the classification society rules. If the classification society rules are not followed directly, the designer must provide, in addition to the required plans, adequate documentation to show the successful history of the design basis. The designer should follow the principles of good marine practice set forth in this guide or provide a viable alternative.

B. Directly Acceptable Classification Society Rules. In general, the Coast Guard will approve a design which meets the ABS Rules for Reinforced Plastic Vessels or Lloyd's Rules, Glass Reinforced Plastics Chapter. Use of other classification society rules will require special consideration by the Coast Guard. A list of classification societies and their addresses are in Enclosure C. The design may be reviewed by the local OCMI against ABS or Lloyd’s Rules, or forwarded to the MSC for special consideration.

1. American Bureau of Shipping.

a. The ABS rules for building and classing many types and sizes of vessels of different materials have long been the basis for Coast Guard approval of marine structures. ABS was delegated plan review authority for large vessels by NVIC 10-82, but the Coast Guard has retained the responsibility for approval of fire fighting, lifesaving and cargo oil safety systems for large vessels, and full responsibility for approval of small passenger vessels covered by 46 CFR Subchapter T CT-boats). Most of the approval for T-boats is done by the cognizant OCMI.

b. The ABS Rules can be a complete guide for designing and building FRP vessels if used by an experienced naval architect and an experienced builder, both familiar with the use of the ABS Rules or working in conjunction with an ABS surveyor. The ABS Rules apply to vessels of normal hull form which are less than 200 feet in length. For vessels of other than normal form, ABS will give special consideration to the design for ABS approved plans and/or classed vessels. However, the Coast Guard performs the approvals of T-boat designs and applies a number of criteria for special considerations, as explained in the following sections.

2. Lloyd's Register of Shipping. Lloyd's Rules are also acceptable to the Coast Guard as a design basis for FRP vessels. Where the current ABS rules are in English and metric units Lloyd's Rules are all metric and only applicable for vessels up to 30 meters in length, or about 100 feet. Designers should note differences in Lloyd's definitions for vessel measurements, material strengths, conversions, span of plating, siding and molding.

C. Other Rules.

1. ABS Yacht Guide. The ABS Guide for Building and Classing Offshore Racing Yachts (1986) is not alone sufficient as a standard for a sailing passenger vessel. This guide contains many design features which may be appropriate for limited purpose racing vessels but not for commercial passenger vessels. However, some design details in the ABS Yacht Guide are appropriate for any vessel and will be directly referenced in this guide. An existing vessel which has already been built to the ABS Yacht Rules may be reviewed according to ABS or Lloyd's Rules, or reviewed to another applicable rule which is properly supported and referenced. Where deviations from the applicable rules are encountered, special consideration will be given based on a sound and complete engineering analysis presented by the designer.

2. Other Classification Society Rules and Standards. The previous direct reference to ABS and Lloyd's Rules is based on the familiarity that Coast Guard inspectors and technical personnel have with reviewing a vessel designed to those standards. This does not prevent a design from being based on the rules of another classification society or on some other standard. A list of classification societies and their addresses are in Enclosure C. The burden of proof rests with the designer to show, with thorough engineering

documentation and logic, that a proposed vessel meets a level of safety at least equivalent to that prescribed by ABS or Lloyd's Rules.

a. <u>Required Documentation</u>. A step by step analysis of how a particular design meets the various requirements of a certain standard must be presented to the Coast Guard reviewing authority along with a complete copy of the standard if the Coast Guard office does not have one. Few Coast Guard field offices have copies of uncommon or foreign standards.

b. <u>Qualification of Standards</u>. Other classification society standards may be accepted by the Coast Guard as long as the design presented falls within the range of applicability of the particular standard. Qualification of other standards will be specially considered, usually by the MSC or Commandant (G-MTH-3), on a case basis. Consideration will be given to the thoroughness of the standard, the number of vessels built to it, the service and success of those vessels and the experience of the builder. This review process may be lengthy and should be undertaken early in the design process.

D. <u>The Five Year Rule</u>.

1. <u>Definition</u>. The "Five Year Rule" is defined in 46 CFR 177.10-1(a) as:

"when scantlings differ from such standards and it can be demonstrated that craft approximating the same size, power and displacement have been built to such scantlings and have been in satisfactory service insofar as structural adequacy is concerned for a period of at least 5 years, such scantlings may be approved. A detailed structural analysis may be required for specialized types or integral parts thereof."

Determinations for meeting this rule are made for each case on an individual basis by the OGMI. There is no similar provision in Subchapter I for cargo and miscellaneous vessels.

2. <u>Burden of Proof</u>. The burden is upon the designer or owner to show the similarities between the proposed vessel and an existing vessel. The Coast Guard approving authority may need documentation showing the similarities in size, power, displacement and scantlings, and may conduct a survey and/or underway check of the similar vessel's performance in the anticipated operating area. Scantlings can vary greatly for similar sized FRP vessels depending on materials used, glass content, construction methods and use of cores. Two vessels from the same mold are not a similar vessel if they are constructed differently.

3. <u>Satisfactory Service</u>. The service life of small passenger vessels vary greatly depending on location and use. An inner harbor tour boat experiences a vastly different service environment than does a deep sea party fishing vessel, and is normally designed quite differently. An existing vessel used as a basis for a proposed new vessel should have experienced at least the same operating environment planned for the new vessel for five years, shoving satisfactory service. A similar relationship of experienced service to

expected service should be presented to the OGMI for an existing vessel changing service into Coast Guard certification.

E. Detailed Design Calculations for Departures From the Rules.

1. General. ABS and Lloyd's FRP Rules have been developed over a long period based on scantlings of successful vessels. As such, these rules are a proven basis for vessel design in which the Coast Guard has confidence. Many design variations can be accommodated by the rules for different material strengths and structural arrangements. where a proposed design differs significantly from these rules and cannot be reasonably based on the "five year rule," the Coast Guard will review the design to ensure an equivalent level of safety. The degree of this specialized review will depend on the degree to which a vessel or parts of a vessel depart from the rules.

2. Supporting Documentation. Vessel designs developed independently from the established rules must be meticulously documented. Detailed engineering calculations must be based on recognized engineering standards and principles and supported by substantiated material test results. Elements of the expected operating environment should be identified and the resulting loads analyzed against the strength of the proposed laminate with an appropriate amount of conservatism.

3. Material Qualifications. A design based on non-standard, special, or high strength materials should have the referenced material properties well documented and proven. ABS Rules contain procedures for process control (1.8), quality control (5.4) and other tests (5.4.6) to be conducted during construction. Test data from manufacturers, independent test labs and government tests are examples of acceptable forms of proof of material properties. Acceptable test methods are the American Society for Testing and Materials (ASTM) tests identified in Chapter 3 of this NVIC. Other test standards or procedures should be submitted to the Coast Guard for approval. Fatigue properties should be evaluated in a manner to simulate extended exposure to the marine environment.

F. Fire Protection. Resins, coatings, paint and sheathing should be fire retardant or made to provide an equivalent degree of fire safety. The intent of specifying fire retardant resins or coatings is to provide material. with a lower probability of ignition and slower flame propagation than wood.

1. Application. These guidelines apply to vessels constructed using the following material arrangements:

   a. Hull, deck, and deckhouse constructed of FRP.

   b. Deck and deckhouse constructed of FRP and hull constructed of some other material (e.g. aluminum).

   c. Wooden vessels with resin gel coats or an FRP sheathing system.

2. Fire Retardant Resins. Polyester resins are determined to be fire retardant if they comply with Military Specification (Milspec) Mil-R-21607. Polyester resins that have not been

yet accepted under Mil-R-21607 and other resin types such as epoxy and vinyl ester, may be accepted as fire retardant resins if they have a flame spread of 25 or less when tested to ASTH Standard E-84. This data should be provided from specimens that have met the aging criteria of Mil-R-7575C or similar. Milspecs may be obtained from Commanding Officer, Naval Supply Depot, 5801 Tabor Avenue, Philadelphia, PA 19120. This information is necessary to determine the suitability of the composite for marine use.

3. Coatings.

a. Gel Coat. The average thickness of general purpose, non-fire retardant gel coat should not exceed .035" when used on surfaces in accommodations, service spaces, control stations and external vertical surfaces on the deckhouse or superstructure. General purpose gel coats can be used to any thickness on hull and horizontal surfaces that are exposed to the weather. Fire retardant gel coats are not limited by location or thickness.

b. FRP Sheathing on Wooden Vessels. FRP sheathing is considered a sealing or protective system only. Sheathing is not credited towards hull strength requirements. It should only be applied to a Coast Guard certificated wooden vessel with the prior approval of the OGMI. Sheathing on the exterior hull and horizontal surfaces exposed to the weather need not use fire retardant resins. Sheathing in accommodations, service spaces, control stations and external vertical surfaces on the deckhouse should be fire retardant.

4. Fire Protection Equivalencies. An equivalent degree of fire safety can be achieved from non-fire retardant resin vessel construction with the following guidelines. Final determinations for equivalencies will be made on a case basis by the OCMI. Exceptions to allowed equivalencies are noted in paragraph 1.F.5. below.

a. Resin. The general purpose (non-fire retardant) resins being used should have a flame spread of 200 or less when tested to ASTM Standard E-84. The resin properties described in Chapter 3 of this NVIC should be provided.

b. Cooking and Heating Appliances. Galleys should be surrounded by B-15 rated fire boundaries (see 46 CFR 72.05-l0(c)(2)). This may not apply to concession stands which are not considered high fire hazard areas (galleys) as long as they do not contain medium to high heat appliances such as deep fat fryers, flat plate type grilles, and open ranges. Open flame systems for cooking and heating are not allowed for equivalencies.

c. Sources of Ignition. Electrical equipment and switch boards should be protected from fuel or water sources. Fuel lines and hoses should be isolated as far as practical from heat sources. Internal combustion engine exhausts, boiler and galley uptakes, and similar sources of ignition should be kept clear of and suitably insulated from any woodwork or other combustible matter. Internal combustion engines that have dry exhaust systems should be installed in accordance with National Fire Protection Association (NFPA) Standard 37, "Stationary Combustion Engines and Gas Turbines." NFPA Standards can be obtained from NFPA, Batterymarch Park, Quincy, MA 02269.

d. <u>Fixed Detection and Extinguishing Systems</u>. A Coast Guard approved fixed fire extinguishing and heat detection system should be installed in the machinery space, per guidance in NVIC 6-72 and 6-72 change 1. Fixed extinguishing systems approved under 46 CFR 162.029 can be used if the systems are installed per the following guidelines:

(1) These systems are only permitted in unmanned machinery spaces. The space must not be larger than the largest space that the system is designed to protect and only one system is permitted to protect each space. The system should be located such that its actuating element will have the best exposure to the high fire risk area.

(2) The system should automatically shutdown all power ventilation fans. All ventilation openings must have manual closures, and the system designed to account for the extinguishing agent losses prior to their closure. Halon systems protecting diesel engine spaces must also have automatic engine shutdowns.

(3) The system should also be capable of manual release from outside the space protected.

(4) Discharge of the system must be automatically signaled at the operator's control station by both audible and visual means.

(5) If the system is actuated by manual release only cylinders and actuation components must be located outside the space protected with the actuation controls easily accessible.

An approved fixed smoke detection system should be installed in enclosed accommodations spaces (e.g. below the main deck on T-S vessels). Additional detectors may be required in isolated spaces, such as voids and storage lockers, if the cognizant OCMI determines that a source of ignition, such as electrical equipment or a "dry type" engine exhaust run, is present. A fixed heat detection system should be installed in the galley.

e. <u>Machinery Space Boundaries</u>. Boundaries that separate machinery spaces from accommodations, service spaces, and control spaces should be lined with noncombustible panels or insulation approved by 46 CFR 164.009.

f <u>Furnishings</u>. Furniture should be constructed of noncombustible or fire retardant materials. Draperies, veneers, and interior finishes should be fire retardant.

5. <u>Exceptions to Equivalencies</u>. The following limitations are placed on granting equivalencies to non-fire retardant vessels.

a. Overnight Accommodations. Vessels with overnight passenger accommodations are not granted equivalencies.

b. Gasoline Fuel Systems. Vessels powered by gasoline engines are not granted equivalencies, except for vessels powered by outboard engines with portable fuel tanks stowed aft, if the arrangement does not present an unreasonable hazard as determined by the OCMI.

c. Route. Route is not considered a determining factor. Fire hazards and escape routes on board a vessel are essentially the same whether the vessel is moored, operating in rivers or on a 20 mile route.

d. Cargo. Vessels that intend to carry hazardous, combustible or flammable cargo will not be considered for equivalence.

CHAPTER 2. PLAN SUBMITTAL GUIDE

A. Introduction.

1. This chapter is intended as a general reference and guide for submitting the plans for a proposed vessel to the Coast Guard. It is not a complete text on naval architecture or a commentary on classification society rules. Plans should be submitted in accordance with 46 CFR 177.05-1 or 91.55. Plans for the MSC should be folded and submitted in triplicate.

2. This chapter uses ABS Rules as a main reference (numbers in parentheses refer to ABS Section numbers), and should be used as a reference for designs based on other standards. This chapter may not be fully applicable to a design which departs from established rules. However, many design features mentioned here are applicable to all designs, so this chapter should serve as a useful guide.

3. Scantling requirements are given by thickness and weight. ABS Rules are thickness based considering a basic laminate of mat and woven roving (4.4). Lightweight mat and cloth are not credited towards the -required thickness (4.4.3) and the final as-built thickness can vary by plus or minus 15 per cent and be acceptable (4.4.4). Further variations must be accounted for by the relationship in (4.4.5). Other rules, Lloyd's Rules for example, are weight based and prescribe a weight of reinforcement per area of basic laminate with appropriate modifications for different strength materials.

B. Determining Section Modulus and Moment of Inertia.

1. Calculation Guide. Figure A-l, Enclosure A, is a sample calculation for section modulus (SM) and moment of inertia (I) of a typical hat section stiffener attached to an effective width of single skin FRP plating. The effective width w is determined from (3.4) as the lesser of the frame spacing or b + 18t where b - width of the base of the stiffener and t - thickness of single-skin plating, or equivalent single-skin thickness for sandwich panels, to which it is attached.

2. Tables for Normal Sections. Standard tables showing moment of inertia properties of various cross sections are available in many handbooks. The properties of these sections, when attached to the effective width of shell plating, may be used to determine the section modulus of the combined structure to compare it to the rule requirement.

3. Sandwich Panels. ABS Rules (7.1.3) require the two skins of a sandwich panel to have the same moment of inertia as the single-skin laminate that they replace. The rules also have a required minimum total thickness. For calculating the section modulus of stiffeners attached to a sandwich panel, (3.4.1) prescribes a single-skin laminate that has the same moment of inertia as skins of the sandwich panel to determine the effective width of plating. Figure A-3 in Enclosure A shows an example of this calculation, and Figure A-2 an example of calculating section modulus with a sandwich panel.

4. <u>High Strength Materials</u>. ABS Rules (4.4.5) and (4.4.6) have relationships on modifying the original laminate where higher strength laminates are used throughout. Mixing of fibers is not recommended. Where a higher strength reinforcement is used in a highly stressed area, such as the top flange of a stiffener, Lloyd's Rules, Section 2.2.4.4.2, describe a method by which the sectional area of the higher strength laminate may be increased by the ratio of the tensile module of the two laminae. Figure A-2 shows a modification of the Figure A-1 example to take this into account. Additionally, for much higher strength materials, care should be taken to match the strain to failure of the reinforcement with that of the resin.

C. <u>Checking the Hull</u>. This is a basic guide on checking a proposed structure against an established rule or design basis. It is based on the ABS FRP Rules, but the principles could be used for following other rules as well. The rules will not be restated here, just generally referenced with notes on applications.

1. Shell. Determination of required shell or hull skin thickness is by straight forward. ABS Rules are divided into displacement and planing vessel sections. The definitions of planing and displacement are in (2e10) and (2.11) but are not specific on a numerical dividing line between displacement and planing vessels. A general guide for making this determination is that a "speed-length" ratio (speed in knots divided by the square root of waterline length in feet) greater than 2 indicates a planing vessel. That is:

$$V / \sqrt{LWL} \rangle 2 \quad \text{:PLANING.}$$

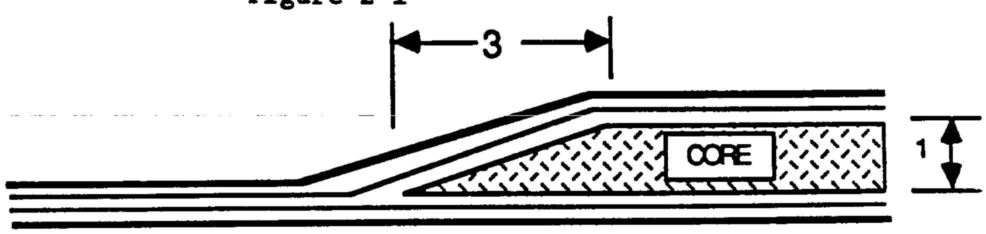
Transitions from sandwich to single-skin laminates are to be on a gradual taper of at least 3 to 1 (5.3.2) as shown in Figure 2-1. Encapsulation of wood other than plywood or balsa for shell plate core is not permitted (4.5.4). Plans submitted for Coast Guard approval required by 46 CFR 177.05, along with supporting information, should include details for the following items:

a. laminate schedule including glass content;

b. Additional reinforcement for through-hull fittings, shaft struts, chain plates, etc; and

c. Chine, transom and keel or hull half joints.

Figure 2-1



SANDWICH TO SINGLE-SKIN TAPER

2. Framing. The various rules have section modulus requirements for the framing system which stiffens the FRP panels (7.2). A sailing vessel with a highly curved cross section may need little panel stiffening because of the curvature of the hull (7.l.2c), but local reinforcement i8 needed for such items as the ballast keel, chain plates and supports for the auxiliary engine. Encapsulation of wood for stiffeners is permitted except for stiffeners inside tanks. Plans submitted for Coast Guard approval should include the following stiffener details:

   a. Laminate schedule, including directionality and glass content for high strength laminate;

   b. Core or stiffener form material;

   c. Bonding angle configuration;

   d. Secondary bond preparation details; and

   e. Limber holes and sealing of same.

3. Keel. The keel must be designed to withstand docking, grounding and transportation loads and, in many cases, to efficiently join hull halves. ABS Rules (7.l.2d-g) prescribe scantlings for reinforcing the hull laminate at the keel. The keel joint for joining hull halves is usually a secondary bond and proper preparation details should be specified in the plans. Additional consideration should be given to increased scantlings for vessels that are regularly beached or operated in ice.

4. Deck-to-Hull Joint. This is one of the most critical joints in an FRP vessel. Designed correctly, it will be relatively trouble free in construction and in service. Designed improperly or such that it is difficult to construct or prone to construction inaccuracies, the deck-to-hull joint may be the source of problems from nuisance leaks, hull or deck cracking, flooding or full joint failure.

   a. ABS Rules. Section (6.10) of the rules prescribes typical acceptable deck-to-hull joints. Where a non-typical joint is presented for Coast Guard approval, it should be presented with additional documentary support described in Section D under the Structural Standards section. Sandwich panels should be tapered to single-skin in way of the joint on a 3 to 1 slope (5.3.2) as in Figure 2-1.

   b. Riveted Joints. Expanding type rivets (blind or "pop" rivets) in deck-to-hull joints are not permitted (6.5.4). Conventional riveted joints (6.5.5) have been used successfully on smaller and limited service vessels and may be considered for approval with documentation of successful service in similar vessels.

5. Integral Tanks. ABS Rules (9) have extensive requirements for integral tanks including plating thickness, stiffeners, access openings and cofferdams between tanks of dissimilar liquids. ABS Rules presently prohibit integral tanks with sandwich panels for fuel or potable water on the shell. 46 CFR 182.20-22(a), allows closed cell, polyvinyl chloride foam cored laminates as integral diesel fuel tank boundaries. U.S. Food and Drug Administration Regulations, 21 CFR 1250, Subpart P:, prohibit integral potable water tanks next to the skin, the bottom of which are less than 2 feet above the waterline.

6. Transoms and Hard Chines. ABS Rules (7.l.2h) and (8.l.2e) prescribe additional reinforcement requirements for transoms and hard chines which are laminated in the same process as the hull. Figure 2-2 shows a method of corner construction for sandwich construction that has been shown (ref 18) to produce stronger corner joints by reducing stress. This simple diagram does not show the required additional reinforcement. Some designers and builders leave the stern open for hull access while building, build the transom separately and attach it after the hull shell is complete. In this case, scantling requirements for plate keels in hulls molded in halves should be applied to attaching transoms as well. Special consideration will be given to other transom designs.

Figure 2-2

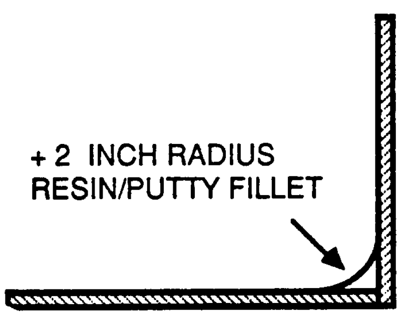
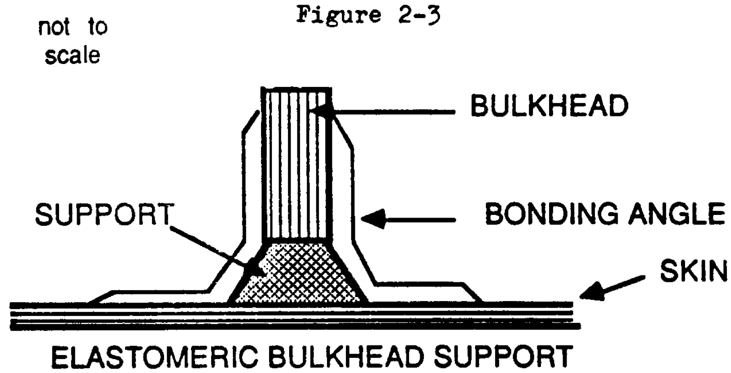


Figure 2-3



7. Bulkheads. Small passenger vessels certificated by the Coast Guard must also meet 46 CFR 170 and 171 for arrangement and spacing of watertight bulkheads. ABS Rules (10) have requirements for scantlings of watertight bulkheads and attaching bonding angles (6.8). Notable items to consider for designing bulkheads are:

   a. Non-watertight bulkheads usually serve as transverse deep webs and should be adequate as such.

   b. Bulkheads are stiffened panels, and general guidelines for designing bottom panels apply.

   c. Penetrations in watertight bulkheads are limited by (10.5) and 46 CFR l7l, Subpart P:. They are to be watertight and as far inboard and as high as possible.

   d. Engine rooms should be enclosed by watertight bulkheads.

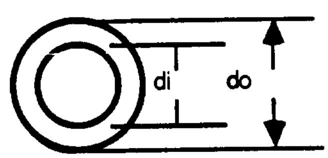
e. Bulkheads should be landed 6n some kind of foam or other elastomeric support as shown in Figure 2-3 above.

D. Checking the Deck. ABS Rules are straight forward on required deck scantlings. Structural members above deck should land on structural supports below deck. Where hull, deck and/or deckhouse are of different materials, the structural connections must be arranged to carry the moment and shear, as well as bearing loads.

1. Stanchions. ABS Rules (11.5) prescribe scantlings for metallic and wood stanchions. (11.5.4) recommends against FRP stanchion.. Use of FRP stanchions will be given special consideration. Stanchions should be arranged to carry loads from above and to reduce the span of deck beams. They should have metallic pads at the ends to distribute loads evenly to the beams and stiffeners. Calculation of radius of gyration and area for stanchions properties is shown in Figure 2-4.

2. Stringer Plates. Stringer plates (11.2.4) are required in way of large openings for all vessels over 100 ft long and should be considered for shallow beamy vessels less than 100 ft long if LID (length/depth) is greater than 14. Construction drawings should indicate that laminate edges are not to be exposed but sealed with resin and that exposed cores are sealed with resin impregnated mat (6.2) or similar fiber reinforcement.

Figure 2-4



$$\text{RADIUS OF GYRATION} = \frac{di^2 + do^2}{4}$$

3. Other Considerations. Some additional items which require particular attention are:

a. Equipment foundations, especially those for anchor windlasses, mooring gear, sail handling winches and deck stepped mast landings. Cored decks must have effective structural inserts for equipment foundations and in way of point loads.

b. Local reinforcement for attachment of rails and towing fittings.

c. Deck opening reinforcements.

d. Heavy use areas such as at boarding ladders, cargo handling decks, and cabin trunks, which may need additional strength.

E. Checking the Deckhouse. ABS Rules (12) prescribe scantlings for the deckhouse. Where local sea conditions consist of steep waves, such as the regulated boating areas designated in 33 CIR 177.08, or where there have been a significant number of casualties dealing with caved in deckhouses, the local OCMI may prescribe additional requirements for certificated vessels. Drawings submitted for Coast Guard approval should include:

1. Laminate schedule;

2. Deckhouse to deck joint details if the deckhouse is not molded integrally with the deck;

3. Portlights, windows and doors;

4. Door sill and weather seal details; and

5. Details showing alignment of structural supports.

F. Machinery Installations. ABS Rules (6.7 with figure 6.5) give some details on machinery foundations. The type of loads to be encountered should be considered when designing machinery installations.

1. Main Propulsion Engines. Main engine arrangements usually contain the propeller thrust bearing in the reduction gear which is attached directly to the engine casing. For large units, the reduction gear and thrust bearing may be separate units. In either case, the longitudinal girders must support engine and gearbox weight, vibration and torque plus propeller thrust. The girders should be continuous through transverse webs and bulkheads, and should be cross braced to resist tripping and support the torque of the drive system. Engine mounting bolts should be properly sized in accordance with the manufacturers instructions.

2. Propeller Shafts and Rudders. ABS Rules (18) have minimum requirements for propellers and shafts including shaft diameters, journal liners, blade thickness and material properties. Documented successful experience with stock equipment is an acceptable alternative as described in Paragraph l.C of this NVIC. Details of attaching these to an FRP hull can be generally derived from (6.7). Shaft struts should be securely bolted to reinforced shell plate considering (6.5.2). For bearings laminated into the hull, the hull should be reinforced (7.l.2i), up to a double thickness for 6 inch diameter openings, over the normal single-skin (single-skin equivalent for sandwich construction) thickness. Rudder bearings should be similarly reinforced.

G. Special Design Details.

1. Sailing Vessels. Sail powered vessels may not require the bottom high powered planing vessel but they have unique loads which must be accounted for in the design.

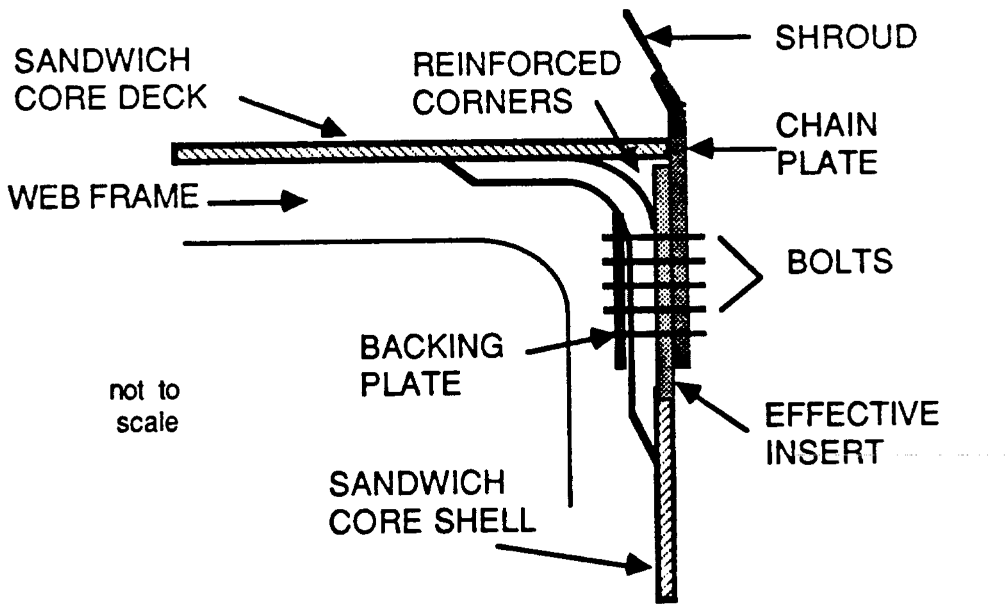
a. Shell Plate. Sailing vessels spend much of their time heeled over with much of the side shell submerged. Unless the vessel is unusually stiff so as not to heel under most sailing conditions, consideration should be given to carrying the bottom shell thickness around to one half the freeboard above the design load waterline.

b. Chain Plates. Chain plates are the attachment points for the shrouds and stays that support the mast(s). Depending on the height of the mast and the performance required of the rig, the chain plates may be under very high constant stresses. ABS Rules (6.9) have requirements for chain plate arrangement$_1$ materials and bolts based on the breaking strength of the attached rigging. The side shell in way of the chain plates is to be increased in thickness 25 per cent for a distance fore and aft of the chain plates equal to the beam of the vessel at the mast (8.l.2f). The plates should be designed to the compressive strength of the FRP laminate and the shear strength of the bolts. Figure 2-5 shows aan arrangement of chain plates. If the rigging loads are transmitted to the shell through the bolts only, the FRP plating or resin filled inserts will stretch or creep around the bolt holes. This effect is more pronounced at higher temperatures or when the constant stress on the FRP is above 20 per cent of its ultimate strength. Resulting problems could range from nuisance leaks, eventually opening up the shell laminate for water penetration and delimitation, to chain plate pull out. Web frames or bulkheads should be arranged in way of the chain plates to support the compressive loads of the rigging.

c. Mast Support. The mast supporting structure must carry in compression the weight of the mast plus the combined tensile loads of the rigging. Solid metallic pads should be provided under the mast to distribute the load evenly to the FRP structure.

(1) Compression Posts. Masts stepped on deck require a compression post or similar structure to transmit the rigging loads to the keel or by another suitable means back to rigging. On smaller vessels, this may take the form of a framework to bridge the centerline passageway. Such frameworks will be specially considered. They should be designed to transmit the load of the mast evenly to the supporting bulkheads or stanchions. The stanchions should be designed to (11.5).

Figure 2-5



(2) Floors. Whether the mast is stepped on deck or on the keel, the load eventually gets transmitted to keel. Floors should be installed to balance the upward pull of the shell plate from the rigging with the compression of the mast. Additional longitudinal structure may be needed to distribute these loads to several floors.

d. Ballast Vertical Keel. Where a lead or iron ballast vertical keel is used on a sailing vessel, ABS Rules (7.l.2g) give minimum requirements for additional FRP scantlings. Where the keel is external and attached by keel bolts, (6.5.2) gives general requirements for bolting. The ABS Yacht Guide (6.3.1) prescribes keel bolt diameters at the bottom of the thread d_k as not less than:

$$d_k = \sqrt{2.55 W_k Y_k / \sum l_i \;{}_y} \text{ mm or in.}$$

where:

W_k = weight of ballast keel in kgs or lbs.

Y_k = vertical distance in mm or in. from the center of gravity of the keel to the bearing surfaces at the bolt connection.

${}_y$ = minimum yield strength or 0.5 times ultimate tensile strength, whichever is less, of the bolt in kg/mm^2 or psi.

$\sum l_i$ = summation of transverse distances from the center of each bolt on one side to the centers of the bolts on the other side of the keel, in mm or in.

Where there are fewer bolts on one side, the summation of distances is to be from the center of the bolts on that side. Where high strength bolts are used, special consideration will be given to the adequacy of arrangements to distribute the ballast weight and the bolting forces evenly over the FRP and ballast keels. Nuts should be self-locking or double nutted. Corrosion resistant bolts should be used and care taken to avoid dissimilar metal contact. All components, attachments and threaded connections are to be able to fully withstand the strength of the required bolts. The keel bolts should be evenly spaced over the length and width of the faying surface between the external ballast keel and the vessel's vertical keel, not all on the centerline. This spacing will distribute the weight evenly, distribute grounding forces, and prevent the keel rocking from side to side which would occur if the bolts were on the centerline.

e. Centerboard Trunks. Centerboard trunk arrangements vary widely among designers. Where possible, the additional scantling requirements for ballast keels (7.l.2g) should be followed. Consideration should be given to supporting the weight of the centerboard, especially if ballasted, and how that weight is supported at the pivot, the landing and by the operating mechanism. Guidelines for machinery installations in Section 2.P should be followed for supporting these point loads. The abrasion from the centerboard riding in the trunk should be accounted for in the scantlings, especially if the trunk is wood or wood composite. Inspection plates should be considered to facilitate later inspections and possibly preclude the need to remove the centerboard for every hauling out.

2. Through-Hull Fittings.. All fittings which penetrate an FRP skin should draw special attention, especially those penetrating the underwater hull. 46 CFR 182.40-l(a)(3) allows nonmetallic fittings which will afford the same degree of safety and heat resistivity as that afforded by the hull. Exposed raw edges of FRP laminates can easily draw water and delaminate or, in the case of wood composites, lead to rapid deterioration of the wood. A flat surface should be laminated or machined into the shell to account for curvature where fitting flat faced fittings to a curved hull. Washers or backing plates on bolts should be greater than 2.25d in diameter and .ld thick (d - bolt diameter), nuts are to be self-locking, double nutted or penned to prevent backing off.

a. Single-Skin Laminates. Through-hull fittings in single skin vessels are usually drilled, sealed and attached. If a hole saw is used, the drilled out disc can be used as a construction material test sample. Adequate bedding and allowances for hull curvature should be detailed in the plans.

b. Sandwich Panels. Through-hull fittings in sandwich panels may be installed in a number of ways. One way is to laminate into the shell a core as structurally effective in compression and shear as a single-skin laminate. Another is to build a full single-skin laminate in place of the core material at the position of the fitting, then cut the hole, seal the edges and install the fitting as for a single-skin laminate. Another is to cut a hole directly through the sandwich panel after the shell is layed up. This hole should be at least big enough to provide an effective insert for the base of the fitting and its attaching bolts. Then, laminate in an effective insert as above, reinforcing the opening and sealing the core, then install the fitting. In any case, it is very important to seal the core material and attaching bolts, and provide adequate strength for the localized loads on the fitting.

3. Deck Fittings. Deck fittings are fitted to the deck using the same guidance for through-hull fittings (6.7.4). Deck fittings experience higher loads than through-hull fittings from mooring, towing, anchoring, and similar loads, so the deck must be adequately reinforced to handle such loads. The bedding material must be able to withstand the adverse effects of the weather while remaining flexible enough to prevent cracking under load.

CHAPTER 3. PRELIMINARY CONSTRUCTION TASKS

A. Material Performance Tests. Material performance tests are conducted to ensure the quality of the materials for meeting the rule material properties or for verifying properties used in detail calculations. Tests are to be conducted according to ABS Rules (5.4.6) and (1.8) or as required by the Coast Guard inspector. For nonstandard materials, such as custom knitted directional fabrics, the tests should be conducted well before a vessel is begun. The ASTM test methods should be closely followed for small variations in the details of the test can produce widely varying test results. Where material performance does not match that specified by the approved plans, the scantlings may need to be increased to meet the required design standard scantling or, if the builder wishes to prove better properties, the tests must be repeated, before and during construction such that the specified properties are consistently met or exceeded. The frequency and amount of testing required will be determined by the OCMI and depend on the relative sophistication of the laminate, the number of boats the builder has built and had material tests performed for, the size and service of the vessel and the experience the OCMI has had with the builder.

1. Flexure. FRP laminates are anisotropic materials. That is, they have different strength properties in different directions. Critical loads experienced by vessels less than 100 feet long are mostly local pressure loads from hydrostatic head, slamming and planing forces. An FRP bottom panel reacts to the load by flexing. The flexural strength is used to determine how much load a panel may carry and flexural modulus determines how much a panel may deflect. Testing of laminates with specially woven or knitted fabrics should be done with samples large enough to develop full strength with a length to width ratio of no more than 3.0. Flexural strength and modulus are to be determined by ASTM Standard D 790-84.

2. Tensile and Compressive. These properties are important for sandwich panel skins where there is less flexing under a given load. The inner and outer skins experience stresses oriented closer to limiting values for tension and compression than to limiting values for flexure for a single-skin laminate. Also, vessels over 100 feet long begin to experience more significant longitudinal bending stresses which alternatively force the upper (deck) and lower (bottom) hull flanges into tension and compression. Tensile and compressive properties are to be determined by ASTM Standard D 3039-16 and D 3410-76, respectively.

3. Glass Content. Determined by a burnout test, the glass content is the amount of glass fiber reinforcement actually in a given sample of laminate after the resin has been burned away. The test should also be used to check the amount, type and directionality of each layer of reinforcement. Usually, test coupons are obtained from through-hull fitting cut-outs. The applicable ASTM Test Method is D2584-68, Ignition Loss of Cured Reinforced Resins.

4. Interlaminar Shear. This test indicates the degree of strength between the layers of a laminate. ASTM Standard D3846-79 applies.

5. Sandwich Composites. Tests are conducted to determine properties of the core without the FRP facings and with the facings. ASTM Standard C 273-61 applies to testing core properties and ASTM Standard C 393-62 to testing various properties of the sandwich composite.

6. Wood Moisture Content. Wood moisture content should be kept fairly low to ensure an adequate bond for laminated stiffeners Moisture content less than 11 per cent is generally acceptable. Moisture content greater than 12 per cent is unacceptable for most resin systems. The test for moisture content involves merely weighing a sample of wood in its ready to use state (W_1) then drying it to the desired content in a slow (220^0F) oven and weighing again (W_2). Moisture content is the additional percentage (P) of water in the wood

$$P = ((W_1 - W_2) / W_2) \times 100$$

B. Material Identification. The various ingredients of an FRP hull must be identified before use. The following material properties should be clearly identified at the building site to match the materials specified on the approved plans and used for material testing:

1. The type, weight, directionality and manufacturer of glass fiber reinforcement.

2. The type and manufacturer of resins, hardeners and special bonding adhesives. Included should be the manufacturers data on picture requirements and shop environmental limits for temperature and humidity.

3. The type of wood reinforcements, plywoods and stiffener cores.

4. The type of metal hardware for bolts, chain plates, shaft struts, rudders, shrouds and stays, etc. Use of dissimilar metals should be avoided and in certain cases may not be allowed by the attending inspector.

C. Personnel Safety. The FRP manufacturing process uses a variety of resins and reinforcements to produce the end product. The construction and repair of FRP boats will be under the jurisdiction of the Occupational Safety and Health Administration (OSHA) or its state equivalent. The purpose of the following section is to provide an introduction to health concerns, personnel protection and sources of further information. Questions about specific regulatory standards should be directed to the appropriate state or federal OSHA office. The federal office address is:

Occupational Safety and Health Administration
Headquarters Office
3rd and Constitution Ave, NW
Washington, DC 20210

l. Hazards. In most FRP processes, styrene is used as a reactant in the formation of the plastic components and as a solvent carrier. Other compounds may be added for elevated temperature curing of the resin. Exposure to fiber aerosols is also a concern. The cleaning of tools adds exposures to solvents, such as acetone or methylene chloride. Reinforcements are usually woven or loose fibers, usually fiberglass. These can be respiratory and contact hazards in addition to other commonly thought of hazards such as noise, use of heavy equipment, cutting tools, etc. A list of most of chemicals found in the industry is in Enclosure B. Hazard information should be consulted for each product from the material safety data sheets (MSDS) required by OSHA regulations in 29 CFR 1910.1200 to be available from each manufacturer of hazardous substances used in the workplace.

a. Styrene. Styrene is commonly used as a solvent as well as a reactant. It is usually added in greater amounts than required for polymerization to provide for optimum viscosity and thorough reaction. Styrene quickly vaporizes into the work environment when first poured. Some unreacted styrene also remains after the curing process, evaporates into the work space air, and becomes a serious health hazard. It is flammable, with a flammable range of about 1.1 to 6.1 volume percent in air. Styrenets most common toxic effects are irritation of the skin, eyes, nose, and respiratory tract. At high exposures it will act as a central nervous system depressant. The ACGIH recommends a TLV-TWA for styrene monomer of 50 ppm, while the OSHA PEL is 100 ppm. OSHA has also determined the IDLH to be 5000 ppm. OSHA has established the following permissible exposure limits for styrene (29 CFR 1910.1000 Table Z-2):

(1)	OSHA-PEL (8 hour TWA)	= 100 ppm
(2)	OSHA-Ceiling	= 200 ppm
(3)	OSHA-Peak 5 min(any 3hrs)	= 600 ppm
(4)	IDLH	= 5000 ppm

The ACGIH has recommended a TLV-TWA of 50 ppm, and a TLV-STEL of 100 ppm.

b. Glass Fibers. Glass fibers are mainly an eye, skin and respiratory irritant. The ACGIH has set a TLV-TWA concentration of fiberglass fibers at 10 mg/m^3 of dust. NIOSH investigations have found that fiberglass, in a form which can be inhaled deep into the lungs, is found only in very small concentrations in most laminating areas. See also the discussion in subparagraph 3.C.l.c below.

c. Other Fibers. NIOSH (ref 14) discusses recent studies of ceramic and other vitreous fibers, and the growing concern that these fibers my pose potentially serious health problems. Although there is presently little conclusive evidence of chronic adverse health consequences associated with fiberglass or other vitreous fibers, many manufacturers are advising caution. Workers should be exposed to the lowest concentrations possible and use effective respiratory protection.

d. Other Toxic Substances. NIOSH (ref 16) describes a number of processes in the FRP industry which utilize any one of a number of other compounds. These are described in Enclosure B. In all cases the MSDS should be consulted for each product, and especially in the case of products which are new to shop personnel.

2. Workplace Practices. In the FRP industry, overexposure of employees to styrene is a serious problem. Of 22 FRP plants investigated in one state, 40 per cent exhibited worker overexposure to styrene. Employees of all categories in the boat building industry exhibited significantly higher exposures than those in plants which manufacture other products. Because of the boat building shop layout, conventional exhaust systems are not fully effective in controlling environmental concentrations resulting in excessive worker exposure. A control option would be to improve work practices. A number of investigators have described work practices and industrial hygiene measures which reduce exposure hazards. Plant owners and operators may wish to consider these options for reducing exposures in their operations. Thirty of the highest ranked procedures which help to reduce exposures are reproduced in Enclosure B.

3. Respiratory Protection. Several respiratory protection considerations are in order where personnel will be exposed to either styrene vapors or fiberglass dust. Positive pressure supplied air is preferred for workers continuously exposed to high concentrations, but masks with combination filter/organic vapor cartridges may also be acceptable in many work situations. A full-face mask should be considered for high concentrations of styrene over 1000 ppm. A full-face mask or protective goggles will also help to prevent eye irritation due to aerosols, fibers or low concentrations of styrene. When selecting combination cartridges, the filter portion will provide greater protection if it is rated as a high-efficiency particulate air ("EPA) filter. Such filters are often advertised for use in asbestos or radionuclide atmospheres. For further information concerning respiratory protection programs see ANSI Standard Z88.2-1980; "Practices for Respiratory Protection," and references 14 and 16.

4. Other Protective Clothing. For eye protection, full-face respirators or goggles should be considered. Styrene enters the body mostly through inhalation, but skin absorption is also possible so protective clothing should be used. NIOSH recommends skin protection with gloves made of polyvinyl alcohol or polyethylene. Rubber gloves or similar protective garments should be avoided because they will be permeable to styrene. Other materials known to have poor resistance include butyl rubber, neoprene, polyvinyl chloride (PVC), chlorinated polyethylene (CPE), saranex, and nitrile products.

5. Health Effects. Styrene has a number of health effects which may be noticed in exposed individuals (ref 15):

a. Central nervous system disorders;

b. Chronic respiratory diseases - impaired pulmonary function, especially obstructive airway diseases;

c. Skin diseases - styrene is a defatting agent and can cause dermatitis;

d. Kidney disease - impaired renal function might impair clearance of absorbed styrene; and

e. Liver disease - impaired hepatic function might impair detoxification of absorbed styrene.

6. OSHA Guidelines. Working conditions in most FRP boat building facilities are subject to regulations promulgated by the Department of Labor, Occupational Safety and Health Administration (OSHA). Applicable regulations will be found under 29 CFR Part 1910 “Occupational Safety and Health Standards."

a. In many cases, states exercise jurisdiction over standards which meet or exceed federal standards under provisions of 29 CFR Part 1902 "State plans for the development of and enforcement of State standards." The applicable state government should be contacted for information regarding its Occupational Health and Safety Plan and associated regulations.

b. With regard to OSHA requirements, particular attention should be given to:

(1) Subpart G (1910.94 through .100) Occupational health and environmental control.

(2) Subpart H (1910.106) Hazardous materials: Flammable and combustible liquids

(3) Subpart I (1910.132 through 140) Personal protective equipment.

(4) Subpart Z (1910.1000) Toxic and hazardous substances: Air contaminants, and (1910.1200) Hazard communications.

7. Shop Safety. In addition to normal shop safety procedures, extra care should be taken to account for fire hazards of resins and the chemical and fire hazards of many of the chemicals used in catalysts and promoters. Material product safety data sheets should be obtained from the manufacturer, studied and understood by all personnel working with the products.

D. Shop Environmental Conditions. ABS Rules (5) identify fabrication and quality control procedures. Noteworthy are requirements for a clean, covered shop with temperature controlled to between 60^0F and 90^0F. The allowable humidity level inside the shop should not be greater than about 80 per cent relative humidity. Condition. much outside these may cause poor resin performance, wood swelling or warping, and must be avoided unless specifically accounted for in the material proof tests.

CHAPTER 4. VESSEL FABRICATION

A. Mold Preparation. Most FRP vessels are produced from molds. Proper preparation of the mold can make the vessel stronger a8 well a8 better looking.

1. Mold Support. A male or female mold should be well supported to prevent the laminate from shifting or flexing during the initial cure and to support the weight of workers and machinery if the building process involves this. Poor support will allow the shell to flex causing delaminations or permanent distortion. Distortion may lead to serious problems when attaching the deck or performed bulkheads.

2. Mold Release and Waxing. Adequate mold preparation is an important first step in the actual construction process. The mold should first be cleaned to present a smooth surface. Many builders then use 2 - 3 coats of highly buffed paste wax. Then, polyvinyl alcohol (PVA) is used to coat the entire surface of the mold as the mold release agent. Inadequate mold release may result in:

a. Part of the shell being stuck to the mold.

b. Detachment of sections of gelcoat or even layers of laminate.

c. Excessive stressing of the unstiffened hull while the boat is being removed from the mold, resulting in hidden damage before the boat even gets into service.

d. Damage to the mold.

3. Gelcoat. The gelcoat is the outer protective hull layer, usually a special resin mix containing color pigments and ultraviolet blockers. Applied correctly at about 20 (not more than 30) mils in wet thickness, a good gelcoat will be durable, protect the hull from excessive water' infiltration and prevent resin damage from sunlight as well as providing a smooth outer surface. If the gelcoat is too thin, water will be able to infiltrate too easily, leading to blistering and delimitation. Too thick a gelcoat will crack easily and lead to similar problems. For female molds, the gelcoat must be sufficiently cured so that the first layer of mat or cloth will not print through or push through the gelcoat to cause thin spots, but must be uncured enough to ensure a good chemical bond to the first layer. Pigments added to the gelcoat can cause problems if improperly applied. Manufacturer's additive guidelines must be closely followed.

4. Skin Coat. A skin coat is applied by some builders as a special barrier to blistering. It consists of a special resin applied with light weight mat or cloth between the gelcoat and the structural laminates beneath it.

B. Construction Methods. There are various ways to actually build a vessels from approved plans. Female molds with hull halves are probably more common to series production while a variety of strip plank male and female methods are used for one-off custom hulls. Regardless of the method, the production of a sound and safe hull is the desired end result. A particular set of plans may not address peculiarities of the construction method that should be addressed before construction begins. General concerns to achieve that result are discussed below. Layup of decks, deckhouses and other sections are adaptations of these.

1. Female Mold. Using a female mold with split hull halves has numerous construction advantages. The split halves can be canted (heeled) about 450 50 that the majority of the work is performed downhand. Bar keels and skegs can be built up easier. The molds can be sturdy but only half as heavy as a single mold and only half the boat needs to be laminated at a time. Disadvantages are that the halves must be joined, usually with a secondary bond, and the halves are likely to be flexible until the stiffening and bulkheads are added, possibly allowing distortion which will cause later fitup problems. Building the molds is a lengthy process usually justified for series production only. Single piece female molds are a tradeoff to the advantages and disadvantages of a two piece mold and should only be used for smooth-sided boats with no tumblehome. A bar keel in a single piece mold will be difficult to laminate properly without allowing too much resin to lay in the mold, so special care should be taken to avoid building a resin rich keel.

2. Male Molds. Male molds are normally used upside down and are sometimes existing vessels or plugs stripped and inverted. Advantages are relative simplicity and avoiding the need to make the mold perfectly faired and smooth because the interior, which is usually hidden in a finished vessel, faces the mold. The main disadvantage to a male mold is that the exterior surface of the new hull must be sanded smooth for every vessel to produce a smooth, even exterior surface.

3. Strip Plank Glass Fibers. This method involves laminating thin sheets of mat on a smooth surface such as a formica counter top, allowing them to reach a partial cure, then stapling them to a simple male or female batten mold. Subsequent layers of laminate are laid up directly onto/into this (preferably still curing) shell. This shell is not counted towards the thickness nor considered part of the laminate schedule required by the approved plans because the strips are not overlapped and numerous staple pullouts present too many flaws.

4. Sandwich Variations. All of the above methods have variations using core materials. One way is to use the core material as a form of mold in the strip plank method, attach the inner or outer skin, remove the hull from the batten mold, then attach the other skin. The important item in sandwich construction is to make absolutely sure that the core is securely attached to both skins. The adhesive may be the same resin used in laminate layup or a special commercially available core bonding system. Continuity of the core must be maintained by filling strip plank staple pull-outs and gaps between the core sections with resin or bonding putty. With end grain balsa or similar cores, the core may initially soak up a large amount of resin, so an extra application of resin to the core must be done before bonding the core to the shell. This is necessary to prevent a resin starved or dry laminate. Where a core is cross sliced to allow conformance to curvature, the crevices of the core must be filled with resin or bonding putty to avoid discontinuities in bonding the FRP skin.

C. Construction. When this stage is reached, all preparations should be complete. The plans should be completely approved, not just submitted, and the construction information for reinforcements, cores, resins, hardeners, fire retardant additives, direction of lay, etc. should be clearly established. Start of construction without approved plans is at the builder's risk. The shop should be relatively clean and atmospherically prepared for the specified resin. The ambient temperature and humidity as well as mold surface temperature must be within the allowable range of environment for the laminating resin. Personnel protection equipment should be ready for all involved in the project. Damage incurred during construction is managed the same as for in-service inspection and repair.

1. <u>Application of Laminations</u>. Following these few simple but important guidelines should ensure a structurally sound hull. Resin should be carefully and thoroughly mixed to achieve maximum strength arid sufficient work time for the applicator to roll the resin completely through the reinforcement. Reinforcements should be laid in continuous plies overlapped 2 inches at the side on each layer. The position of these overlaps should be staggered at least 4 inches per layer (5.3.1). If end of ply butt joints are unavoidable, they should be overlapped and staggered also. Transitions in laminate thickness, such as for bottom to side shell reductions, should be done on a gradual basis by at least 2 inches per ply on the perimeter of a thickness change. Extra reinforcement areas for through-hull fittings, bar keels, deck edge joints, and the like should be monitored as the hull is layed up as it is difficult to add these items effectively after the hull is finished. Runoff tabs for lay-up test panels should be provided where any of the following conditions exist:

    a. Through-hull fitting cut-outs will not be numerous or large enough to adequately perform the construction material tests.

    b. High strength laminates or high glass content laminates are called for in the plans and extra construction tests are required to prove these properties.

2. <u>Secondary Bonds</u>. A secondary bond occurs when fresh laminate is placed after the existing laminate has fully cured. Thus, the joint is an adhesive joint instead of chemically bonded. A rough rule of thumb for the curing time involved is the greater of twice the gel time or the gel time plus 2 hours. Recent research has shown that certain resins, if the surface is kept clean, may exhibit high strength secondary bonds as long as one week after the original laminate was layed. Resin manufacturers information and technical advisors should be consulted for detailed information on this subject. Secondary bond joint preparation should involve a peel ply of cloth or light fabric, or surface roughening by sanding or grinding (5.3.3).

3. <u>Building and Attaching Stiffeners</u>. Hull stiffeners can be prefabricated then glass tabbed to the hull or fabricated directly onto the hull by the rules in (6.4) and (6.8). The glass tabbing is usually a secondary bond and should be prepared as such. Special attention should be paid to high strength or unidirectional reinforcements in the flange of stiffeners. Joining longitudinal. to transverse webs or bulkheads should be according to (6.4.4) or a similar effective method. Where stiffeners can be attached using a primary bond, special consideration may be given to alternative attachment procedures.

4. <u>Bulkheads</u>. Bulkheads should be landed after the hull halves are joined. Fitup of the bulkhead to shell should be checked before bonding to the hull. Details on the plans for extra reinforcement, elastomeric supports, bolting and boundary angle thickness, taper

and composition should be carefully followed. Some bulkheads may already have a smooth surface finish, such as formica or a vinyl wall covering, applied before installation. This surface must be roughened or cut away in way of the glass tabbing to provide a suitable bonding surface.

5. Hull Liners. Some builders may prefabricate many of the internal bulkheads, bunks and stiffeners into a single unit called a hull liner. Such a liner should be carefully checked before attaching to ensure it actually fits closely to the hull and that required joints can be adequately made. If the shell has flexed or warped out of the mold, fitting the liner may be a laborious but necessarily thorough process.

6. Attaching the Core. In addition to the guidelines in the construction methods section above, the following items should be addressed for sandwich construction:

   a. If the hull must be laminated in more than one session, a break in construction is best done after the core has been attached to one of the skins to avoid secondary bond problems in the laminate.

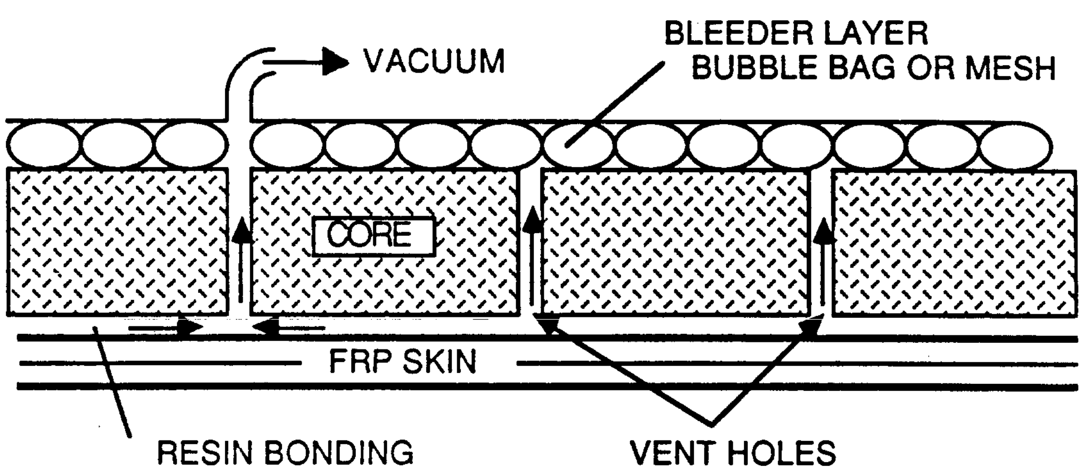
   b. Tapering the core to single skin laminate at the keel or deck edge must be kept to a gradual taper at least a 3 to 1 ratio as shown in Figure 1-1.

   c. Structurally effective inserts must be placed at through-hull fittings.

   d. Thorough contact between the core and skin must be maintained.

   Vacuum bagging is used by some builders to ensure that the core is thoroughly attached to one of the skins. This system works to evacuate air from the bonded side of the skin 80 that atmospheric pressure will push the skin up tightly against the core as shown in Figure 4-1. One indicator of a complete bond is that resin or bonding putty appears in the vacuum holes after the process i8 completed.

Figure 4-1



D. Removal From the Mold. Removal from the mold may occur at any stage after the shell is adequately cured and/or stiffened.

1. Barcol Hardness. The barcol hardness test is a method for determining the state of cure of the laminating resin. The tester is a relatively simple instrument available at most industry supply centers. Readings should be taken at regular intervals along the length of the hull. A barcol hardness of 40 or more (5.4.6) is usually an adequate cure for removing the shell from the mold. Some resins may have a somewhat softer final hardness so the manufacturers data should be consulted. Removing the shell at a lesser cure may damage the laminate since the bond between the resin and reinforcement is incomplete, or may allow the shell to warp or sag, causing fitup problems for bulkheads or the deck.

2. Checking the Finished Shell. After removing the shell from the mold it should be checked for many flaws that may later be covered by paint, ceiling and equipment. Bar keel halves from two piece female molds can be checked for complete filling and proper lamination before joining the halves. Locations of effective inserts for through-hull fittings and chain plates in sandwich shells may be ascertained. Damage from staples or other temporary attachments pulling out of strip plank molds can be identified and repaired.

3. Joining Hull Halves. For the split hull female mold method, this is a critical stage. Failure of this joint more than any other in a boat can lead quickest to structural failure.

a. ABS Rules. (7.l.2e) describes the required thickness and joint design. The guidelines in Chapter 4 of this circular should be followed for the laminating sequence of this joint. The importance of building this joint directly according to the approved hull plans and by the care expressed above cannot be overstressed.

b. Joint Design. Layup of the joint should be continuous to avoid additional secondary bonds. The existing joint surface should be prepared as for any secondary bond by sanding, grinding or adding a peel ply to the original hull layup. If there is an external bar keel, a layer of resin wetted mat should be laid between the (prepared for secondary bond) bars before the halves are joined.

E. Attaching the Deck and Deckhouse. The deck-to-hull joint is an important joint in a vessel. The joint should match that on the approved plans. ABS Rules (6.10) or a specifically approved equivalent should be met. The fitup between sections should be checked and where a panel of either the deck or hull is excessively distorted such that it will not easily fit into place, an alternative joint or a repair method should be arranged to remedy the situation. Forcing joints together may induce locked in stresses which will lead to excess stress in operation. Attaching the deckhouse should be done with similar care, for failure of either of these joints may result in leaks or flooding.

F. Outfit. After the main structure is completed, there are various items of outfit which are important to the safety of the vessel, many of which affect the structure. Approved plans for key items such as fuel tanks, engine exhausts, fixed and portable fire systems, bilge piping, and the like may indicate location and type but not installation details. The same principles for installation of large structural items should be followed in proper scale, for other items of outfit. For example, self-tapping screws would be appropriate for mounting a certificate enclosure on the inside of the deckhouse. They would also be appropriate for a similar light weight attachment exposed to the weather, but should be sealed with resin. Self-tapping screws would not be appropriate for mounting a 50 lb. CO_2 bottle to a bulkhead. A better method would be to bolt through the bulkhead with a backing plate to mount an effective bracket.

1. Machinery Installations. The approved plans should provide complete details on proper installation. ABS Rules (6.7) has additional details. Engine manufacturers usually supply guidance on foundations, bedding and bolt sizes. Engine cooling water lines, raw water piping, bilge piping and other accessory piping is frequently routed through stiffeners at the builders discretion after hull construction. Large pipe tunnels or limber holes should be detailed on the plans. Smaller pipe penetrations, where the pipe diameter is less than 1/6 the stiffener height, should be made below the upper third of the stiffener height. The hole should be drilled and sealed following the guidelines in Chapter 2, paragraph G.2 of this NVIC. The engine(s) should have a drip pan or segregated bilge area to isolate oily bilge. Turbochargers and dry exhausts should be insulated and located a safe distance from an FRP laminate. 46 CFR 58.10-10(d) has specific requirements for exhausts.

2. Deck Fittings. Fittings should be installed according to the approved plans and to guidelines in Chapter 2, paragraph G.3. Bedding compound or resin putty should be evenly layed around the base of the fitting or equipment so that as it is tightened to the deck, the bedding is evenly distributed around the base and the bolt or screw holes. Washers or backing plates on bolts should be greater than 2.25d in diameter and 0.ld thick (d = bolt diameter) but not less than 0.1 inch. Nuts are to be self-locking, double nutted or peened to prevent backing off.

G. Certification.

1. Notation of Special Materials. Coast Guard OCMIs keep construction records (as should the builder and owner) on vessels they have certificated. However, there is always the possibility that a vessel will require some damage repair away from where it was built or certificated. The operator and the local OCMI need to be alerted to special aspects of design so that appropriate repairs are made. For this reason, the following items of construction will be noted on the Coast Guard's Marine Safety Information System (MSIS) file kept on each vessel in that vessel's Special Design Features Details section:

   a. Core material for sandwich construction.

   b. Location and type of high strength, high modulus or unidirectional reinforcing fibers.

   c. Type of laminating resins, including fire retardant resin particulars.

   d. Special bonding details.

2. Notation of Fire Protection Equivalencies. Similarly, an MSIS record will be kept in a vessel's Special Fire-Fighting Procedures or Hazards section. This entry will note items of fire protection equipment that are added as an alternative to fire retardant resins to meet equivalencies allowed in Chapter 1, paragraph F. of this NVIC.

CHAPTER 5. IN-SERVICE INSPECTIONS

A. Introduction.

1. Maintenance of any vessel over its life cycle is as important as its proper design and construction. Fiber reinforced plastic vessels have advantages over other vessels in the areas of corrosion, attack from borers, electrolysis (except for fittings) but have disadvantages in areas such as water infiltration, creep and ultraviolet degradation. Identifying these and other problem areas for FRP vessels is the object of this chapter.

2. The Coast Guard shares with the owner a strong interest in the proper maintenance of a certificated vessel. A well maintained vessel ensures the safety of the passengers and crew. Periodic inspections are required by the regulations and special inspections are required when a certificated vessel undergoes major alterations or experiences damage. Astute owners know that proper and timely maintenance reduces operating costs by reducing unplanned downtime, lost revenues and increased insurance premiums.

3. Requirements for periodic inspection intervals are found in 46 CFR Part 176 and 91 as applicable. Initial certification for a new vessel requires plan review and a construction inspection, as described in previous chapters. Inspections or reinspections are required every year and drydocking is required every 18 to 60 months depending on the time a T-boat is operated in salt water or fresh water as required by 46 CFR 176.15, and 24 to 60 months for cargo vessels as required by 46 CFR 91.40. Damage inspections are required by 46 CFR 176.20 and 185.15 for T-boats, and 46 CFR 97.07 and 91.45 for cargo and miscellaneous vessels, whenever a certificated vessel is involved in an incident, such as a collision, fire or grounding. Owners are encouraged to conduct more frequent inspections of areas where their vessels may be prone to damage.

4. In this chapter, the term "inspector" will be used inclusively, to mean Coast Guard inspector, ABS surveyor, insurance surveyor or the owner looking to maintain his own vessel. Discrepancies which are safety related or could lead to a critical failure will be detailed. Occasionally, a discrepancy will be noted as possibly leading to failure, but not requiring immediate attention. For example, a deteriorating mast seal boot (where the mast goes through the deck) that is not yet holed but is the source of nuisance leaks, will eventually lead to flooding. These are judgment calls in a field where judgment plays an important role. For any inspector, such determinations can be made three different ways:

    a. The condition requires immediate attention.

    b. The condition is not an immediate safety problem but will become one before the next inspection. It must be rectified within a certain period of time. A Coast Guard Form CG-835, Merchant Marine Inspection Requirements, may be issued to a certificated vessel by the Coast Guard inspector to officially determine the conditions of a repair.

    c. The condition is not serious and should be satisfactory until the next inspection.

B. Preparing a Vessel for Inspection. There are many items of preparation that should be accomplished or arranged for by the owner before the inspector arrives. Each inspector will have his/her own preferences for which particular items are to be done, usually arranged by telephone or letter well before the inspection. The following is a general list of what to expect:

1. The vessel should be well supported if on land. FRP surfaces are usually smooth, so side supports must be arranged to prevent slipping out of place when there is movement on board.

2. A certain amount of inside ballast may be specified for removal in order to inspect the bilges.

3. Certain fasteners, as for shaft struts, ballast keel bolts or rudder plate bolts, may be specified for removal and inspection.

4. Ground tackle, life jackets and other gear should be removed to provide clear access to the hull and to be ready for inspection.

5. Bilges should be drained or pumped dry to a proper reception facility, and be relatively clean.

6. Bolted hatches should be opened and voids well ventilated.

7. The external hull should be relatively clear of marine growth.

This list is just for structural inspections, which this guide is primarily concerned with. For a full Coast Guard inspection for certification, many other items will be checked, such as navigation gear and charts, operator's licenses, lifesaving gear, electrical installations and machinery. The likelihood of many or all of these items being checked on a single visit reflects even more on the necessity for proper preparation.

C. Checking the Hull. As in design and construction, the exterior hull shell is a good starting point for an inspection. During a drydock inspection, (or when the subject vessel is in a cradle) exterior damage will give an indication of damage to be found inside. Certain types of vessels have common problem areas which should routinely be checked.

l. Visual Examination. An inspectors first impression of a vessel will be visually at a distance. The inspector may notice a list or trim if the boat is in the water, generally how the vessel is cared for, and how well it is supported in a dry berth cradle. Lack of ventilation implies a damp interior and related problems, such as delaminated or rotted plywood bulkheads or corroded metal fastenings. These first impressions will set the tone for the rest of the inspection. Most discrepancies will be found visually then checked by other methods to determine the seriousness.

a. Cracks. Cracks found on the surface of an FRP hull may indicate:

(1) The gelcoat is too thick and is cracking with normal flexing of the hull.

(2) There is a stress raiser such as at a fitting or where a bulkhead is landed without a doubler.

(3) The edge of a delimitation.

(4) A crack in the laminate.

Scratches may be just scratches but should also be checked with a magnifying glass or a .009 in. feeler gauge for the inclusion of cracks. Cracks in the exterior coating or in wet areas are a serious problem. Cracks deeper than 0.030 inches have likely penetrated the gelcoat and allowed water to enter the laminate where it can cause delaminations, freeze-thaw damage or bubbles. Small cracks above the waterline may not require immediate attention for safety purposes but for good maintenance should be cleaned and filled. The problem will not cure itself and will likely get worse and require more extensive repairs later. Large cracks and those below the waterline should be repaired when found, for the acceleration of structural damage to a critical point cannot be accurately predicted.

b. Blisters. Blisters on the surface of the gelcoat indicate that some water has penetrated the gelcoat through osmosis and has reacted with styrene to produce a milky liquid in the blister. They are an indication that:

(1) The gelcoat is too thin or was improperly mixed or applied.

(2) The gelcoat is unable to cope with pollutants in the water.

(3) There is air under the surface of the laminate.

(4) The laminating resin was improperly formulated, mixed or applied.

Water will penetrate all polyester gelcoats to some degree. Small (less than 1/6 in. diameter), widely scattered blisters are not a major problem and may be left alone. A few should be popped to ensure that the damage has not penetrated through the reinforcement. Larger numbers of blister., many of a larger size or a lot grouped in one area should be repaired. Often blisters on a hull out of the water for some time or sitting in the sun will dry out, but the problem will not disappear. For this reason) the vessel should be inspected shortly after hauling out.

c. Unfairness. Unfairness can be an indentation, bulge or sharp departure from smooth curvature. Indentations are usually an indication of collision and, even though the surface appears smooth, a large dent indicates the possibility of broken plies of laminate, internal separation of glass tabbing or a compressed or detached sandwich core. A bulge indicates a blow or load from the inside and may have been caused by allowing a power boat to sit in cradles without support under the engines, a piece of auxiliary machinery inadequately supported, inadequate support under a mast step, a bulkhead landed on the shell without a doubler or a bulkhead poorly fitted, or concentrating the loads on a number of small areas. These problems may be accompanied by cracks in the gelcoat, broken or delaminated plies, secondary damage or separation of the stiffeners at the glass tabbing. Correction of problems will depend on the size of the damage, where it is on the vessel, and how much secondary damage is present.

d. Delaminations. Isolated areas of delaminated or separated plies may not be an immediate source of structural failure, but will certainly lead to a larger damaged area and must be repaired. Delaminations are caused by poor previous repairs, improper dry layup in original construction, or external or internal damage. They may show up as cracks showing the edge of a ply, as a flimsy unsupported outer skin of a sandwich shell or the outer ply of laminate. Signs of delimitation should be further investigated by hammer testing, non-destructive examination or coring.

e. Sandwich Panels. Separation of either FRP skin from the core material is a serious problem that can spread and lead to total structural failure. Indications on a sandwich panel may be a delimitation in the skin, separation of the skin from the core or damage in the core just under the skin to core bonding surface. A hole saw should be used to positively identify the type of failure.

2. Physical Examinations. For each instance of visual flaw detection there usually follows some sort of physical examination. This exam should not necessarily be destructive but should give the inspector a better idea of how extensive the damage is.

a. Hammer Testing. This sounds like a drastic measure for an FRP vessel, but is intended to mean light tapping at intervals on the shell or other FRP laminate to indicate discontinuities in the structure. Many inspectors use plastic mallets to prevent causing damage. Others use a very small ball peen hammer with a lighter tapping to give a clearer ringing sound. Either way, the testing must be done prudently to prevent inadvertent damage. The tapping may indicate delaminations or water saturated areas in glass reinforcements and the same plus rot in wood reinforcements. The indications are a difference in sound from good laminate to the damaged - a clearer ringing sound to a more dull thud.

b. Probing. Probing with a sharp spike, an angled scraper or a knife is often needed to further investigate suspected problem areas. However, such probing must be done carefully so as not to cause more damage but to determine the extent of known damage.

c. Moisture Testing. There are a number of moisture testing devices on the market used to check for moisture below a surface that looks dry. These non-destructive "moisture meters" can check for wide areas of moisture and avoid destructively removing a layer suspect of delimitation and holding moisture. These meters can give false readings in some circumstances and are not foolproof devices.

d. Non-Destructive Examination (NDE). FRP panels are not good subjects for NDE. FRP is not a homogeneous dense material that will readily carry ultrasonic waves. Very sensitive equipment may be able to determine the thickness of or find a delamination in single skin construction but will only measure one of the skins in sandwich construction and will not be able to show if it is delaminated or not. X-ray equipment is able to give a reasonable cross section picture of a full panel, but is quite expensive and not normally used. When NDE is specified for a condition inspection, the equipment and the operator should be proved on a test panel of known dimension and flaws. Use of NDE instead of destructive testing is usually at the owner's expense and discretion.

e. Destructive Testing (DT). Destructive testing is an alternative to NDE for further investigation of suspect areas discovered by other means. It is not a routine first inspection method. A small (1/4 to 1/2 inch) drill hole can be used to check for thickness or delamination. Drill holes are part of some repair procedures, so are not that drastic for DT. A known damage area can be cut back until a good solid laminate is reached, and may be extended over relatively small area to check another suspected area. A hole saw can be used to check a suspect sandwich panel problem, preferably from the inner skin. The sample cut will pull or fall out and show the location of the failure.

3. Deck-to-Hull Joint. This deterioration, and should seaworthy vessel. Cracks may be an indication that is overstressed. If this been periodically checked is a critical hull joint prone to damage and be checked very carefully to ensure a safe, in the gelcoat or laminate around this joint it was forced together at construction and particular problem appears serious, or has and found to be getting worse, the joint should be unfastened, cut or built up to fit, resealed and refastened.

a. Fasteners. Fasteners in the deck-to-hull joint should be checked for all the features that should have been designed and built in at new construction. Check for proper material, adequate size and spacing of bolts, adequate diameter and thickness of washers, tightness and self-locking features. If a discrepancy in any of these areas is found at an easily accessible location, even though there may be no damage evident, suspicion should be extended to the whole joint and a more thorough inspection of the joint should be conducted.

b. Sealant Condition and Hose Testing. Joints are supposed to be sealed when built. Often there is a rub rail or reinforcing wood or aluminum strip as part of the joint. When the joint is suspect, this strip should be removed at a number of locations for a short length to further check the condition visually and physically. Where further suspect, the joint should be hose tested with a direct stream of water. The water may run down the joint for a short distance before showing up inside depending on the vessel's trim. Where small scattered leaks are found, the joint may be cleaned, injection sealed or caulked. Where widespread leaks are found, the joint should be systematically unfastened and repaired.

4. Sail Vessels.

a. Ballast Keel Bolts. Ballast keels are heavy items, often half the total weight of the vessel. The attaching bolts must be checked for corrosion, torque and adequate bearing surface. Corrosion can be checked by pulling one or two bolts if the keel joint is opened up and the bolt heads are exposed anyway. Checking the bolts for tightness will show corrosion or lack of holding in the ballast such that the bolt will turn with the nut. Continued turning without pulling out indicates a lack of holding. The bolt should then be pulled out to positively determine the extent of deterioration.

b. Ballast Keel Joints. Ballast keels are either bolted on or formed in the hull shell and inserted in the void. Bolted keels should have sealant in the faying surface. Inside keels should be glassed over or secured by some means to prevent shifting or falling out. Bolted joints may work a bit, even with perfectly sound bolts, opening up the gelcoat and allowing water to penetrate into the hull laminate. This type of delamination must be repaired on the hull shell. The repair should assume that the ballast will flex again and should be made in a way to keep the upper hull laminate from being damaged when the ballast shifts again.

c. Chain Plates. Chain plates are highly stressed for long periods of time (longer if not properly slacked during storage or lay up) and will readily indicate poor construction or overstressing. The bolt holes into the shell viii appear elongated upward from FRP creep if they have been overstressed by never, stronger rigging or if the shell has been poorly designed. In either case, filling the holes is not sufficient. The chain plates and bolts should be checked for adequate size and backing. If these are inadequate, new properly designed plates and/or bolts should be fitted. If the plates and bolts are adequate, the shell should be reinforced in the area of the plates to bring it to the requirement for new vessels described in Chapter 2, subparagraph G.l.b. of this NVIC.

d. Mast Steps. Mast supports and seals are always a suspect problem area. A deck-stepped mast should be checked for a substantial landing pad or doubler to distribute the load. Crazing (numerous small cracks) on the deck around the mast indicates inadequate support. Underdeck, the compression post or framework distributing the mast compression loads to reinforced bulkheads or to the shell, should be thoroughly inspected. Keel stepped masts or the compression post landing on the keel should be similarly checked. In addition, the deck seal and the framework for distributing the lateral loads of the mast at the deck should be checked. Problems found should be analyzed to determine the source then repaired as original or with extra reinforcement depending on what the situation warrants.

e. Centerboard Trunks. Centerboard trunks are difficult to inspect and can be a source of serious problems. They should be thoroughly inspected and, at the least sign of trouble, the centerboard should be removed for further inspection.

D. Stiffeners. Another major area of inspection concentration should be on the hull shell and deck stiffeners including frames, webs, and bulkheads. Overstressed stiffeners will show cracks in the top flange or have delaminated bonding angles. General delaminations are an indication of an inadequate design or initial construction deficiency. Auxiliary piping and wiring run cut-outs may show cracks, especially if they are located in the top half of the stiffener depth. Encapsulated wood frames in the bilge should be checked for rot or dampness. Indications are a dull thud when struck with a hammer, bonding angle delamination or discoloration under a clear laminate. Bonding angles should be checked for delaminations in a number of locations along the length of the vessel. Where a general problem is found, a more thorough search should be conducted in hidden areas. Drainage holes through stiffeners should be checked for proper sealing, bonding and adequacy for draining the bilge.

E. Through-Hull Fittings. Through-hull fittings are a source of potentially dangerous leaks and shell laminate problems. A fitting which leaks around its base while a vessel is in the water is cause for immediate concern. If the fitting itself is sound, such a leak indicates that the attaching bolts are loose or corroded, the bedding or seal is broken or chipped away, or the FRP laminate around the base is delaminated. If the problem is either of the first two, the bolts can be replaced or the hole plugged and the fitting sealed with a rubber gasket until the next drydocking. If these temporary repairs are not feasible, or the laminate is suspected of leaking or rotting (for wood), the vessel should be drydocked for permanent repairs. In drydock, a suspect fitting is one where:

1. The bedding is cracked or falling out;

2. The fitting will rock on its base as a result of corroded or loose bolts or a flat based fitting fitted to a curved shell; or

3. The laminate is weakened.

In any case, permanent repairs should be made.

F. Machinery Installations. While checking the stiffeners, check main engine and auxiliary machinery attachments to the stiffeners. Check the attaching bolts to see if the holes have elongated or the washers are pulling through the laminate. Check the bonding angles around the girders supporting the engines - failure on the same side of both indicates inadequate cross stiffening to take engine torque. Numerous delaminated angles indicate poor initial design, construction or oil or bilge water working to degrade the connections. Check fore and aft on the engine girders to see if attachments to and through bulkheads or transverse webs are sound. Discrepancies require permanent repairs and possibly a look back at the design section for modifications to provide additional strength.

G. Deck Fittings. When looking for discrepancies on deck, consider deck fittings as similar to through-hull fittings. Indications of problems inside will be signs of leaks in the form of salt crust or water marks on the overhead lining or on the deck below. Minor leaks may seem unimportant but could be a sign of more serious problems which should be investigated by removing the fitting to better check the fitting, attaching bolts and the laminate.

H. Modifications. Modifications to certificated FRP vessels involving the structure to any extent are to be brought to the attention of the local OCMI as required by 46 CFR 176.20 or 91.45, as applicable. Modifications should be planned and made following the guidance in this NVIC.

I. Damage Inspections. Regular inspections are conducted with the idea that damage of some kind may be found. When special damage inspections are necessary, the damage is usually serious. The guidance that follows can be used for investigating both. Damage inspections are required by 46 CFR 176.20 and 185.15 for T-boats, and 46 CFR 97.07 and 91.45 for cargo and miscellaneous vessels.

1. Extent of Damage. Once damage is evident, the boundaries should be determined to specify and plan repair. Shell laminate damage extent can be found by hammer testing or, if the laminate is holed and the hull has not dried completely, a moisture meter will show how far water has migrated. Inside, there may be no obvious damage in the shell, especially in sandwich construction where the core deforms and distracts to absorb much of the damage energy. Stiffeners and fittings in the immediate area should be checked for damage, delaminated bonding angles and sheared bolt 8. The shell may flex a lot during impact and not be damaged, but bonding angles and fittings are likely locations for damage under the same impact.

2. Secondary Damage. Minor damage incidents rarely involve secondary damage. Discovering secondary damage from major incidents is more a matter of intuition than a rule of thumb. For example:

a. A side impact outboard of a web frame may pop some of the bonding angles on the other side of the boat.

b. A frontal or collision impact may be severe enough to damage main engine or machinery mounts much further aft or overstress the back stay of a sailboat.

c. A bottom impact low on one side of a bulkhead may push the bulkhead through the deck or delaminate the bonding angle on the other side.

When checking damage, a diagnosis should be made of where secondary damage may show up and those locations should be checked.

3. Sandwich Panel Damage. Impact damage to sandwich panels is tolerated differently by the various types of cores.

a. Cross-linked PVC foam cores provide more local support to the FRP skin but when an impact is severe enough, will crack across the core to the other side. Additional loading of the structure may cause this damage to propagate in the opposite skin under the core to skin bond line and lead to major structural failure.

b. Linear PVC foams provide somewhat less local support to the FRP skins and may allow a thin PEP skin to be sheared under sharp impacts, but will not crack and separate and allow the damage to propagate under the skin.

c. Balsa cores will crack through under high enough impacts but do not allow the failure to propagate easily on the opposite skin.

In any case, suspected damage should be thoroughly inspected at the earliest opportunity.

4. <u>Temporary Repairs</u>. PEP vessels can absorb considerable damage and still survive to carry the occupants back to safety. Temporary repairs should aim for that goal. Temporary repairs will not have the advantage of a thorough inspection and full service repair facilities. Temporary repairs should take into consideration the severity of the damage, the type of service the vessel is in, how far the vessel must go before permanent repairs are made, and the adequacy of the temporary repair. Temporary repairs should have the approval of the local OCMI for certificated Y885518.

5. <u>Damage Prom Land Storage and Transportation</u>. Boats are designed to take the loads from a widely distributed hydrostatic or hydrodynamic load and usually the gentle lifting of an inclined railway on the reinforced keel. Land storage and transportation are another matter. Following are some examples of damage resulting from improper land handling:

a. Boats lifted with travel lifts and slings may show deck buckling from longitudinal bending, gouges if the lift has inadequate straps, or deck-to-hull joint problems if the slings are not spread properly and squeeze the hull between bulkheads or web frame 8.

b. Dry storage without support under heavy engines will show bulges in the external hull and separated bonding angles inside.

c. Boats transported over rough roads supported by loose choking may show severe local impact loads from hitting the chocks, resulting in sheared or delaminated shells.

Once some type of land storage or transportation damage is evident, closer examination is warranted.

CHAPTER 6. REPAIRS

A. Introduction.

1. Repairs to FRP vessels are somewhat less difficult in execution than for other materials but the preparation is just as critical. Resin bonding requires a clean dry surface and careful on site material manufacturing. Often the owner is pressed to meet a commercial schedule and must wait impatiently for fast curing resins to fully cure whereas a welded steel or aluminum hull is ready for service as soon as the weld cools.

2. The severity of service that a repaired section is likely to see should be assessed along with the repair method. An item that has broken or delaminated from the normal service environment should not be renewed as original since it is an indication that the original item was insufficient. An alternate arrangement or extra reinforcement is necessary. A large hole in the bottom near midship requires a repair atmosphere of a new construction shop whereas a small hole in the topsides bow can be repaired in decent weather at -the dock. The primary concern is to make repairs that maintain the structural integrity of the vessel and its safety equipment.

B. Hull Shell Repairs.

Hull Shell Repairs. The most critical of repairs is to the hull shell. During original construction for FRP vessels, the shell is constructed with mostly primary (chemical) bonds, so a repair is always a secondary bond. Repairs to bring the shell back to original strength require additional reinforcement, stronger bonding resins or both. For major repairs, the hull should have support in addition to its normal cradle. The original laminate should be determined from plans, records, damaged material checks or burnout tests. Orientation and order of lay of reinforcements should be duplicated. A complete survey should be conducted to establish the extent of damage and secondary damage.

1. Edge and Surface Preparation. Once the area to be repaired is defined, the shell should be cut open back to good laminate. If the damage is from a glancing blow, only the surface layers may need replacement. In this case, a router can be used to cut back to the intact inner layers. The edges of the sound laminate should be tapered back 1 to 12 or more as shown in Figure 6-1b. The surface of the taper should be prepared by sanding or grinding to produce a roughened area for the secondary bond.

2. Molding. Obtaining molds for large area repairs can range from simple to very difficult. If the damaged area is still somewhat intact, it can be filled and sanded then used as a base for making a female mold before it is cut out. The original female mold can be placed back around the vessel, used to make a full thickness panel for insert into -the repair area, or to make a matching female mold panel for laminating the repair into on the vessel. Guidance for preparing and supporting molds in Chapter 4 of this circular should be followed.

3. Laminating. Repair joints were once made by laminating in progressively larger layers as in Figure 6-la. However, it was found that this method produced a relatively weak resin rich layer at the joint surface and is no longer recommended. The recommended method is to lay the first layer over the entire joint, including overlap, then build up the required

thickness as in Figure 6-lb. The subsequent layers should be somewhat wider than necessary, then ground smooth after cured for the final layer used to seal the exposed edges. The laminating process should be done carefully to ensure that the proper glass content is maintained and the plies are fully pressed into the various breaks in the joint. Figure 6-1b also shows the additional reinforcement overlaps suggested by ABS Rules (7.l.2c) for hull half joints. The extent to which this additional reinforcement is carried is dependent upon the location of the repair in the vessel, the size of the repaired area and the quality of the repair materials.

4. Sandwich Construction. For cored FRP vessels, the extent of damage to the core must be determined when cutting out the damage. If both skins and the core are damaged, the layup of each skin can be similar to that for single skin, including additional reinforcement as shown in Figure 6-2. The core should be thoroughly bonded to both skins.

5. Blisters. Blisters should be drained, the damaged gelcoat removed and the area rinsed with fresh water and dried. Drying can be done with heat lamps, but not above a surface temperature of 150^0F. The damaged areas should be ground or sanded away, cleaned and coated with fresh resin. Some boat builders use sand blasting to remove the blisters. Vinyl ester or epoxy resin is recommended for better adhesion and to provide a better seal against further blistering.

6. Cracks. Crack repair is similar to blister repair. Any damage to the underlying laminate must also be repaired with tapers and procedures similar to large area repairs previously described. If the condition which caused the crack to form is internal, such as a load concentration, it should be eliminated.

C. Stiffeners. The main problem with stiffeners is delamination of the bonding angle. Minor delaminations (less than the length of one leg of the angle) can be cleaned, saturated with resin and clamped into place. Often, the delaminated angle is not discovered until long after it has failed, and the joint is so dirty it cannot be cleaned to hold a bond. In this case, and with larger areas of failure, the failed angle should be cut out and new one installed, overlapping onto the remaining angle at both ends. The joint should be clean, roughened for the secondary bond and laminated back to original (which was already a secondarybond). Damage to the stiffeners should be assessed and repaired similar to single skin repair methods with the additional reinforcement.

D. Deck-to-Hull Joint. Minor leaks in this joint may be caulked and noted for a careful check at the next survey. More serious failures or leaks require the following repair:

1. Pull the fasteners. This will give a good indication of their adequacy for size and washers.

2. Separate the joint.

3. Clean out the old bedding.

4. Reseal and refasten the joint.

Caulking may have to be used at the ends of the failed area of the joint where old bedding may not be accessible. In general, joints should be rebuilt to the guidelines for new joints.

E. Through-Hull and Deck Fittings. If the attachment of a sound fitting is suspect, it should be removed and the cause of leaks or looseness investigated. The following deficiencies, most stemming from new construction faults, are possible:

FIGURE 6-1a

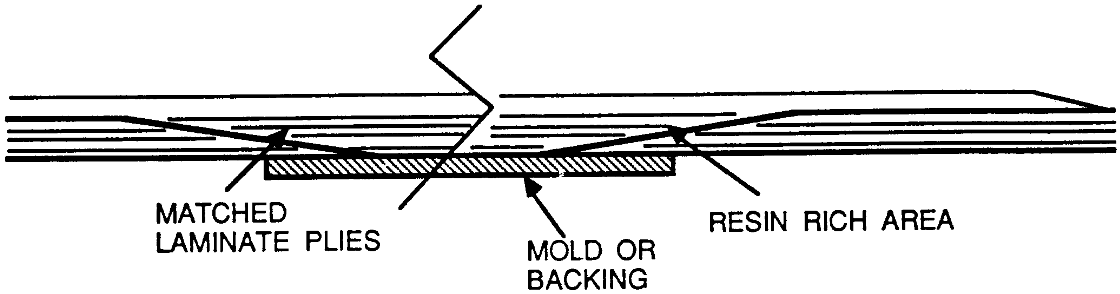


FIGURE 6-1b

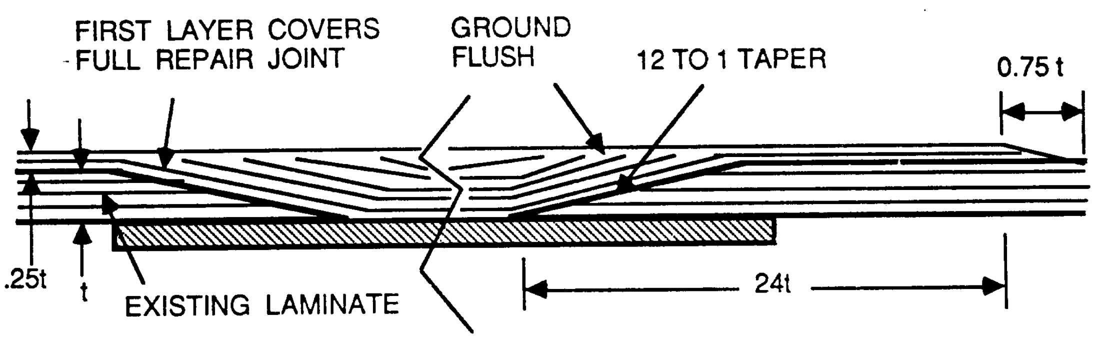
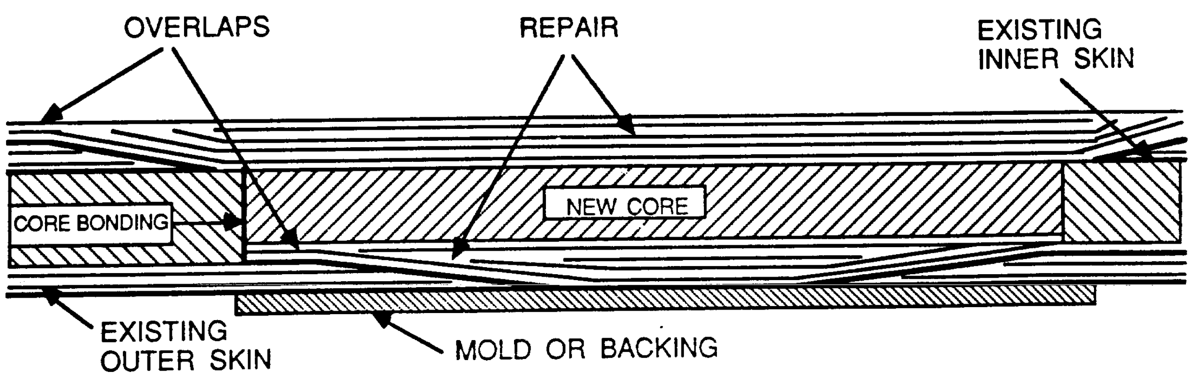


FIGURE 6-2



1. The attaching bolts are corroded or broken.

2. Bolt washers or backing plates are too small and the bolts are pulling through the laminate.

3. A flat based fitting is attached to a curved surface. In this case the bedding or sealant has served as a base plate, but has failed because of the improper joint surface.

4. The sealant or bedding has failed.

5. The sealant has failed and the laminate is damaged from water infiltration.

6. The surrounding laminate has failed due to one of the above or was not properly prepared to begin with.

In any case, a suspect fitting should be checked for all of these deficiencies and brought back to the standards for new construction.

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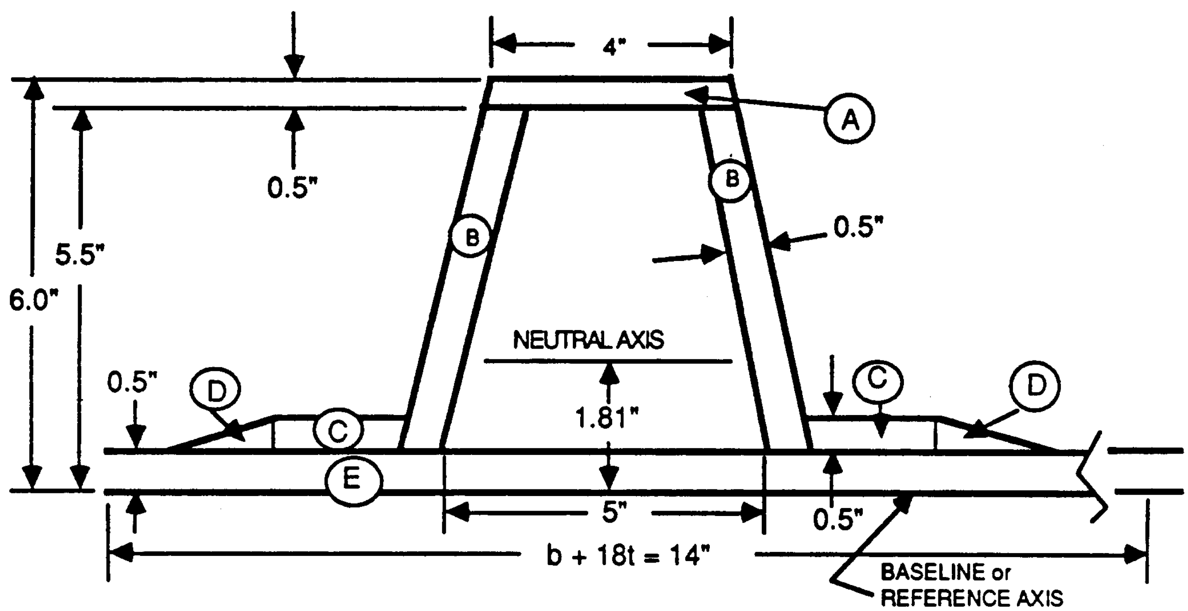
ENCLOSURE A

SECTION MODULUS and MOMENT of INERTIA CALCULATION GUIDE

Figure A-1



ITEM	b	h	A=bxh	d	Ad	Ad^2	i_o
A	4.00	0.50	2.00	5.75	11.50	66.13	0.04
B	0.50	5.10	2.55	3.00	7.65	23.95	5.31
B	0.50	5.10	2.55	3.00	7.65	23.95	5.31
C	2.00	0.50	1.00	0.75	0.75	0.56	0.02
C	2.00	0.50	1.00	0.75	0.75	0.56	0.02
D	14.00	0.50	7.00	0.25	1.75	0.44	0.15
E	3.00	0.50	0.75	0.67	0.50	0.33	0.01
			16.85		30.55	115.92	10.86

$d_{NA} = \Sigma Ad / \Sigma A = 30.55/16.85 = 1.81$ in.

$I_{NA} = \Sigma i_o + \Sigma Ad^2 - [A(d^2)]$

$= 10.86 + 115.92 - [16.85 \times (1.81)^2] = 71.58 \text{ in}^4$

$SM_{top} = I/d_{NA\ top} = 71.58/4.19 = 30.26 \text{ in}^3$

$SM_{bottom} = I/d_{NA\ bottom} = 71.58/1.81 = 39.55 \text{ in}^3$

NOTES ON SAMPLE CALCULATION

1. SYMBOLS
   - b = width or horizontal dimension   A = bxh = area
   - h = height or vertical dimension   SM = section modulus
   - d = height to center of A from reference axis
   - NA = neutral axis (equal area moments on both sides)
   - i_o = item moment of inertia = $bh^3/12$
   - d_{NA} = distance from reference axis to real NA
   - I_{NA} = moment of inertia stiffener and plate together about the real neutral axis.
2. The assumed neutral axis is at the outer shell so all distances are positive.
3. Note how the stiffened plate is divided into discreet areas and lettered.
4. Items B and C have the same effect on section properties and are counted twice.
5. Some simplifications were made for the vertical legs of the stiffener, item B. The darkened triangular area at the base was left out and the same at the top was added. Then the item i_o was calculated using the equation for the I of an inclined rectangle. Considering the legs as vertical members would be a further simplification. Either way, very little error is involved.
6. Item E is combined from both sides of the required bonding angle taper.

EXAMPLE

50 FT LOA SINGLE - SKIN VESSEL
46 FT LBP
20 KT MAX SPEED
8 FT WEB FRAME SPACING

Speed Length Ratio = $V/\sqrt{LWL} = 20/\sqrt{46} = 2.95$ so it should be analyzed as a planing vessel.

ABS 7.2.5b SM required $= .0072cVsl^2 \text{ in}^3$
$= .0072(0.6)(20)(2)(8^2)$
$= 11.06 \text{ in}^3$

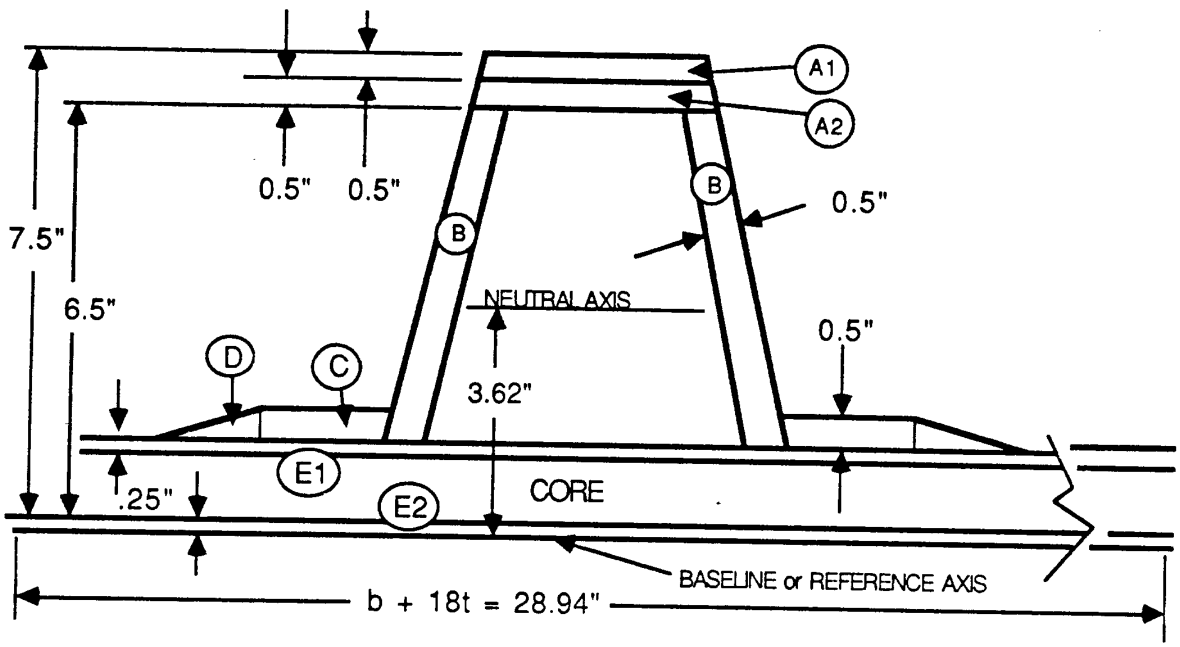
I required $= .0031cVsl^3 \text{ in}^4$
$= .0031(0.6)(20)(2)(8^3)$
$= 38.09 \text{ in}^4$

Therefore, the hat section stiffener and shell plating combination used for the sample calculation would be more than adequate for this particular vessel.

HIGH STRENGTH MATERIALS

Consider the use of a 3 inch wide layer of kevlar in the top flange of the stiffener, in a polyester resin, with a 1 inch cored shell.

Figure A-2.



ITEM	b	h	A=bxh	d	Ad	Ad^2	i_o
A1	3.70	0.50	3.29*	7.25	52.56	381.08	0.039
A2	3.80	0.50	1.90	6.75	12.83	86.57	0.040
B	0.50	5.00	2.50	4.00	10.00	40.00	5.208
B	0.50	5.00	2.50	4.00	10.00	40.00	5.208
C	2.00	0.50	1.00	1.75	1.75	3.06	0.021
C	2.00	0.50	1.00	1.75	0.75	0.56	0.021
D	3.00	0.50	0.75	0.67	0.50	0.33	0.01
E1	28.94	0.25	7.23	1.375	9.95	13.68	0.038
E2	28.94	0.25	7.23	0.125	0.90	0.11	0.038
			27.40		99.24	565.39	10.620

$d_{NA} = \Sigma Ad / \Sigma A = 99.24/27.40 = 3.62$ in.

$I_{NA} = \Sigma i_o + \Sigma Ad^2 - [A(d^2)]$

$= 10.62 + 565.39 - [27.40 \times (3.62)^2] = 216.95 \text{ in}^4$

$SM_{top} = I/d_{NA\ top} = 216.95/3.88 = 55.92 \text{ in}^3$

$SM_{bottom} = I/d_{NA\ bottom} = 216.95/3.62 = 59.93 \text{ in}^3$

NOTES ON SAMPLE CALCULATION FIGURE A-3

1. Ratio of Elastic Moduli $E = E_{kevlar} / E_{E\text{-}glass} = 9.8msi/5.5msi$ $= 1.78$ in a polyester resin.
2. * Effective Area of kevlar compared to the E-glass = 3.7 x 0.5 x 1.78 = 3.29
3. The overall required section modulus for this example must also reflect the mixed materials calculated as a modifier to the required section modulus:

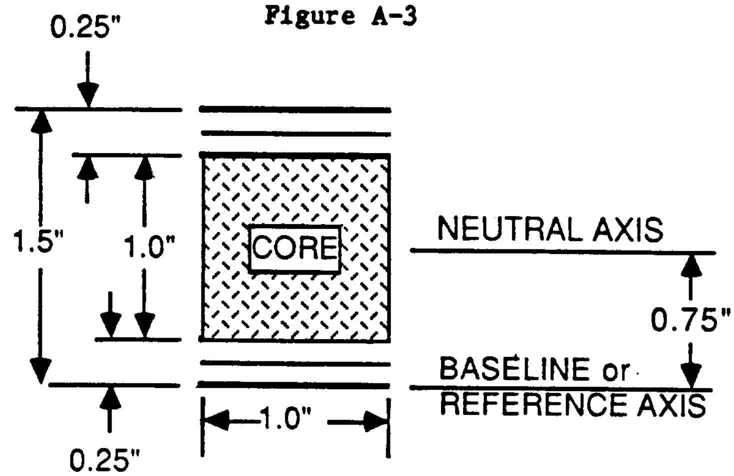
   (E_{kevlar} / E_{glass}) X (Ult. Strength glass/ Ult. kevlar)

   9.8msi/5.5msi X 110ksi/196ksi = 1.0

   Reinforcing fibers of different strengths and different moduli can be limited in the amount of strength that the fibers can develop by the maximum elongation tolerated by the resin and the strain to failure of the surrounding laminate. Therefore, the strength of the overall laminate should be analyzed and, for marginal safety factor designs or arrangements meeting the minimum of a rule, tests of a sample laminate should be conducted to prove the integrity of the design. In this example, the required section modulus was unchanged but the credit for the actual section modulus to meet the rule was significant.

EQUIVALENT SINGLE-SKIN THICKNESS FOR SANDWICH PANEL

Figure A-3



ITEM	b	h	A=bxh	d	Ad	Ad^2	i_o
A	1.00	0.25	0.25	1.375	0.344	0.47	0.0013
B	1.00	0.25	0.25	0.125	0.031	0.004	0.0013
			0.50		0.375	0.477	0.0026

$d_{NA} = \Sigma Ad / \Sigma A = 0.375/0.50 = 0.75$ in.

$I_{NA} = \Sigma i_o + \Sigma Ad^2 - A(d^2)$

$= 0.0026 + 0.477 - [0.50 \times (0.75)^2] = 0.198 \text{ in}^4$

Single-skin equivalent moment $I = bh^3/12 = 1.0 \times h^3/12 = 0.198$

$h = \sqrt[3]{(.198 \times 12)/1} = 1.33$ inches

Effective width of plating for stiffened section calculations is the lesser of b + 18t or the frame spacing. Assuming the frame spacing is greater:

$w = b + 18t = 5.0 + 18 \times 1.33 = 28.94$

HAZARDOUS SUBSTANCES IN FRP CONSTRUCTION MATERIALS

Following is a list of some toxic or hazardous substances which may be encountered in parts of the FRP industry:

aluminum oxide (as fire retardant)
antimony oxide (fire retardant)
benzoyl peroxide
Chloran TM (fire retardant), or
    [2,3-dicarboxy-5,8-endomethylene-5,6,7,8,9,9-hexachloro-l,2,3,4,4a,5,8, a-octahydro-napthalene anhydride)
chlorindic anhydride (as fire retardant), or
    [2,3-dicarboxy-l,4,5,6,7,7-hexachlorobicyclo[2.2.l]-5-heptene anhydride]
cobalt accelerators (cobalt naphthenate) cyclohexane peroxide
diallyl phthalate
dicarboxylic acid (saturated and unsaturated) diethylene glycols
dihydric alcohol (saturated) dime thylaniline fumaric acid
glycols (assorted):
- butylene,
- ethylene glycol,
- propylene. hydroperoxides:
- methylethylketone peroxide-MEKO,
- benzoyl peroxide. isophthalic anhydride itaconic acid, maleic acid (anhydride) mesaconic acid

methyl ethyl ketone peroxide methyl methacrylate phthalic anhydride polyhydric alcohols vinyl monomers (usually styrene) vinyl toluene

The following are more likely to be encountered in the FRP boat industry:

benzoyl peroxide (catalyst)
cobalt accelerators (cobalt naphthenate, cobalt octoate - promoters)
dimethylaniline (accelerator)
methyl ethyl ketone peroxide (catalyst)
phthalic anhydride
2,4 pentanedione (retarder)

WORKPLACE PRACTICES

The following are recommended workplace practices:

- Turning on spray booth exhaust fans in specified circumstances.
- Keeping breathing zones at least 18 inches from sources of styrene.
- Keeping styrene off of the akin.
- Working on the upwind side of sources of airborne styrene.
- Working only in specific areas to take advantage of exhaust ventilation
- Avoiding a position in front of a person operating a spray gun.
- Avoiding spraying towards another worker.

- Spraying towards the exhaust ports of booths.
- Spraying so that most of the spray hits the mold or part.
- Locating molds and parts to take advantage of the airflow.

Housekeeping Conditions:

- All spray booth filters should be in place.
- Overspray buildup on booth filters should be kept below 1.25 cm in chop spray booths and 0.625 cm in gelcoat booths.
- Floors in work areas should be covered by disposable materials.
- Floor coverings should not be torn or soaked through with resin.
- Resin-soaked debris should be removed from work areas.
- Overspray buildup on booth floors should be kept below 2.54 cm.
- Overspray buildup on roll out area floors should be kept below 1.25 cm.
- Floors and work table tops should be free of resin and gelcoat spills larger than a diameter of 15 cm.
- Overspray buildup on booth walls should be kept below 1.25 cm.
- Spray booth lights should be operational and visible.
- Waste cans should be available in spray booths.
- Table coverings should not be torn or soaked through with resin.
- Work areas should be free of empty chemical containers.
- When work on them is completed, curing parts should be removed.
- Wheels on mold carriages should turn freely.
- Resin and gelcoat containers should be covered.
- Spray equipment gauges should be visible.
- Acetone containers should be closed when not in use.
- Spray guns and hoses should not leak.
- Work areas should be free of food and drink.

CLASSIFICATION SOCIETIES

	Main Office	U.S. Office
1.	American Bureau of Shipping 45 Eisenhower Drive Paramus, NJ 07653 Tele: 201-368-9100	Same
2.	Lloyd's Register of Shipping 71 Fenchurch Street London, EC3M 4BS, England Tele: 01-709-9166	17 Battery Place New York, NY 10004 Tele: 212-425-8050
3.	Det Norske Veritas Veritasvelen 1 Post Office Box 300 1322 Hovik, Oslo, Norway	Veritas Marine Service Center 111 Galway Place Teaneck, NJ 07666 Tele: 201-837-9360
4.	Germanischer Lloyd Vorsetzen 32 Post Office Box 11 16 06 D-2000 Hamburg 11, Federal Republic of Germany Tele: 040/36 14 91	11 Broadway, Suite 1420 New York, NY 10004 Tele: 212-425-5241
5.	Bureau Veritas 31 Rue Henri Rochefort 75821 Paris Cedex 17 Tele: 766-51-05	1250 Broadway New York, NY 10001 Tele: 212-279-3344
6.	Registro Italiano Navale Via del Viminale 43 Rome, Italy Tele: 46-55-80	799 Broadway, Room 212 New York, NY 10003 Tele: (212) 982-9058
7.	Nippon Kaiji Kyokai 4-7 Kio-cho Chiyoda-ku, Tokyo 102 Japan Tele: 03-230-1201	17 Battery Place, Suite 203 New York, NY 10004 Tele: (212) 425-3799

COMDTPUB P16700.4
NVIC 8-87, CH-1
AUG 30 1993

NAVIGATION AND VESSEL INSPECTION CIRCULAR NO. 8-87, CHANGE-1
Electronic Version For Distribution Via the World Wide Web

Subj: CH-1 TO NVIC 8-87, NOTES ON DESIGN, CONSTRUCTION, INSPECTION AND REPAIR OF FIBER REINFORCED PLASTIC (FRP) VESSELS

1. PURPOSE. This Circular transmits a change to NVIC 8-87 dated 6 November 1987. The restrictions concerning the use of general purpose (non-fire retardant) resins and overnight accommodations have been modified.

2. PROCEDURES.

a. The restriction requiring small passenger vessels built with general purpose (non-fire retardant) resins to have a flame spread of 200 or less when tested to ASTM Standard E-84 is rescinded.

b. The restriction prohibiting vessels built with general purpose (non-fire retardant) resins is amended. Vessels built with general purpose (non-fire retardant) resins, which carry 12 passengers or less and have overnight accommodations, may be allowed to use the equivalency provisions in NVIC 8-87.

c. Officers in Charge, Marine Inspection are encouraged to bring this change to the attention of appropriate individuals in the marine industry within their zones.

3. DISCUSSION.

a. NVIC 8-87 requires the use of fire retardant resins in FRP vessels carrying passengers. However, small passenger vessels can be built with general purpose (non-fire retardant) resins provided additional requirements are followed which provide an equivalent degree of safety to fire retardant resins. One of the conditions for an equivalency includes general purpose resins having a flame spread of 200 or less when tested to ASTM Standard E-84. The equivalency policy was promulgated to allow existing FRP vessels manufactured with resins meeting the industry standard for pleasure service, to be able to be certificated for limited service as small passenger vessels. During the research that went into the development of NVIC 8-87, it was determined that resins were readily available to the industry with a flame spread rating of less than 200. However, resins commonly in use in the industry have a flame spread rating of 300 to 400 range. Since the requirement for resins to have a flame spread of 200 or less contradicted the intent of the equivalency policy, it was rescinded on 21 September 1989 by Commandant (G-MVI). Change 1 incorporates this revision.

b. NVIC 8-87 did not allow vessels built with general purpose (non-fire retardant) resins to have overnight passenger accommodations. This policy has been changed. FRP vessels may have passenger accommodations for 12 or less passengers provided they meet the present equivalency requirements outlined in NVIC 8-87. This policy change is consistent with international standards contained in SOLAS 74 (as amended), which requires passenger vessels carrying more than 12 passengers to be built with steel or equivalent materials.

4. IMPLEMENTATION. Make the following pen and ink changes to enclosure (1) of NVIC 8-87:

a. Delete paragraph l.F.4.a on page 1-6. Renumber the following paragraphs as noted:
l.F.4.b to l.F.4.a
l.F.4.c to l.F.4.b
l.F.4.d to l.F.4.c
l.F.4.e to l.F.4.d
1.F.4.f to l.F.4.e

b. Add the following after the word "accommodations" on line two of paragraph 1.F.5.a on page 1-7, “for more than 12 passengers.”

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