MIL-W-2038C(SHIPS)
26 October 1960
SUPERSEDING
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MILITARY SPECIFICATION

WOOD LAMINATES, DOUGLAS FIR

(FOR SHIP AND BOAT USE)

1. SCOPE

1.1 Scope. - This specification covers laminated Douglas fir members for ship and boat use. Such material is suitable for use as straight and mildly curved structural members in small craft, patrol craft, minesweepers, other wooden vessels, and for other applications where structural Douglas fir laminates with fully waterproof durable adhesive bonds are desired.

1.2 Classification. - Laminations used in Douglas fir laminates shall consist of the following grades, types, densities, and classes:

Grade:
- Grade A
- Grade B
- Grade C
- Grade D

Type (orientation of annual rings).
- Type 1 - Either flat grain or edge grain.
- Type 2 - Flat grain.
- Type 3 - Edge grain.

Density:
- Close grain, or better.
- Dense material.

Class: (Decay susceptibility).
- Class 1 - Least decay susceptible.
- Class 2 - Intermediate decay susceptibility.
- Class 3 - Most decay susceptible.

2. APPLICABLE DOCUMENTS

2.1 The following specifications and standards, of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified herein.

SPECIFICATIONS

FEDERAL

TT-A-468 - Aluminum-Pigment; Powder and Paste for Paint.

MILITARY

MIL-V-1174 - Varnish, Spar, Water Resisting (Formula No. 80).

MIL-W-6110 - Wood; Determination of Moisture Content of.

MIL-W-18142 - Wood Preservative Solutions; Oil Borne; Ship and Boat Use.

MIL-A-22397 - Adhesive, Phenol and Resorcinal Resin Base (for Marine Service Use).

STANDARDS

MILITARY

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

(Copies of specifications, standards, and drawings required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. - The following document forms a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids shall apply.

OFFICIAL CLASSIFICATION COMMITTEE
Uniform Freight Classification Rules.

(Application for copies should be addressed to the Official Classification Committee, 1 Park Avenue at 33rd Street, New York 16, N. Y.)

3. REQUIREMENTS

3.1 Facilities survey. - When a facilities survey is required by the contract or order, facilities and personnel for producing Douglas fir laminates in accordance with this specification shall be the minimum described in Appendix I, which are applicable to Douglas fir laminates (see 6.2(b) and 6.5).

3.2 Douglas fir laminations. - Laminations used in laminated assemblies shall be one piece for length and width. Edge-joints and end joints may be used to form laminations of the required dimensions. Douglas fir laminations (includes edge-glued and end-glued components) used in laminated assemblies shall be free from splits, surface checks over 1/32 inch wide or over 4 inches long, ring shake, honeycomb, collapse, case-hardening, or oversteaming (see 4.5.2), wane, and decay in any stage.

3.2.1 Moisture content. - The moisture content at the time of gluing shall be not less than 10 nor more than 14 percent. The moisture content of the core as determined by a distribution section (see figure 1) taken from any board shall not vary from that of the shell by more than 2.0 percent (see 4.5.1).

3.2.2 Grades. - Grades and applicable defect limitations shall be in accordance with table I, 3.2.2.1 and 3.2.2.2, (see 6.2(d)).

Table I - Permissible cross grain, and permissible equivalent knot defect limitations, for various lamination grades.

Lamination grade (see table VIII)	Maximum slope of cross grain expressed as one inch rise in inches of length	Maximum sums of diameters of equivalent knot defects (including sound tight knots) in any 3 feet of length of lamination for the given lamination width (maximum in inches) after fabrication of laminates							
		(Lamination width - inches)							
		1	1-3/4	2-3/4	3-3/4	4-3/4	6-3/4	8-3/4	10 and over
		(sum of knot diameters - inches)							
Grade A	1 in 15	1/8	1/4	3/8	1/2	5/8	3/4	1	1-1/4
Grade B	1 in 12	1/8	1/4	1/2	5/8	3/4	1	1-1/4	1-1/2
Grade C	1 in 10	1/4	3/8	5/8	3/4	1	1-1/4	1-1/2	1-1/2
Grade D	1 in 8	1/4	1/2	3/4	1	1-1/4	1-1/2	1-1/2	1-1/2

3.2.2.1 Cross grain.- When measured as specified in 4 5.3, cross grain along the length of any face or edge of a lamination shall not be steeper than the maximum slope specified in table I for the applicable grade

3.2.2.2 Knots and equivalent knot defects. - The sums of diameters of knots and equivalent knot defects for various lamination grades shall be as specified in table I Knot and equivalent knot defect limitations are based on the finished lamination width within the finished dimension of the Douglas fir laminate in which it appears.

3.2.2.2.1 Knots.- All knots shall be sound. Knot clusters are not permissible. Intergrown knots containing checks will be equivalent to a sound tight knot of the same size. All knots appearing on the edge surfaces of laminations, and on the face surfaces of laminations less than 3 inches wide shall be tight. In laminations 3 inches in width and wider, knots on the face surface larger than 3/8 inch in diameter, shall be tight. The diameter of knots shall be determined as specified in 4.5.4.

3.2.2.2 2 Burls.- Burls shall be considered as equivalent knot defects of the same size.

3.2.2.2.3 Holes.- Holes are not permissible on edge surfaces, and face surfaces less than 3 inches wide. In laminations 3 inches and wider, knot holes and sound holes (due to mechanical damage) up to and including 3/8 inch in diameter (average) appearing on face surface shall be considered the same as a sound tight knot of the same size. Holes greater than 3/8 inch in diameter are not permissible in any location.

3.2.2.2.4 Pitch pockets and bark pockets.- Assigned equivalent knot defect values for pitch pockets and bark pockets are listed in table II. Pitch pockets with soft or exuding pitch are not permissible.

Table II - Assigned equivalent knot defect values for pitch pockets and bark pockets.

Pitch pocket (or bark pocket)	Equivalent knot defect	
	Flat-grain laminations	Edge-grain lamination
	Inch	Inch
1/16 inch wide and 2 inches in length, or 1/8 inch wide and 1 inch in length	1/8	0

Table II - Assigned equivalent knot defect values for pitch pockets and bark pockets - Continued

Pitch pocket (or bark pocket)	Equivalent knot defect	
	Flat-grain laminations	Edge-grain lamination
	Inch	Inch
1/16 inch in width and 3 inches in length, or 1/8 inch wide and 2 inches in length	1/4	1/8
1/16 inch in width and 3 inches in length, or 1/8 inch in width and 4 inches in length, or 1/4 inch wide and 2 inches in length	3/8	1/4
1/16 inch in width and 8 inches in length, or 1/8 inch in width and 6 inches in length, or 1/4 inch wide and 3 inches in length	1/2	3/8
1/8 inch in width and 8 inches in length, or 1/4 inch in width and 4 inches in length, or or 1/4 inch in width and 4 inches in length, or 3/8 inch in width and 2 inches in length	5/8	1/2

3.2.3 Type (orientation of annual rings) (see 6.2(d)).-

3.2.3.1 Type 1.- Laminations may contain either flat grain or edge grain, and individual boards or other lamination components may contain both flat and edge-grain. However, lamination and board components shall be segregated according to grain, so that flat grain surfaces are glued to predominatly flat grain surfaces, and edge-grain surfaces are glued to predominantly edge-grain surfaces.

3.2.3.2 Type 2 (flat grain).- The annual growth rings in laminations and lamination components shall be so oriented that a tangent line to the annual growth rings form an angle of more than 45 degrees with an imaginary line drawn at a right angle through the wide surface of the piece.

3.2.3.3 Type 3 (edge-grain).- The annual growth rings in laminations and lamination components shall be so oriented that a tangent line to the annual rings form an angle of less than 45 degrees with an imaginary line at a right angle through the wide surface of the piece.

3.2.4 Density (see 6.2(d)).-

3.2.4.1 Close grain.- The annual rings in laminations and lamination components shall average not less than 6 nor more than 30 annual rings per inch when measured at right angles to the rings. An average of 5 rings per inch, or more than 30 rings per inch, will be considered acceptable if the rings contain 1/3 or more summerwood (the dark portion of the annual rings).

3.2.4.2 Dense material.- The annual rings in laminations and lamination components shall average not less than 6 nor more than fifty annual rings per inch when measured at a right angle to the rings, and in addition the annual rings shall contain one-third or more summerwood when measured at a right angle to the rings.

3.2.5 Class (see 6.2(d)).-

3.2.5.1 Class 1 (least decay susceptible).- Laminations shall be free from sapwood, or shall be treated with tanalith preservative in accordance with 3.2.5.1.1 through 3.2.5.1.4.

3.2.5.1.1 Preparation for treatment.- The wood before treatment shall be sufficiently seasoned to a moisture content not in excess of 18 percent in the sapwood for proper impregnation with preservative.

3.2.5.1.2 Preservative material (Flourchrome-arsenate-phenol mixture).- The preservative shall consist of approximately 25 percent sodium fluoride, 25 percent disodium hydrogen arsenate, 37-1/2 percent sodium chromate, and 12-1/2 percent dinitrophenol, by weight, subject to the following tolerances: The minimum proportions of these compounds, in dry salt or treating solution, on the moisture free basis, may be 22, 34 and 10 percent, respectively, but the preservative shall contain a total of at least 95 percent of these active materials. The pH of the treating solution shall be not less than 7.2 nor more than 7.8 The treating solution shall be of a uniform concentration of 5 ± 0.5 percent, or the concentration and treating process shall be such as to provide 0.50 lbs/ft^3 dry salt retention in the sapwood.

3.2.5.1.3 Treatment.- The treatment shall be any method which does not use a pressure higher than 150 pounds per square inch (p.s.i.) or a temperature higher than 140° Fahrenheit (F.), and provides 100 percent penetration of preservative in the sapwood with a dry salt retention of not less than 0.50 lbs/ft^3 of sapwood.

3.2.5.1.4 Treatment of wood after conditioning.- Lumber treated with the water-borne preservative may be dried to the required moisture content by either air drying or kiln drying, using temperatures less than 150°F.

3.2.5.2 Class 2 (intermediate decay susceptibility).- The area of edge or wide surfaces of any lamination may contain up to 10 percent unstained sapwood.

3.2.5.3 Class 3 (most decay susceptible).- The area of edge or wide surfaces of any lamination may contain up to 20 percent unstained sapwood.

3.3 Adhesives.- Adhesives used for all gluing operations shall conform to type II, class 2 of Specification MIL-A-397. Only products which have been approved for listing on the applicable Qualified Products List shall be utilized.

3.4 Construction.- A laminate shall consist of layers of laminations joined together by the adhesive specified in 3.3 in accordance with the process requirements of 3.5.

3.4.1 Lamination thickness.- All laminations in a given laminate shall be approximately the same thickness. The maximum lamination thickness for straight laminates shall be one inch. The maximum lamination thickness for curved laminates shall be in accordance with table III.

Table III - Minimum allowable radius of curvature to which laminations of a given thickness can be bent.

Minimum radius of curvature to which a lamination will be bent	Maximum permitted lamination thickness (laminations thicker than 1 inch and thinner than 1/4 inch not permitted)
Inches	Inches
200	1 (maximum permitted)
187	15/16
173	7/8
160	13/16
147	3/4
134	11/16
121	5/8

Table III - Minimum allowable radius of curvature to which laminations of a given thickness can be bent - Continued

Minimum radius of curvature to which a lamination will be bent	Maximum permitted lamination thickness (laminations thicker than 1 inch and thinner than 1/4 inch not permitted)
Inches	Inches
108	9/16
95	1/2
82	7/16
69	3/8
56	5/16
43	1/4

3.4.2 Arrangements of end joints. - Laminated assemblies shall be classified as to arrangement of end joints (all end joint spacings are measured center to center and in the lengthwise direction of the lamination) as follows and as specified (see 6.2 (e)):

Arrangement 1. - End joints in any group of 3 consecutive laminations shall be spaced not less than 12 inches apart for laminations 1/2 inch and less in thickness and not less than 18 inches for laminations over 1/2 inch in thickness.

Arrangement 2. - End joints in any 2 adjacent laminations shall be spaced not less than 20 times the thickness of a lamination, provided the number of such joints in any 12 inch section of the finished laminated piece shall not exceed one-fourth the total number of laminations in such section.

Arrangement 3. - Laminations closer to either face than 1/4 the total depth of the piece shall permit end joint spacing as specified for arrangment 1. In the center half of the depth of the piece, end joints in any two adjacent laminations shall be spaced not less than 12 times the thickness of a lamination.

3.4.3 Finished dimensions. - Laminated Douglas fir members shall be manufactured to full dimensions required by the procuring activity and shall conform to the pattern lines as determined from templates or drawings furnished (see 6.2(c)).

3.5 Process requirements. - Edge-gluing of lumber components to produce laminations of required width and end-gluing of lumber components to form laminations to required length shall precede final surfacing and gluing of laminations.

3.5.1 Machining of surfaces to be bonded. -

3.5.1.1 Edge-surfaces. - Strips of Douglas fir used to build up laminations for width by edge-gluing shall have a minimum width of 1-1/2 inches at the time of fabrication. Strips to be edge glued shall be machined to produce a uniform flat (without tongue and groove, or similar construction) and true surface with a minimum of damage to wood fibers.

3.5.1.2 End-surfaces. - Laminations built up for length by end-joining of lumber components shall require use of a plain flat scarf-joint with a slope not steeper than one inch rise in 12 inches of length.

3.5.1.3 Surfacing laminations. - Laminations shall be dressed to a uniform thickness throughout, and the total thickness variation of any lamination at the time of gluing shall not exceed a maximum of 0.01 inch, as determined through the use of an accurate thickness gage. Surfaces shall not show manufacturing defects to an extent which will prevent sufficient contact between gluing surfaces for complete adhesion. Surfaces shall not be sanded to remove such defects after surfacing.

3.5.2 Adhesive spread. - The adhesive shall be uniformly applied to both contact faces.

3.5.3 Assembly. - At the time of gluing the temperature of lumber materials and ambient air temperature shall be 75° ± 15°F., and surfaces to be bonded shall be free of oil, dirt, crayon marks, and other foreign material which may interfere with bonding of the adhesive.

3.5.4 Clamping. - Application of pressure to glue lines shall be accomplished within the assembly period limitations required for the particular adhesive used. Cauls, clamps, and clamp spacing shall be adequate so as to uniformly apply and hold a glue line pressure of 125 p.s.i. with a plus tolerance of 50 p.s.i. throughout the cure. During initial application of pressure, clamps shall be loose enough to allow slippage of material into proper position. During application of final pressure, clamping procedure shall be such as to allow glued surfaces to be forced into intimate contact at all points.

3.5.4.1 Edge-joints. - Bearing surfaces on clamps, and clamp spacing shall be such as to apply and hold required pressure without damage to material.

3.5.4.2 End-joints.- Clamping procedure shall result in no splitting of feathered edges or other material damage which will affect the strength.

3.5.4.3 Laminate assemblies.- Either male or female forms for gluing bent members are acceptable unless otherwise specified in the procurement contract or order (see 6.2(f)). Laminate assemblies shall be provided with top and bottom cauls of oak or equally hard and strong materials of such thickness, which in conjunction with suitable clamps and clamp spacing, will provide the required glue line pressure uniformly, and which will not result in damage to the laminate material. Clamps with equalizing pressure heads or equally effective pressing equipment shall be uniformly spaced close enough to develop pressure as specified at all points. Spacing of the clamps or units will vary with the number and thickness of the cauls used and the pressure required. Clamping shall be at a central point in the curve of a laminated assembly and shall proceed progressively toward each end. In straight members, clamping shall begin at any one point and proceed progressively toward the ends.

3.5.5 Curing.- In the curing process, a glue line temperature of not less than 150°F. shall be maintained for not less than the period required for the particular approved adhesive. Where wood is treated with preservative prior to gluing, at no time shall the ambient chamber temperature exceed 215°F., nor shall it exceed 170°F. for a period of time greater than 60 minutes. The curing temperature shall be determined at the innermost glue line through the use of an accurate potentiometer and thermocouples, while assemblies are under full clamp pressure. Where assemblies are large, or where more than one assembly is cured in the same curing chamber a sufficient number of determinations shall be made to assure that glue line temperatures are being met throughout the curing chamber.

3.5.5.1 Edge-joints.- During the curing operation, temperature and relative humidity controls shall be maintained in such a manner that all applicable requirements of 3.2 are met throughout the lamination length.

3.5.5.2 End-joints.- During the curing operation temperature and relative humidity controls shall be maintained in such a manner that all applicable requirements of 3.2 are met throughout the lamination length.

3.5.5.3 Laminate assemblies.- A dry kiln or equally effective curing chamber shall be provided with adequate controls for uniformly maintaining the temperature and humidity conditions required in the curing process. If clamped assemblies are to be moved into a separate curing chamber for the curing process, they shall not be removed from the laminating jig, and the portable jig shall be rigid enough to prevent shifting of the assembly in the jig. Clamped assemblies shall be placed in the curing chamber before the temperature in the chamber reaches 100°F. The curing period shall commence when the innermost glue line temperature reaches the temperature required for the particular approved adhesive, and shall continue for the required curing period.

3.6 Test requirements.-

3.6.1 Moisture content of finished laminate.- The finished material shall have a moisture content not less than 10 percent nor more than 15 percent (see 4.5.1).

3.6.2 Block shear (see 4.5.5).-

3.6.2.1 Types 1 and 2.- The average block shear strength between laminations shall be not less than 950 p.s.i. with at least 75 percent wood failure. No individual glue line shall have a shear strength less than 650 p.s.i., unless additional block shear tests conducted on that glue line prove the deficiency to be local.

3.6.2.2 Type 3.- The average block shear strength between laminations shall be not less than 1150 p.s.i., with at least 75 percent wood failure. No individual glue line shall have shear strength less than 650 p.s.i., unless additional block shear tests conducted on that glue line prove the deficiency to be local.

3.6.3 Resistance to delamination.- The maximum permissible delaminations shall be as specified in 3.6.3.1, 3.6.3.2 and 3.6.3.3 (see 4.5.6).

3.6.3.1 Between laminations.- Delamination between laminations shall either not exceed 5 percent at the end of the second cycle or 8 percent at the end of the third cycle.

3.6.3.2 Edge-joints.- Where a single edge-joint appears in a test specimen, delamination shall either not exceed 10 percent at the end of the second cycle, or 20 percent at the end of the third cycle. Where two or more edge-joints appear in a specimen, delamination shall either not exceed 5 percent at the end of the second cycle, or 10 percent at the end of the third cycle.

3.6.3.3 End-joints.- Delamination in end-joints shall either not exceed 5 percent at the end of the second cycle, or 10 percent at the end of the third cycle.

3.7 Finished laminate.- Finished laminates shall show no signs of opening up at the glue line, or damaged fibers from improper use of cauls and clamps.

3.8 Coatings.-

3.8.1 Preservative treatment.- After machining, laminated assemblies shall be coated on ends and sides with one coat of preservative solution conforming to type A or B of Specification MIL-W-18142. The preservative shall be allowed to dry before applying paint.

3.8.2 End coating.- The ends of laminated Douglas fir shall be painted with two coats of aluminum or mica paint after the preservative has dried for at least 24 hours. Aluminum paint shall consist of 2 pounds of aluminum paste, conforming to type II, class B of Specification TT-A-468, and 1 gallon of phenolic varnish, conforming to Specification MIL-V-1174. A drying interval of 24 hours shall elapse before applying a second coat. A second alternate and coating may be any suitable commercial end coating which is satisfactory to the bureau or agency concerned.

3.8.3 Side coating.- When specified (see 6.2(g) and 6.6) and after preservative required by 3.8.1 has dried, the sides and ends of the laminated Douglas fir shall be painted with two coats of aluminum paint consisting of two pounds of aluminum paste, conforming to type II, class B of Specification TT-A-468, and 1 gallon of phenolic varnish conforming to Specification MIL-V-1174. The coating shall be applied to the member after sawing, and a drying interval of 24 hours allowed before applying the second coat.

3.9 Marking.- Each member shall be marked to identify the intended use (see 6.2(c)).

4. QUALITY ASSURANCE PROVISIONS

4.1 The supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own or any other inspection facilities and services acceptable to the Government. Inspection records of the examination and tests shall be kept complete and available to the Government as specified in the contract or order. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.1.1 Supplier quality control system.- The supplier shall provide and maintain an effective quality control system acceptable to the Government covering materials under this specification. A current written description of the procedures, practices and methods of the quality control system will be submitted to the Government prior to initiation of production.

4.1.2 Government verification. - All quality control operations performed by the contractor shall be subject to Government verification at unscheduled intervals. Verification shall consist of, (a) surveillance of the operations to determine whether the practices, methods, and procedures are being properly applied, and (b) Government product inspection to measure quality to product offered for acceptance. Instances of poor practices which might have an affect upon the quality of the product shall be immediately called to the attention of the contractor. Failure of the contractor to promptly correct deficiencies discovered shall be cause for suspension of acceptance until correction has been made or until conformance of the product to the prescribed acceptance criteria of this specification has been demonstrated. To minimize interference with operations, the contractor will designate a responsible official or officials to whom the Government inspector will report such instances, and who will alert the Government inspector of action taken to correct production difficulties which occur. Repeated failures to meet specification requirements will result in cancellation of the contract or order.

4.2 Inspection lot.-

4.2.1 Lamination components. - All components or pieces prior to end-joining shall be considered a lot.

4.2.2 Laminations.- A lot shall consist of all laminations submitted for inspection at the same time.

4.2.3 Laminate.- A lot shall consist of all laminates submitted for inspection at the same time, which are manufactured for approximately the same end use using a single lot of adhesive, and are fabricated under approximately the same temperature and process conditions as determined by process inspection.

4.3 Sampling for examination and tests.-

4.3.1 Sampling for examination and test of laminations (or components).- For the examinations and tests specified in 4.4.1 laminations (or components prior to end-joining where specified) shall be sampled on an unbiased random basis in accordance with table IV and Standard MIL-STD-105. Where applicable the same sample may be utilized in inspecting for more than one defect.

Table IV - Sampling levels for examination and test for various lamination defects, corresponding acceptable quality levels, and basis for acceptance or rejection.

Requirement	Sampling level	Acceptable Quality Level for lot acceptance (percent)	Basis for rejection of lot
Grain, dense (when specified) (see 3.2.4.2)	I-components prior to end-joining	4.0 close-grain	Any board is poorer than close grain, or if the number of boards with close grain exceed the acceptance number
Grain, close (see 3.2.4.1)	I-components prior to end-joining	6.5- Five rings per inch, and between 31 and 40 rings per inch	a. Individual boards have less than 5 or greater than 40 rings per inch (excluding dense boards) b. The number of boards with 5 rings per inch, or between 31 and 40 rings per inch (excluding dense boards), exceeds the acceptance number
Orientation of annual rings (flat or edge-grain) (see 3.2.9)	I-components prior to end-joining	15.0-where no grain is specified 4.0-where grain is specified	a. Where no grain is specified, the number of laminations which have components which are not segregated according to grain exceeds the acceptance number b. Where either grain is specified, any lamination is predominantly the wrong grain. c. Where either grain is specified the number of laminations with components which do not have the required grain exceeds the acceptance number
Casehardening (see 3.2)	L-6 -lamination components prior to end-joining (test 4.5.2)	4.0-casehardened or over steamed	a. The number of laminations which are casehardened or oversteamed exceeds the quality acceptance number. (Individual laminations which have components which are casehardened or oversteamed shall be rejected.)
The combined AQL for all of the following counted together shall be 15 percent			
Class (see 3.2.5)	I (board with sapwood where preservative is used)	4.0 for untreated wood 1.5 for preservative treated wood	a. The number of laminations which do not meet the required class requirement, exceeds the acceptance number. (Individual laminations which do not meet the class requirement shall be rejected.)
Moisture content	I (test 4.5.1)	6.5-for moisture content up to two percent outside limitations	a. Any lamination has components which are more than 2 percent outside required limitations b. Number of laminations which have components with moisture up to two percent outside moisture content laminations exceeds the quality acceptance number.

Table IV - Sampling levels for examination and test for various lamination defects, corresponding acceptable quality levels, and basis for acceptance or rejection (cont'd.).

Requirement	Sampling level	Acceptable Quality Level for lot acceptance (percent)	Basis for rejection of lot
Excess cross grain (see 3.2.2.1)	I	4.0 - within next lower grade	a. Any lamination contains cross grain which falls below the next lower grade (slope of 1 in 6 for grade D). b. The number of laminations which have cross grain falling within the next lower grade, exceeds the acceptance number
Knot defects	I	4.0 - next lower grade	a. Laminations have knots defects in excess of 1 - 1/2 inches, or fall below next lower grade. b. The number of laminations which have knot defects which fall within the next lower grade but not in excess of 1-1/2 inches, exceeds the acceptance number.
Surface checks	I	4.0	a. The number of laminations which do not meet the requirements of 3.2 exceed the acceptance number.
Edge-joints	I examination only	6.5-wood strips too narrow	a. Any lamination shows a defective edge-joint glue line. b. The number of laminations which show strips too narrow exceeds the acceptance number.
End-joints	I-examination only	None	a. Any lamination contains end-joints with too steep slope, or visually defective bonds, or contains wood at the end-joint which is charred, split, or otherwise damaged to the extent which will cause loss in strength.
Other non-permissible lamination defects	I	None	Any lamination contains one or more of the following or any other defect which affects strength, durability, or glueability. (1) Soft or incipient decay in any amount. (2) Ring shake. (3) Soft, or oozing pitch. (4) Honeycomb, or collapse. (5) Splits. (6) Oil, crayon marks, wax, etc. on surfaces to be bonded.

4.3.1.1 Sampling for test of end-joints. - When a laminator has not supplied wood laminates with end-joints conforming to this specification for the previous 12 months, seven end-joints shall be fabricated under surveillance of the inspector in accordance with regular production procedure, and all seven shall be prepared and tested as outlined in 4.4.1. When a laminator has supplied wood laminates in the previous 12 months, whose end-joints met specification requirements, each production week throughout the period of production, the inspector shall select an end-joint from a regular production lamination for test in cyclic delamination as specified in 4.4.1.1.

4.3.2 Sampling for use of suitable adhesive, adhesive use, process and facilities. - A systematic and effective quality control procedure shall be maintained by the laminator to provide an effective and accurate examination as outlined in 4.4.3.

4.3.3 Sampling for examination of finished laminates. - Sampling for the examination specified in 4.4.3 shall be in accordance with sampling level II of Standard MIL-STD-105. The Acceptable Quality Level for minor defects such as dimension slightly off, and slight material degrade due to curing or mechanical damage during manufacture shall be 4.0 percent defective.

4.3.4 Sampling for test of finished laminates. -

4.3.4.1 Tests conducted by the laminator. - Sampling for moisture content determination of laminate, and block shear test of interlamination glue lines shall be (on a random unbiased basis) in accordance with sampling level II of Standard MIL-STD-105. The acceptable quality level for moisture content shall be AQL = 4.0 percent defective. The acceptable quality level for laminates not meeting either part of the block shear test requirement shall be as follows for shear strength not more than 50 p.s.i. below the required minimum, and percent wood failure of 70 to 75 percent:

AQL = 1.5 percent defective when sample is less than lot size.
AQL = 4.0 percent defective when the entire lot is the sample.

4.3.4.2 Tests at a laboratory. - Samples for test at a laboratory satisfactory to the Bureau of Ships shall be selected in accordance with 4.3.4.2.1, 4.3.4.2.2, 4.3.4.2.3, or depending on previous production experience under this specification. Samples for verification tests shall generally be taken from laminates not included in the laminators' lot sample, from laminates which showed borderline results in laminator test, and from laminates intended for more severe service use. The acceptable quality level for laminates not meeting either part of the block shear test requirement shall be as follows for shear strength not more than 50 p.s.i. below the required minimum and percent wood failure of 70 to 75 percent:

AQL = 1.5 percent defective when sample size is based on normal or reduced sampling.
AQL = 4.0 percent defective when sample size is based on augmented sampling.

4.3.4.2.1 No previous production experience. - When a laminator who has not previously produced marine laminates conforming to this specification is beginning production, the inspector shall select specimens for test from each member, until seven consecutively produced members have passed all requirements of this specification. Thereafter, samples shall be selected for test by the inspector in accordance with sampling level III of Standard MIL-STD-105 until seventeen consecutively tested, major members, such as frames and stems, have met the requirements. Thereafter, members shall be sampled in accordance with 4.3.4.2.2.

4.3.4.2.2 Continued production. - When a laminator has met the prerequisites in 4.3.4.2.1, specimens shall be selected for block shear and cyclic delamination tests on an unbiased random basis in accordance with Standard MIL-STD-105, and tables V and VI. The acceptable quality level for block shear results shall be 1.5 percent defective.

4.3.4.2.3 Lapse in production. - When a laminator has not produced laminates conforming to this specification for a period of 12 months, the inspector shall select specimens for test from each member, until seven consecutively produced members have passed all requirements of this specification. Thereafter samples shall be selected for test in accordance with 4.3.4.2.2.

4.4 Lot acceptance examination and test (by the laminator except where otherwise specified). -

4.4.1 Examination and test of laminations. - Laminations (or components) selected in accordance with 4.3.1 shall be inspected to determine conformance with the applicable requirement. Acceptance or rejection of lamination (or component) lots shall be in accordance with table IV. Where edge-joints are used to form lamination for width, edge-joint mating surfaces shall be examined for slope of grain requirement prior to edge-gluing.

4.4.1.1 Test of end-joints. - When an end-joint sample is selected for test as specified in 4.3.1.1 a fifteen inch section of lamination shall be cut so that the centerline of the end-joint is at the center of the section. The section shall be glued as the center lamination of a test beam with four other laminations of the same width, thickness, and length. A section at least 4 inches long, and the full cross section of the block shall be prepared so that the center of the end-joint is at the center of the section. The section shall be cut, suitably marked, and submitted to a laboratory for test. Failure of 2 consecutive end-joints to meet the requirement of 3.6.3.3 shall be basis for rejection of material containing end-joints until test results are presented which shows that the laminator can on a production basis fabricate at least seven consecutive end-joints meeting the requirements of 3.6.3.3.

Table V - Sampling for block shear tests.

Member	Sampling level		
	Reduced sampling	Normal sampling	Augmented sampling
	(Shear strength and percent wood failure requirements consistently met in all specimens tested in 5 preceding consecutive lots).	(Shear strength and percent wood failure requirements met in all specimens tested in 5 preceding consecutive lots)	One or more test specimens in 3 preceding consecutive lots failed to meet at least one part of the shear requirement; or if the lot is sampled for retest.
All members directly exposed to salt water and/or severe exterior exposure - (stems, keels, skegs, horn timbers, garboards, bilge keels, masts, etc.)	L-5	L-8	III
All interior members not directly exposed to salt water (except filler blocks)	L-3	L-5	II
Filler blocks	L-1	L-3	I

Table VI - Sampling for cyclic delamination tests.

Member	Sampling level		
	Reduced sampling	Normal sampling	Augmented sampling
	Percent delamination requirement met in all specimens tested in 3 preceding consecutive lots an average value for all specimens below 5 percent delamination	Percent delamination requirement met in all specimens tested in 3 preceding consecutive lots	At least one test specimen in 3 immediately preceding consecutive lots failed to meet percent delamination requirement
All members directly exposed to salt water (stems, keels, skegs, horn timbers, garboards, bilge keels, etc.)	L-5	L-8	III
All interior members not directly exposed to salt water (except filler blocks)	L-1	L-3	I
Interior filler blocks)	None	None	None

4.4.1.2 Examination and test for preservative (type I only). - A 0.2 inch diameter boring shall be taken from each sample board with sapwood selected in accordance with table IV, so that the boring extends through the deepest section of the sapwood into the heartwood. The borings shall be examined and tested in accordance with 4.5.7, for preservative penetration and retention.

4.4.2 Inspection for use of suitable adhesive, adhesive use, process and facilities. - In accordance with the effective procedure specified in 4.3.2, inspection shall be made to determine use of suitable adhesive, meeting adhesive use requirements, process requirements, and proper calibration, performance, and use of facilities. Failure to use suitable adhesive will result in rejection of any lot involved. Failure to conform to adhesive use requirements, process requirements, and proper calibration performance and use of facilities will result in immediate temporary rejection of lots until the difficulty has been diagnosed and corrected. Acceptability of involved laminates shall be based on results of the inspector's diagnosis as to seriousness. Failure of the laminator to take effective corrective action shall result in rejection of subsequent lots. Repeated failure of the laminator to adhere to the general laminating requirements set forth shall result in cancellation of the procurement contract or order.

4.4.3 Examination of finished laminates. - Each of the sample laminates selected in accordance with 4.3.3 shall be examined to determine conformance

with the requirements of the specification, in so far as can be determined by visual and dimensional inspection. If any laminate in the sample does not conform to requirements for lamination thickness, end-joint spacing, deviates considerably from required dimensions or shape, or has visually defective adhesive bonds, *shall be rejected, pending* individual examination of each laminate. All laminates with one or more of these major defects shall be rejected. (Members which show defective adhesive bonds shall be rejected even though specimens taken from the ends of that member passed the requirements of 3.6.) Also, if the total number of all minor defects in the sample exceed the acceptance level listed in 4.3.3, the lot represented by the sample shall be rejected.

4.4.4 Test of finished laminates. -

4.4.4.1 By laminator. -

4.4.4.1.1 Moisture content. - Moisture content of finished laminates shall be determined in accordance with 4.5.1. If the number of members not meeting the moisture content requirements of 3.6.1 exceed the acceptance level listed in 4.3.4.1 the lot represented by the sample shall be rejected.

4.4.4.1.2 Block shear test of interlamination glue line. - Each of the samples selected for block shear tests in accordance with 4.3.4.1 shall be tested in accordance with 4.5.5. Failure of any sample member to conform to the requirements of 3.6.2 shall be basis for rejection of the lot, and every member in the lot shall then be tested individually.

4.4.4.2 At a laboratory. -

4.4.4.2.1 Block shear test of interlamination glue lines. - Block shear tests shall be conducted in accordance with 4.5.5. Failure of any sample member to conform to the acceptance criteria of 4.3.4.2 shall result in rejection of the lot. The rejection of two lots in succession for failure to conform to 3.6.2 shall cause the inspector to discontinue his acceptance of material for inspection until the manufacturer presents test information which shows that the difficulty has been diagnosed and corrected, the requirements can be met, and the quality control system has been corrected to effectively screen out defective laminates. The rejection of 3 lots in succession is considered sufficient reason for cancellation of the procurement contract.

4.4.4.2.2 *Cyclic delamination test.* - Test sections selected in accordance with 4.3.4.2 shall be at least 4 inches in length and the full cross sectional dimensions of the member from which it is taken. Tests shall be conducted in accordance with 4.5.6. Failure of any of the sample members to conform to any of the requirements of 3.6.3.1 and 3.6.3.2 shall be basis for rejection of the lot involved, and every member in the lot shall be tested individually. All individual members not meeting the requirements of 3.6.3.1 or 3.6.3.2 shall be rejected. The rejection of any members in 2 lots in succession for failure to conform with 3.6.3.1 shall cause the inspector to discontinue his acceptance of laminates for inspection until the manufacturer presents test information which indicates that the difficulty has been diagnosed and corrected, and the requirements can be met. Failure of 2 consecutive edge-joint samples to meet the requirements of 3.6.3.2 shall be basis for rejection of material containing edge-joints until the manufacturer presents test information which indicates that can be met. Consecutive failures of interlamination glue line in excess of those listed above shall be considered sufficient reason for cancellation of the procurement contract or order.

4.5 Test methods. -

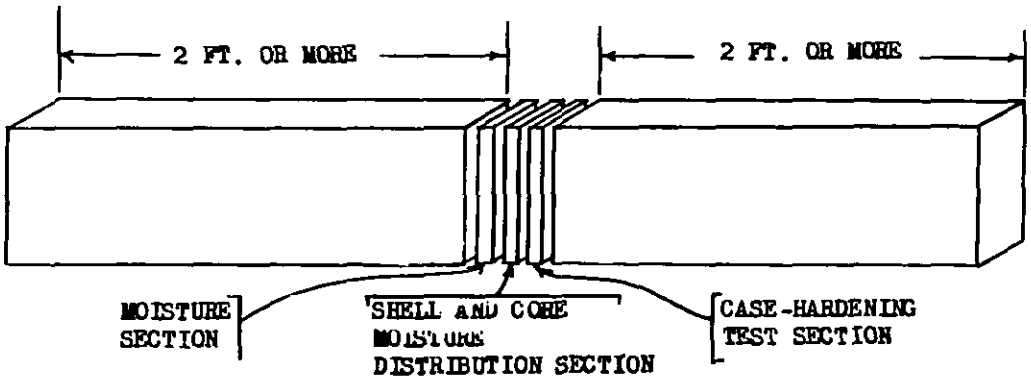
4.5.1 Moisture content. - Moisture content in lumber in laminations shall be determined using an accurate moisture meter or oven test in accordance with Specification MIL-W-6110. If a moisture meter is used, it shall be equipped with probes for determining moisture content at the shell and core. Moisture content of finished laminates shall be determined with a resistance type moisture meter.

4.5.2 Casehardening. - Casehardening shall be determined in accordance with figure 1D.

4.5.3 Slope of grain measurement. - Slope of grain shall be measured on faces and edges of laminations. Where edge-joints or end-joints are used, slope of grain on mating surfaces shall be measured prior to assembly. Slope of grain measured on a given face or edge is considered as the general slope of grain along that length of face or edge. This disregards normal local variations around permissible knots, knot holes, and other acceptable imperfections. This also disregards other local slope of grain variations which may have been caused by such defects as knots which originally occurred in the trimmed-off portion of the board, provided these areas are not more than 8 inches in length, are not more than twice as steep as the permissible general slope of grain, and that these areas are not spaced closer than 4 feet along the length of the piece.

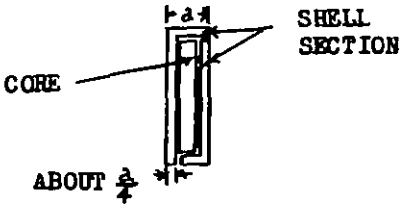
4.5.4 Measurement of diameters of knots. - Diameters of knots shall be as specified in 4.5.4.1 and 4.5.4.2.

4.5.4.1 Knots on wide surfaces. - Knots on the wide surface whose outer extremities are not

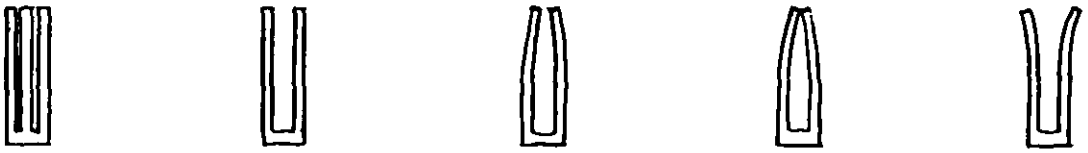


-A- SELECTION OF TEST SECTIONS FOR DETERMINING MOISTURE CONTENT, MOISTURE DISTRIBUTION, AND CASE-HARDENING.

-B- MOISTURE SECTION



-C- SHELL AND CORE MOISTURE DISTRIBUTION SECTIONS



TEST SECTION CUT WITH SAW TO PRODUCE THREE PRONGS OF EQUAL THICKNESS. (BREAK OUT CENTER PRONG.)

NOT CASE HARDENED

SLIGHTLY CASE-HARDENED

CASE HARDENED

EFFECT OF OVER STEAMING

-D- TESTING FOR CASE-HARDENING. (SECTION TO BE ROOM DRIED BEFORE CONCLUSION AS TO CASE-HARDENING IS MADE.)

Figure 1 - Test Sections for Determining Moisture Content, Moisture Distribution, and Case-Hardening.

closer than 1/2 inch to either edge shall be determined by measuring the distance between lines parallel to the edges of the piece and tangent to the knot.

4.5.4.2 Knots on edges. - The diameter of knots on edge faces, or edges of a wide faces, shall be determined by measuring the largest dimension appearing on the surface.

4.5.5 Block shear test. -

4.5.5.1 Test specimens. - Adhesive lines in a given sample shall be clearly marked with ink in arabic numerals. Adhesive lines shall then be sampled for test on an unbiased random basis in accordance with sampling level II of Standard MIL-STD-105, and test specimens prepared. The remainder of the material shall be retained for verification testing of other glue lines if necessary. The test specimens shall be cut as shown on figure 2 and may conform to either (A) or (B) so that the grain direction is parallel to the direction of loading during test. Care shall be taken in preparing the test specimen to make the loading surfaces smooth and parallel to each other and perpendicular to the height. When sawing the bonded assembly, care shall be exercised to insure that the saw cuts extend to but not beyond, the adhesive line. The width and height of the specimen at the adhesive line shall be measured to the nearest 0.010 inch to determine the shear area.

4.5.5.2 Apparatus. - The testing machine shall be fitted with a compression shearing tool containing a self-aligning seat to insure uniform lateral distribution of the load. The shearing tool shown on figure 3 has been found satisfactory.

4.5.5.2.1 For tests conducted by laminator. - For range of loads encountered in test, indicated loads shall be accurate within ± 2.5 percent of true values as determined by standard procedures for verification of testing machine. Increments of load on the indicating device shall be in easily readable divisions between one and 2.5 percent of the value of loads encountered when test specimens break. The load indicating device shall include damping apparatus which permit reading of ultimate loads under conditions of sudden failure. Provisions should be included for a fairly uniform rate of separation to failure.

4.5.5.2.2 Tests conducted at a laboratory. - The machine shall maintain a uniform rate of grip separation, so that the load may be applied with a continuous motion of the movable head to a maximum load at a rate of 0.025 inch per minute with a permissible variation of ± 25 percent. For tests conducted at a laboratory, indicated loads shall be accurate within plus or minus one percent of true value.

4.5.5.3 Procedure. - The test specimen shall be placed in the shearing tool so that the load may be applied as specified in 4.5.5.2. The loading shall be applied with a continuous motion of the movable head at a rate of 0.025 inch per minute to failure. The shear stress at failure shall be calculated in pounds per square inch, by dividing load at failure by the area of the adhesive line area between the two laminations measured to the nearest 0.01 square inch. Also the percent wood failure for each adhesive line shall be estimated to the nearest five percent. The average percent wood failure and shear strength shall be calculated for each specimen. If either the average percent wood failure or shear strength fail to meet the requirements of 3.6.2, the remainder of the adhesive lines in the test specimen shall be prepared and tested, and a new average for shear strength and percent wood failure shall be computed which includes all adhesive lines in the test specimen.

4.5.6 Cyclical delamination test. -

4.5.6.1 Test specimen. - Specimens for cyclical exposure test shall be 3 inches in length in the direction of the grain and full cross section of the member. When an end-joint appears in the cyclical exposure test specimen, it shall be located in the sample so that it appears equally on both exposure faces.

4.5.6.2 Test procedure. -

4.5.6.2.1 Vacuum pressure cycle. - The specimens specified in 4.5.6.1 shall be placed in an autoclave, weighted down, and water at a temperature of 65° to 80° F. shall be admitted into the autoclave in quantity sufficient to submerge the specimens completely. Thereafter, a vacuum of 20 to 25 inches of mercury shall be drawn and held for 2 hours. The vacuum shall then be broken, and a pressure of 80 + 5 p.s.i. shall be applied to the submerged specimens and held for 2 hours. The pressure shall then be released and a vacuum of 20 to 25 inches of mercury shall again be drawn and held for 2 hours while the specimens remain submerged. The vacuum shall be released again and a pressure of 80 + 5 p.s.i. applied to the submerged specimens and held for 2 hours.

4.5.6.2.2 Drying period. - The specimens shall be dried for a period of 88 hours (3-2/3 days) in air at 80 to 85° F. and 25 to 30 percent relative humidity, and circulating at the rate of 500 ± 50 feet per minute. During the drying the specimens shall be placed at least 2 inches apart and with the end surfaces parallel to the stream of air.

4.5.6.2.3 Duration of test. - The soaking and drying periods specified in 4.5.6.2.1 and 4.5.6.2.2 shall be repeated once, for a total of 2 cycles of setting and drying, at the end of which period

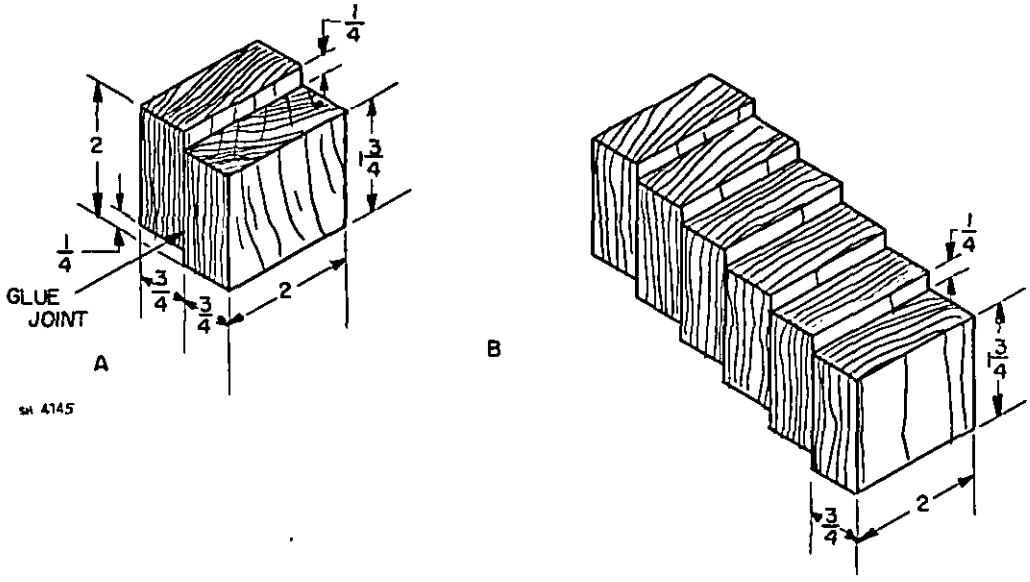


Figure 2 - Standard Block (A) and Stair Step Type (B) Shear Specimens for Testing Glue Joint Strength.

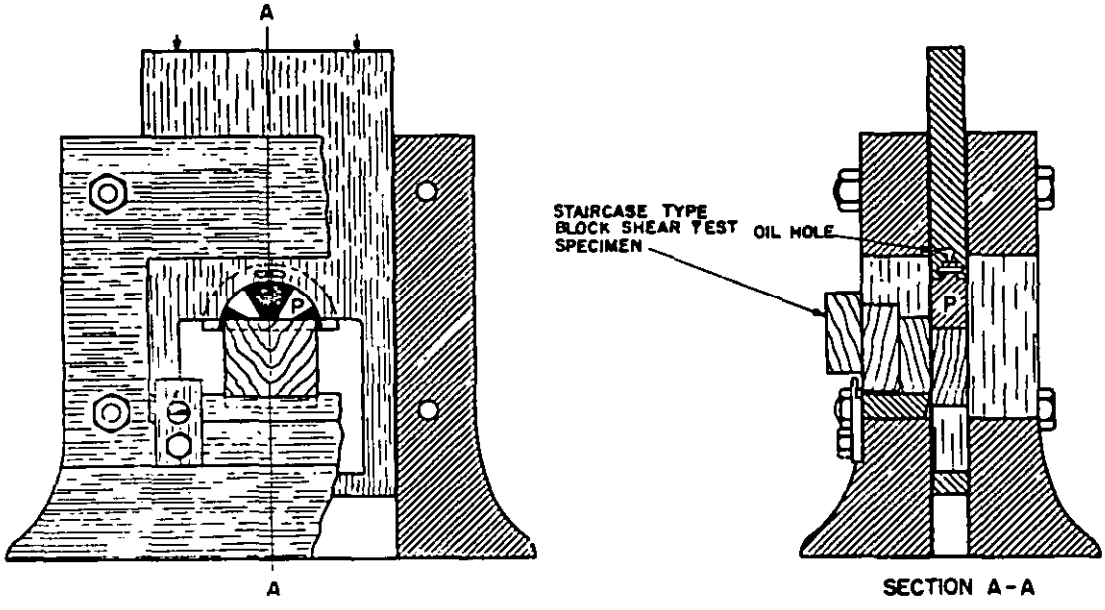


Figure 3 - Shearing Tool.

delamination shall be measured in accordance with 4.5.6.2.4. If the second cycle test requirements of 3.6.3 are met, the test shall be discontinued. However, if any of the second cycle requirements of 3.6.3 are not met, the soaking and drying cycle shall be repeated once more for a total of 3 cycles of soaking and drying, comprising a total test period of 12 days, and delamination again measured.

4.5.6.2.4 Measurement of delamination. - At the end of the soaking and drying cycle prescribed in 4.5.6.2.3, the total length of each type of glue line (interlamination, edge-joint, scarf-joint) shall be measured to the nearest 0.05 inch on both end grain surfaces of the exposure test specimen. Also, shall be measured the total length of delamination in each type of glue line on both end-grain surfaces. (Delamination is a term used to express separation of wood surfaces at the glue lines. When the separation is in the wood, even though very close to the glue line, it is termed wood failure or checking. Magnification is often necessary to determine whether the failure is in the glue or wood. A feeler gage, 0.004 inch in thickness is convenient for probing into the glue line to determine if separation actually exists.)

4.5.6.2.5 Calculations. -

a. Delamination interlamination glue lines: Percent delamination in interlamination glue lines shall be calculated as follows:

$$\text{Percent delamination} = \frac{\text{Total length of delamination in interlamination glue lines measured on the end grain surfaces of test specimen}}{\text{Total length of interlamination glue lines measured on the end grain surfaces of test specimen}} \times 100$$

b. Delamination in edge-joints: Percent delamination in edge-joints shall be calculated as follows:

$$\text{Percent delamination} = \frac{\text{Total length of delamination in edge-joint glue lines measured on the end grain surfaces of test specimen}}{\text{Total length of edge-joint glue lines measured on end grain surfaces of test specimen}} \times 100$$

c. Delamination in scarf-joints: Percent delamination in scarf-joints shall be calculated as follows:

$$\frac{\text{Total length of delamination in scarf-joint glue lines measured on the end grain surfaces of test specimens}}{\text{Total length of scarf-joint glue lines measured on the end grain surfaces of test specimens}} \times 100$$

4.5.7 Determination of preservative penetration and retention (type I only). -

4.5.7.1 Preservative penetration. - Each boring shall be examined for extent of preservative penetration in the sapwood. Where doubt exists as to penetration, chemicals in accordance with 4.5.7.1.1 and 4.5.7.1.2 may be used as an aid.

4.5.7.1.1 Reagents. -

(a) Solution 1. - Dissolve 3.5 grams ammonium molybdate in 90 mℓ. distilled water; then add 9 mℓ. concentrated nitric acid.
(b) Solution 2. - Dissolve 0.05 gm. benzidine in 10 mℓ. concentrated acetic acid; then add 90 mℓ. distilled water.
(c) Solution 3. - Dissolve 30 gm. stannous chloride in 100 mℓ. 1 to 1 hydrochloric acid (1 part concentrated hydrochloric acid added to 1 part distilled water).
(d) Best results are obtained with freshly prepared solutions. Agitate the solution until all chemicals are dissolved. Solution 1 is clear and colorless; solution 2 (benzidine is difficult to dissolve) is clear, light violet in color; and solution 3 is colorless or slightly turbid. Solution 1 must be prepared for each day's testing; solutions 2 and 3 will keep in clean, glass-stoppered, brown-glass bottles for 1 week.

4.5.7.1.2 Method of application. -

(a) Solution 1 is first applied by dipping the boring or cross section in a flat glass dish containing the solution or pouring the solution over the cross-section or boring. The entire wood surface must be saturated. After waiting 2 minutes, shake off the excess solution and allow to dry for about 1 minute.

(b) Solution 2 is next applied in the same manner as solution 1. After waiting 2 minutes, shake off excess solution and allow to dry for about 1 minute.
(c) Solution 3 is applied last by pouring the solution on the cross-section or boring, beginning at the untreated part. The entire wood surface will immediately turn bluish; hence, it is necessary to wait several minutes for the reaction to bring about the maximum color contrast. Untreated portions will fade to a bright red or reddish orange, while treated portions will be light bluish-green to dark bluish-green. Usually the color differences are more distinct when the specimens are observed at arm's length.
(d) After about 1 hour the stain fades; the colors may then be renewed by another application of solution 3.

4.5.7.2 Preservative retention. - The entire sapwood of each boring shall be separated from the heartwood. The sapwood portions shall be composited, and the composite analyzed by any accurate and recognized assay method.

4.6 Additional inspection and tests. - Where other specifications form a part of this specification, unless otherwise specified herein, sampling, examination and tests shall be conducted as required in referenced specifications.

4.7 Inspection for preparation for delivery. - Laminates which are shipped shall be inspected to verify conformance to the requirements of section 5 herein.

5. PREPARATION FOR DELIVERY

5.1 Domestic shipment and early use. -

5.1.1 Wood laminates. -

5.1.1.1 Packaging. - Laminated frame members shall be bundled in pairs or other suitable grouping, and each member within the bundle shall be suitably marked (see 3.9). Smaller laminated members should be bundled, when practicable. Bundles shall be secured by means of steel strapping. No screws, bolts, or spikes shall be inserted into the members for packaging and packing purposes. All members of the bundle shall be protected against cutting of the strapping by means of strips of plywood, metal, fiberboard or other protective material placed between the bundle members and the strapping. The packaging shall be sufficient to afford adequate protection against deterioration and physical damage during shipment from the supply source to the using activity and until early use.

5.1.1.2 Packing. - Packing shall be accomplished in a manner which will insure acceptance by carrier and will afford protection against physical damage during handling and direct shipment from the supply source to the using activity for early use. The wood laminates shall be shipped in open or closed cars according to size of the individual member. When loaded in open cars (gondola and flat car) loading shall be in strict accordance with Section 5 of the Association of American Railroads "Rules Governing the Loading of Forest Products on Open Top Cars". The wood laminates, protected as specified (see 3.8) shall be covered with waterproof paper or other suitable weather resistant material. When loaded in closed freight cars or covered vans material shall be loaded in accordance with the methods recommended in Pamphlet No. 20 of the Association of American Railroads or other carrier regulations applicable to the mode of transportation.

5.1.1.3 Marking. - Shipment marking information shall be provided in accordance with the contractors commercial practice. The information shall include nomenclature, grade, type, density and class, contract or order number, contractor's name and address.

6. NOTES

6.1 Intended use. - Douglas fir laminates covered by this specification are suitable for marine use and for other severe exterior exposure. The adhesive bonds have high strength, have extreme resistance to salt water and shrinkage and swelling, and have long time durability. Douglas fir laminates are considered suitable for use in small craft, patrol craft, minesweepers, and other wooden vessels, in applications where curvature is comparatively mild, and where shock resistance is not of prime importance.

6.2 Ordering data. - Procurement documents should specify the following:

(a) Title, number, and date of this specification.
(b) Whether or not in order for the laminating firm to be eligible to supply products in accordance with this specification it is required to submit information satisfactory to the Government, which shows that it has adequate facilities and personnel to manufacture Douglas fir laminates which comply with this specification, and results of tests to show that the firm has fabricated Douglas fir laminates on a production type

basis which met all requirements of this specification (see 3. 1 and 6. 5).
(c) Thickness, width, length, shape (include drawings and sharpest radius of curvature, if curved members are required), and intended use (for example frame, keel, etc.) of laminates (see 3. 4. 3 and 3. 9).
(d) Grade, type, density, and class of laminations (see 3. 2 and 6. 4 through 6. 7).
(e) Arrangement of end-joints in laminates (see 3. 4. 2).
(f) Whether male or female laminating jig is required (see 3. 5. 4. 3).
(g) Coatings required (see 3. 8 and 6. 8).
(h) That the contractor should pile material awaiting shipment on stickers, and protect it from precipitation and the direct rays of the sun, when directed by the inspector.

6. 3 Definitions. -

6. 3. 1 Laminated wood. - For purposes of this specification laminated wood is considered to be an adhesive-bonded assembly consisting of layers of wood with their grain running in the same direction.

6. 3. 2 Lamination. - A lamination is a single layer of wood used in a laminated assembly.

6. 3. 3 Equivalent knot defects. - Lamination defects listed in this specification which have been assigned a value equivalent to a knot of a given diameter size (see 3. 2. 2. 2).

6. 4 Grade of laminations. - The lamination grades developed for this specification are such that they should be readily available. However, the lower quality material is more readily available and less costly than the higher grades. Where permissible by strength requirements, weight limitations, and other design factors, the lower grades should be used where feasible. Douglas fir boards are generally manufactured and stocked in fixed nominal widths. In order to reduce material waste and cost, where feasible, lamination widths in the finished laminate form should be based on these readily available nominal board dimensions. For convenience in design and ordering lumber for laminate use, table VII lists standard nominal board widths, corresponding economically desirable finished laminate (lamination width) dimensions, and knot and equivalent knot defects for the specified grades.

Table VII - Knot defects for standard dimensions.

Nominal board width	Standard lamination width in finished laminate form	Sums of diameters of equivalent knot defects (including sound tight knots) in any 3 feet of length (maximum in inches)			
Inches	Inches	Grade A	Grade B	Grade C	Grade D
2	1-1/4	1/8	1/8	1/4	1/4
3	2-1/4	1/4	1/4	3/8	1/2
4	3-1/4	3/8	1/2	5/8	3/4
5*	4-1/4	1/2	5/8	3/4	1
6	5 or 5-1/4	5/8	3/4	1	1-1/4
8	7	3/4	1	1-1/4	1-1/2
10	9	1	1-1/4	1-1/2	1-1/2
12	11	1-1/4	1-1/2	1-1/2	1-1/2
Over 12	Minus 1-1/2	1-1/4	1-1/2	1-1/2	1-1/2

*(Obtained on special order.)

6. 5 Facilities survey. - Where the laminator has not previously produced acceptable laminates for the Government in accordance with the requirements of this specification, a facilities survey is recommended, prior to fabrication and acceptance of wood laminates for Government use under any prime contract, subcontract, or purchase order (see 3. 1 and 6. 2(b)).

6.6 Side coatings. - Side coatings should be specified if the laminated Douglas fir is stored outdoors, unprotected. End coatings should be renewed as necessary when laminated Douglas fir is stored outdoors in covered piles. When specifying side coatings, the end use should be taken into account. Surfaces in the exterior underwater portions of ships and boats are coated with antifouling paint. Since aluminum coating has a tendency to blister when used under such paints, it should not be specified for these surfaces if the end product is to be supplied ready to install. Provisions for covered transportation and storage should be specified if side coatings are not specified.

Preparing activity:
Navy - Bureau of Ships
(Project 5510-N003Sh)

APPENDIX - I

MINIMUM FACILITIES AND PERSONNEL REQUIRED FOR PRODUCING WOOD LAMINATES FOR MARINE USE, AND RECOMMENDED MINIMUM PROCEDURES FOR DETERMINING THEIR ADEQUACY

10. SCOPE

10.1 In present Navy wood ship and boat construction wood laminates are rapidly replacing solid wood as structural components. Laminates possess advantages of complete seasoning throughout, ability to be formed to shape in the process of assembly, prefabrication aspects, and greater strength. A laminated member can be built by assembling small pieces of wood without the use of fastenings. Solid wood of the proper grade and large dimensions is rapidly becoming depleted. A much greater supply of wood for ship and boat use thus becomes available through sawing low-grade material into boards, removing objectionable defects, and laminating. However, the glowing advantages listed for this new engineering material for marine use require that the adhesive bonds holding the layers of wood together must have unquestionable integrity. Achievement of this requisite requires use of very special adhesives, extensive equipment, a high degree of technical skill, and maintenance of very close process control throughout production. This document discusses in some detail the facilities which are considered necessary for the production of wood laminates for marine use, and recommends procedures for evaluating their adequacy for the use intended. Also is discussed the need for competently trained personnel to facilitate a successful marine laminating operation.

20. APPLICABLE DOCUMENTS

20.1 Other publications. - The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids shall apply.

FOREST PRODUCTS LABORATORY
Bulletin No. 1651 of October 1952 - Relative Humidity and Equilibrium Moisture Content Graphs and Tables for use in Kiln Drying Lumber.

(Copies may be obtained from the Director, Forest Products Laboratory, Madison 5, Wisconsin.)

AMERICAN SOCIETY FOR TESTING MATERIALS
ASTM Standard E4-50T - Verification of Testing Machines

(Copies may be obtained from American Society For Testing Materials, 1916 Race Street, Philadelphia 3, Pennsylvania.)

30. FACILITIES

30.1 Below is a descriptive list of facilities which are considered the minimum necessary to produce acceptable wood laminates for marine use. The quantity of each item is determined largely by the production schedule. However, the number and size of laminating jigs, curing chambers, and clamps required depend on the size, shape, and number of laminates to be produced. It is very important that all of the items be thoroughly checked for adequacy. Although many facility item which a plant has may be suitable for laminating more than one species of wood, other facility may be found suitable for laminating one species of wood only. Therefore, it is very important that facility item be checked for their applicability in fabricating laminates from the species of wood intended to be used in production.

30.2 Straight line rip saw. - For cutting lumber to the required width and removing defects. Any chain feed rip saw of good quality is satisfactory for this operation (not to be confused with 30.18.1 below which discusses a very special saw for preparing surfaces for subsequent edge gluing).

30.3 Rough planer. - For surfacing rough lumber before cross cutting of defects, and before edge gluing and scarfing. Must provide true flat surfaces in order to give a proper reference bed for surfacing edges and scarfs for gluing.

30.4 Trim saw. - For trimming boards to the desired length and to remove defects.

30.5 Scarfing equipment. - For scarfing lumber to form laminations of the desired length. Must be capable of consistently producing the quality of scarf required in the laminating specifications.

30.5.1 Scarf cutter. - An acceptable method of cutting good scarfs is one which produces a good cut with no digging, tearing of the grain, chipping, or peeling between the annual rings. The scarf cutter must also produce a uniform cut across the board without splitting. To date the most satisfactory methods for consistently producing satisfactory scarf joints have been on a cabinet surfacer used with a form for holding the lumber, on a modified surfacer, and on an Onsrude veneer scarfer. A modified radial arm saw with a bar type cutter head has also been used. However, it has generally not produced consistently satisfactory cuts, and is very difficult to keep in proper maintenance. If a surfacer is used in preparing scarfs, a relative cut to the approximate angle of the surface should be made by sawing or surfacing so that when the final scarf surface is prepared only a minimum cut is required. (If care is not taken, an initial cut by a saw will result in splitting of the feathered edge.) Forms for producing scarfs on a surfacer should be of sufficient length to assure uniform contact with the bed of the machine without danger of canting or clipping.

30.5.2 Clamps for scarf package. - The clamping assembly must be capable of safely applying and holding 150 - 200 p. s. i. pressure on all points of the glued assembly. The most reliable and economical method found to date for applying pressure to scarf joints during the curing process is in a package assembly. In this method a number of scarf assemblies are laid one above the other using a thin metal plate between each layer to prevent sticking together of layers, for heat conductivity, and for distribution of pressure. Using heavy oak cauls on top and bottom of the package, pressure is applied by means of three calibrated rocker head clamps.

30.5.3 Equipment for curing of scarfs. - The method used for curing of scarfs must be capable of consistently producing acceptable quality scarfs in accordance with specifications. This requires a procedure which results in full strength. The curing temperature at all points of the glue line should be not less than that temperature listed on Qualified Products List QPL-397, as an adhesive conforming to the Type II, Class 2 requirements of Military Specification MIL-A-397. The curing period should also be not less than the period listed. At no point in the curing chamber of glue line should the temperature exceed 215° F. Relative humidity should be maintained to the extent that no appreciable change in moisture content of the wood occurs. Also no degrade of the wood should result. Curing has been done most satisfactorily in a chamber or under curing blankets. Hot platens and dielectric heating methods in general have not produced acceptable quality scarfs.

30.6 Cabinet surfacer. - For dressing laminations to the required thickness before assembling. The cabinet surfacer to be used for final surfacing of laminations must be capable of surfacing stock to a maximum tolerance of ± .005 inches. It is desirable that lumber be rough surfaced to approximate thickness before final surfacing and laminating. The maximum material to be removed by surfacing for laminating should not exceed 1/16 inch for each face. Knives should be carefully jointed to eliminate revolution marks. Planer speed should be so regulated as to insure a minimum of 20 and a maximum of 30 knife cuts per inch. It should be remembered that the cutting angle for hardwood should be less than for softwoods. The recommended cutting angle for oak should not exceed 15 degrees and for Douglas fir 20 degrees. A double head cabinet surfacer with ball bearing cutter heads has proved most satisfactory for dressing laminations. For limited production, a single head surfacer with ball bearings is satisfactory if tolerances for thickness can be maintained. If four-side matchers are used, particular attention must be given to the condition of the bed plates and pressure bars. It is very difficult to hold the necessary tolerances on molders or matchers.

30.7 Laminating jigs. - Must be capable of withstanding load under clamp-pressures and curing conditions as outlined in laminating specifications. All laminating jigs must be of rigid construction. The type and size of laminating jig used will depend largely on type and size material to be laminated.

30.8 Laminate assembly clamps. - Application of correct, uniform pressure on a glue line is a prime requisite to the formation of a good bond. This requires that all clamps be uniformly spaced and uniformly tightened to the proper load which will deliver the required glue line pressure for the given clamp spacing and glue line area. For Douglas fir the proper glue line pressure is 150 ± 25 p. s. i., and for white oak is 175 ± 25 p. s. i. Inadequate attention to this feature has been one of the largest causes of failure in production. Yet, it is one of the easiest production items to control. To achieve this, clamps must be capable of applying and holding pressures required in the laminating specifications and withstanding repeated heating in the curing chamber without warping. The clamps must be equipped with rocker head type equalizing pressure heads to distribute pressure evenly on a laminated assembly. The pressure heads must be sturdily built and reinforced with webbing to prevent distortion and to permit even distribution of pressures across the whole member. In order that pressures along the length of a glue line can be uniformly applied and maintained, each individual clamp must have provisions for regulating the load applied, and easy means for determining this load.

The most reliable clamps found to date are those which use a threaded shaft system to apply pressure. This type of clamp can be easily checked for adequacy through the use of a compressometer. Also, through the use of calibration data, the load delivered by a clamp can be easily determined through the use of a torque wrench. In selecting such clamps for use it is pointed out that acme threaded shafts, although generally a little more expensive, have less tendency to bind and hang under heavy load. They also will provide longer service. To date, clamping systems which use a hose containing water or compressed air to distribute pressure have not proven satisfactory.

30.9 Chamber for curing laminated assemblies. - The curing chamber used for curing laminates must be of such design as to provide proper uniform heat and humidity to the material. This requires that the walls of the chamber be insulated for both heat and vapor, and that the chamber be so constructed that air can circulate freely about the curing material, distributing uniform heat and humidity. Temperature and relative humidity conditions must be maintained uniformly throughout the process in the curing chamber. The purpose is to maintain the required temperature needed to cure the adhesive at all points of the glue line, and to keep the average moisture content of the wood essentially the same as it was before the period was begun. Also no degrade should result from the curing process. Several types of chambers have been successfully used, such as lumber dry kilns, specially built stationary curing chambers, or portable curing chambers.

30.10 Torque wrenches. - Should have at least two torque wrenches calibrated to the particular type of clamps used.

30.11 Adhesive. - The adhesive used for all marine laminating operations shall be an adhesive listed on the latest issue of Qualified Products List QPL-397 as an adhesive conforming to the Type II, Class 2 requirements of Military Specification MIL-A-397.

30.11.1 Adhesive storage. - Must have adequate facilities for proper storage of adhesives in accordance with specifications.

30.11.2 Weighing mechanism. - Must have adequate weighing mechanism for weighing of adhesive components and for determination of glue line spread.

30.11.3 Proper equipment for mixing of adhesive. - This should be a mechanical type mixer capable of thoroughly mixing the adhesive to proper consistency without lumps, yet must be designed so that it will cause no bubbles or foam during the mixing process.

30.11.4 Proper equipment for spreading of adhesive. - Method of applying adhesive must be such that the correct amount of adhesive can be applied quickly. No foreign matter should be deposited on laminating stock which will interfere with the glue bond. For full scale laminating operations, commercial glue spreaders with rubber rolls, and which have provisions for adjusting rate of glue spread, have proven most successful. For smaller operations clean paint rollers which do not shed have also proven adequate.

30.12 Laminating room. - The laminating room should be such that it can be kept clean with a minimum of dust or particles present which will cause interferences with the glue bond. All wood working machinery must be equipped with dust collection systems. In addition, the room should be controlled so that room temperatures required in the laminating specifications can be met, yet to provide adequate ventilation for removal of objectionable adhesive solvent vapors which are given off.

30.13 Facilities for proper storage of lumber and dressed laminations. - Must have adequate facilities for storage of lumber under cover, including adequate space for storage of dressed laminations.

30.14 Equipment for handling lumber and laminates. - Adequate handling equipment must be provided for moving laminated members around the laminating shop and the yard without damage.

30.15 Shaping equipment. - Must have either a marine type band saw, or a conventional 36" band saw (heavy duty equipment), capable of carrying up to 1-1/2" blade. Filing room equipment adequate for servicing heavy duty band saws should be provided. If contour shaping to various bevels are contemplated, the band saw must be of tiltable type. In most operations a tiltable table will not work satisfactorily. In addition, if specifications or purchase orders require that laminates be dressed to specific dimensions after fabrication, suitable equipment for performing this operation is necessary.

30.16 Maintenance equipment. - Should have a grinding room adequately equipped for maintenance of cutter heads and saws. Also facilities should be available for maintenance of other equipment.

30.17 Testing equipment. -

30.17.1 Drying oven. - Must have a drying oven which is capable of maintaining a temperature of 105° C. (215° F.), to be used for determining moisture content and moisture distribution in lumber by the standard oven test.

30.17.2 Weighing apparatus. - Must have suitable mechanism for weighing lumber test samples to

determine moisture content of wood. The weighing mechanism should be accurate enough so that weights can be correct within at least one percent and be able to indicate the weight of samples to the nearest 0.01 gram.

30.17.3 Moisture meter. - Must have an accurate moisture meter for quick determination of moisture content in lumber. Some moisture meters have a tendency to become inaccurate when batteries become depleted, or when room humidity conditions are adverse. Therefore, moisture meters should be checked for accuracy against standard oven tests at periodic intervals.

30.17.4 Pontentiometer and thermocouples for accurate determination of glue line temperature in scarf-joints, laminate assemblies, and edge-joints. - Must be checked for accuracy through the use of a laboratory thermometer and a hot water bath. Calibration should include a full temperature range from 60° F. to 212° F. Although a potentiometer is generally used to measure glue line temperature it can also be used to determine ambient dry bulb and wet bulb chamber temperature conditions. This is done by using two units next to each other with a wet sleeve over one as is done with a normal wet and dry bulb system.

30.17.5 Compressometer. - Must have frequent periodic access to an accurate compressometer or equally effective portable apparatus for measuring compression loads for calibrating torque wrenches and clamps. The compression load measuring apparatus must be calibrated and certified for accuracy by a test laboratory.

30.17.6 Block shear testing apparatus for laminator tests. - Must have a suitable block shear testing apparatus to conduct block shear tests on material prior to submittal for Government inspection and test. The shear test tool must be similar to that described in military specifications for wood laminates for marine use. The load measuring device should be accurately calibrated and should include a damping apparatus which permits readings of ultimate loads under conditions of sudden failure. The loading device should give an accurate full scale reading of no more than 150 percent that of the maximum range of loads at which shear blocks will normally break. The accurately readable increments of load should not be greater than 1.5 percent of the maximum load reading on the scale and not greater than 5 percent of the minimum load at which the block shear test specimens will normally break. This is determined as follows: For example, if 8000 pounds is the anticipated maximum shear block breaking strength, the full scale reading on the dial gauge should not be greater than 8000 x 1.50, or 12,000 pounds. The maximum load reading on the dial is multiplied by 0.015. The minimum anticipated breaking strength is multiplied by 0.05. The lower of the two figures determines the minimum degree of accuracy required, and is therefore to be used as the maximum permissible dial increment figure. For example, if the maximum anticipated load is 8000 pounds, and the full scale reading on the dial is 12,000 pounds, the dial increment figure would be 12,000 x 0.015, or 180 pounds. If the minimum anticipated breaking strength were 3000 pounds, the dial increment figure would be 3000 x 0.05, or 150 pounds. Therefore, in order to test shear blocks which will normally break at loads ranging from 3000 pounds to 8000 pounds, with occasional higher loads not in excess of 12,000 pounds, the scale on the dial must be accurately calibrated to increments of 150 pounds or less. It is pointed out that the increment of load determined in this manner is the maximum acceptable. For greater accuracy and ease in correlation of test results with an approved laboratory, it would be even more desirable for increment of load on the dial to be calibrated in smaller units. Another aspect which should be considered is the desirability of utilizing one apparatus for testing more than one species of wood laminates. In certain instances this can be accomplished by utilizing an accurately calibrated dial with smaller increments of load to provide a wider useful range. For example, if a dial with a maximum load reading of 12,000 pounds were calibrated in increments of 100 pounds, the apparatus could be utilized in testing shear block specimens which break at loads ranging from 100 - 0.05, or 2000 pounds to 8000 pounds, with occasional load not in excess of 12,000 pounds. An apparatus with such a dial should normally be able to be used in conducting the standard block shear test (standard shear area of 3 square inches) on most species of wood laminates fabricated for marine use.

30.17.7 Small band saw. - Small band saw for preparation of casehardening samples, moisture determination samples, and for preparation of block shear test specimens.

30.18 Miscellaneous laboratory equipment. - This includes such items as thermometers, gauges, micrometers, etc.

30.18.1 Edge-joining equipment (required only if edge-joints are to be fabricated). - Producing high quality edge-joints for use in marine laminates requires adherence to very close tolerances in equipment and methods. The extent of marine laminating, the type of marine laminates being produced, and the availability of equipment and experienced personnel will determine the practicability of using edge-joined material. It will also determine whether the laminator should do his own edge-joining or whether he will find it more advantageous to purchase edge-joined material from a manufacturer

who has already established his qualifications as a supplier of edge-joined dimension stock. Below is a list of additional equipment which would be necessary for a laminator to produce his own edge joints, and procedures for checking the adequacy of this equipment.

30. 18. 2 Equipment for preparing surfaces for edge-joining. - Equipment for producing surfaces for edge-joining should be of reasonably late design and must be in first class condition. The equipment must be capable of preparing edge-joint surfaces on the longest length of edge-glued material expected to be used in production. If a chain feed straight line edge-joining rip saw is used for this purpose, it requires that the ball bearings on the saw arbor, and the grooves and track on the chain be in first class condition. The saw must be well balanced and fitted. For limited production, surfacing of edge joints has been satisfactorily accomplished on a molder that is kept in the very best of condition. For very limited production, surfacing of edge joints can be successfully accomplished on a hand jointer which is maintained by an expert millwright. However, this last method is a very cumbersome and expensive procedure and is probably practical only for short (4' or less) length material. Whichever method is used, the resulting edge joints should be carefully checked for smoothness and evenness of cut. Assurance should also be made that the planes of the edge joint surfaces are perpendicular to the planes of the flat surfaces of the lamination, and that the prepared surfaces will match when assembled. Special care must be given in matching edge-joint surfaces prepared on a jointer.

30. 18. 3 Clamps for edge-joining. - Application of the correct, uniform pressure on a glue line is a prime requisite to the formation of a good bond. This requires that all clamps be uniformly spaced and uniformly tightened to the proper load which will deliver the required glue line pressure for the given clamp spacing and glue line area. For Douglas fir the proper glue line pressure is 150 ± 25 p. s. i., and for white oak is 175 ± 25 p. s. i. Inadequate attention to this feature has been one of the largest causes of failure in production; yet, it is one of the easiest production items to control, particularly if a standard clamp spacing, or a few standard clamp spacings are used for all edge-gluing operations. In edge-gluing lumber for width, the maximum clamp spacing measured on centers should not exceed 14 inches. Closer clamp spacing is often necessary to more uniformly distribute the load supplied by the clamps to the glue line, and to assure that the clamp loading heads do not crush the wood. The most satisfactory methods found to date for applying pressure to edge-joint glue lines are stock type clamp carriers and stacking clamps. Stacking clamps have generally been found much more adaptable to producing edge joints for laminations for marine use. This is due to their low initial cost, versatility in clamping various lengths of material (particularly lumber over 8 feet in length), ease of handling and storage, low maintenance costs, and ability to hold material flat. They also generally require less extensive curing facilities. Both stacking clamps and clamp carriers have threaded shafts for applying pressure to each individual clamp head, which can be readily calibrated to determine the load delivered for a given torque. To date, other clamping systems such as hydraulic or air clamps have not proven satisfactory. This is primarily due to the difficulty of determining and regulating pressures along the full length of the glue line. Therefore, unless these features can be provided, the use of fluid or air pressure is not considered acceptable.

30. 18. 4 Curing chamber. - The curing chamber used for curing edge joints must be such as to provide proper uniform heat and humidity to the edge-joined material. This requires that the walls of the chamber be insulated for both heat and vapor, and that the chamber be so constructed that air can circulate freely about the curing material, distributing uniform heat and humidity. Temperature and relative humidity conditions must be maintained uniformly throughout the process in the curing chamber. The purpose is to maintain the required temperature needed to cure the adhesive at all points of the glue line, and to keep the average moisture content of the wood essentially the same as it was before the period was begun. Also no degrade should result from the curing process. Several types of chambers have been successfully used, such as lumber dry kilns, specially built stationary curing chambers, or portable curing chambers. To date, high frequency methods for curing have not been found to do a consistently reliable curing operation for marine use.

40. PERSONNEL REQUIREMENTS

40. 1 In addition to adequate equipment, a successful marine laminating operation requires adequately trained personnel.

40. 2 Supervisory technical personnel. - Supervisory technical personnel require a high degree of technical knowledge in wood working operations and equipment, wood technology, and an ability to understand and supervise marine laminating operations within the scope of governing specification requirements. Previous experience in commercial structural laminating operations is usually helpful. However, it is pointed out that in general marine laminating operations are much more exacting than most commercial operations. Therefore, a sound foundation is necessary regarding these differences in order to avoid failures in production.

40.3 Production personnel. - In order to make a marine laminating operation a success, personnel must be thoroughly indoctrinated in the materials and process requirements of the applicable military specifications.

40.4 Maintenance personnel. - Because of the consistently reliable performance to close tolerances required of equipment for marine laminating operations, a firm engaged in such operations must have first class maintenance personnel to service this equipment.

40.5 Quality control engineer and inspection personnel. - Marine laminating requires close quality control and inspection procedures throughout the process to maintain the required close tolerances in production processes. A trained quality control engineer is required to analyze specification requirements and to devise definite procedures by which these requirements can be checked for conformity. Trained inspectors, under the supervision of the quality control engineer, are required to inspect for conformity with the process and material requirements of the specification by the procedures developed by the quality control engineer. Trained personnel are also required to conduct such laboratory tests as block shear tests, make moisture content and casehardening determinations, and to check accuracy of instruments, devices such as controls, moisture meters, torque wrenches, etc. To be most efficient, the quality control organization should be independent of the production department.

50. CALIBRATION OF VARIOUS EQUIPMENTS

50.1 Certain equipments used for marine laminating operations require calibration to assure correct performance. Below are recommended procedures for calibrating such equipments. Whether or not a piece of equipment remains in calibration depends on use and quality. During production recalibration must be such frequency as to provide accuracy with reasonable assurance at all times.

50.2 Calibration of clamps. - Assuming that clamps with threaded shaft systems are used for applying glue line pressure, the following procedure is used for their calibration with an accurate compressometer and an accurate torque wrench.

50.2.1 Calibration procedure. - Insert the compressometer between the pressure heads of the clamp. It may be necessary to insert white oak cauls between the pressure head of the clamp and the bearing surfaces of the compressometer. Using the torque wrench, tighten the clamps to compress the compressometer. The applied load can be read on the dial gauge of the compressometer in pounds, and the corresponding torque on the torque wrench can be read in ft.-lbs. A full range of load readings should be taken. As in production use, all clamps should be well greased and be in maintenance. This will aid in preventing hanging or binding due to an abnormally high co-efficient of friction on the screw. Care should also be taken to assure that the compressometer dial actually reads total load in pounds. If the dial reads fluid pressure in pounds per square inch, this reading must be converted to total load readings in pounds. By plotting on graph paper observed torque readings against the corresponding load readings, the safe capacity for the clamp can be determined. As noted in figures 1 and 2, a straight line can usually be drawn through the first group of points. Then at a given load the points deviate from a straight line. The point on the graph where the curve deviates from the straight line relationship is known as the yield point or elastic limit and is the point at which weakening of the metal takes place. Clamps should not be loaded beyond the yield point. A suitable number of clamps of each type used should be calibrated to assure adequate representation.

50.2.2 Determination of proper clamp spacing and proper load applied by clamps. The proper load to be applied by the clamps for any given uniform clamp spacing and lamination width can be readily determined from the calibration information as shown by the following:

50.2.2.1 Clamps for clamping final laminate assemblies. - Assume that clamps are spaced on 7 inch centers and that the material to be bonded is 7 inches wide. For white oak the required glue line pressure is 175 ± 25 p.s.i. Assume for practical purposes that the load applied by each uniformly spaced clamp is uniformly distributed for a distance of at least 3.5 inches to each side of the clamp, or over an area of 49 (7x7) square inches. (This assumption can be made only if clamps are spaced close enough together, and the cauls and/or the material are rigid enough to uniformly distribute the load.) In order to apply the required 175 p.s.i. pressure to the glue lines, each individual clamp must supply a load of 175 p.s.i. x 49 square inches, or approximately 8575 pounds. Similarly computed for a minimum glue line pressure of 150 p.s.i., each clamp would be required to exert a load of 7350 pounds. At the maximum 200 p.s.i. pressure range, each clamp would be required to supply a load of 9800 pounds. As noted in the example calibration graph, (Figure 1) the particular clamps could be safely loaded beyond 9800 pounds without damage. Also taken from the graph, a torque reading of 93 ft.-lbs. on the torque wrench would be required for the clamp to exert a load of 7350 pounds. 109 ft.-lbs. would correspond to a load of 8575 pounds. 127 ft.-lbs. would correspond to a load of 9800 pounds. Therefore, using these particular clamps and the above cited clamp spacing

and lamination width, a torque reading of 109 ± 16 ft. -lbs. would be required to maintain a glue line pressure of 175 ± 25 p. s. i. If from the calibration graph it is found that the clamps will not safely take a load of at least 9800 pounds without deforming beyond the elastic limit, heavier clamps are necessary for use with that width material and clamp spacing. Closer spacing of clamps will, of course, require less load to be supplied by each clamp. For example, if the particular clamps described above were spaced on 5-inch centers, the load required to be delivered by each clamp to supply a pressure of 200 p. s. i. at the glue line would be 7000 pounds (5" x 7" x 200 p. s. i.). This is 3800 pounds less than the load required to be delivered if clamps were spaced on 7-inch centers.

50. 2. 2. 2 Clamps for edge-gluing. - Assume that clamps are spaced on centers at the maximum recommended distance of 14 inches, and that the material to be edge glued is 7/8 inch in thickness. For white oak, the required glue line pressure is 175 ± 25 p. s. i. Assume for practical purposes that the load applied by each uniformly spaced clamp is uniformly distributed for a distance of at least 7 inches to either side of the clamp, or over an area of 12. 25 (7/8 x 14) square inches. (This assumption can be made only if clamps are spaced close enough together, and the cauls and/or the material are rigid enough to uniformly distribute the load.) In order to apply the required 175 p. s. i. pressure to the edge glue line of white oak, each individual clamp must supply a load of 175 p. s. i. x 12. 25 square inches, or approximately 2144 pounds. Similarly computed for a minimum pressure of 150 p. s. i. and a maximum of 200 p. s. i. the range allowed would be not less than 1838 pounds nor more than 2450 pounds respectively. The torque necessary to tighten the clamp to these respective loads can be taken directly from the graph plotted from the results of calibration of clamps with the compressometer. From the example graph shown in Figure 2, the torques required to be applied by the torque wrench to supply 1838, 2144, and 2450 pound loads respectively would be 35, 38. 8, and 42. 6 ft. -lbs. Rounded off these would be approximately 35, 39, and 43 ft. -lbs. Therefore, using these particular clamps and the 7/8-inch lumber thickness and 14-inch clamp spacing cited above, a torque reading of 39 ± 4 ft. -lbs. would be required to maintain a glue line pressure of 175 ± 25 p. s. i.

50. 2. 2. 2. 1 Production use of clamps. - In the production use of clamps, care should be taken to assure that the loading heads on the clamps do not damage the wood, particularly directly under the loading heads. If damage does take place, the load supplied by each clamp is too great. This can be easily corrected by reducing the clamp load by a suitable amount, and recalculating a shorter uniform clamp spacing which will provide the required glue line pressure.

50. 3 Calibration of torque wrenches. - Torque wrenches are calibrated in conjunction with clamps through use of an accurately calibrated compressometer as outlined above.

50. 4 Compressometer. - The compressometer or equally effective portable device for measuring compression loads should be calibrated by comparing various loads indicated by it with those of a standard test machine, which in turn has been recently verified for accuracy, by one of the methods listed in American Society For Testing Materials (ASTM) standard E4-50T "Verification of Testing Machines. " Loads should be calibrated at frequent intervals throughout the full range of the load indicating dial of the compressometer. For visual comparative purposes, a graph should be drawn in which corresponding loads shown by the compressometer and the standard test machine are plotted against each other.

50. 5 Calibration of temperature and humidity indicating and recording instruments used in curing laminate assemblies, scarf-joints, and edge-joints. - A complete calibration should be made of all temperature and humidity recording and indicating instruments by means of a hot water bath and an accurate laboratory thermometer. This calibration should also include potentiometer and thermocouple units. The calibration range should run from approximately 60° F. to approximately 212° F. Calibration of indicating and recording temperature units are accomplished as follows:

50. 5. 1 Calibration procedure. - Clean all temperature elements thoroughly and immerse in a large glass container of distilled water at a temperature of approximately 60° F. Also in the water bath insert an accurate laboratory thermometer which is graduated in increments of not larger than 1° F. Stir the water around the temperature actuating units until the indicating or recording instruments show an equilibrium with the temperature of the water. Record the temperature indicated on the laboratory thermometer and corresponding readings indicated or recorded by the other instruments. Raise the temperature of the water in the container an increment of approximately 15° F. Stir the water in the container until the indicating or recording temperature actuating units are in equilibrium with the temperature of the water. Again record the temperature indicated on the laboratory thermometer and the corresponding readings taken from the instruments being calibrated. In a like manner, the calibration should be extended to a useful range of approximately 212° F.

50. 6 Weighing mechanisms. - Should be calibrated for accuracy by use of standard weights.

50.7 Moisture meters. - A simple procedure for checking accuracy of a moisture meter is to take readings with the moisture meter on a few typical pieces of lumber. Within a short time thereafter, cut sections out of the boards where the moisture readings were taken; weigh the small sections with the weighing mechanism described above, and dry in an oven kept at 105° C. (215° F.) until there is no appreciable loss in weight (for 1-1/2" x 1-1/2" square block of 1" nominal material drying takes approximately 6 to 8 hours).

$$\text{Percent moisture content (based on oven dry weight)} = \frac{\text{wt. before drying - wt. after drying}}{\text{wt. after drying}} \times 100$$

50.8 Block shear testing apparatus. - Any of the methods listed in American Society For Testing Materials Designation E4-50T "Verification of Testing Machines" is considered acceptable for calibration or verification of the shear test machine. Another permissible alternate would be to compare various loads registered by the laminator's apparatus with those of a standard test machine which has been recently verified for accuracy. A full range of loads indicated by the dial of the test apparatus being calibrated should be verified. A graph should be drawn in which corresponding values of the block shear test apparatus and the verification apparatus are plotted against each other.

60. PERFORMANCE TYPE TESTS FOR DETERMINING ADEQUACY OF VARIOUS EQUIPMENT

60.1 During production determining performance of equipments must be of such frequency as to provide required performance with reasonable assurance at all times.

60.2 Methods for Testing Scarf Joints. - The cyclical exposure test as outlined in applicable military wood laminate specifications is considered a suitable method for evaluating adequacy of glue line in scarf-joints (provided all process requirements have been met). A preliminary method which indicates whether or not individual scarf joints will meet the exposure test requirements is a simple bending test in which a scarfed section of lamination is compared in breakage strength with the adjacent solid sections of wood lamination making up the scarf joint. In this comparison the scarfed section of lamination should be at least 85 percent the strength of the weakest adjacent solid section. Also when the scarfed section is broken, the failure should occur in at least 75 percent of the wood. (In other words, on the scarf surface which is broken no more than 25 percent, the area of the glued surface should show glue failure). The span length for the bending test should be not less than 18 inches. Regardless of which test is used, at least 21 consecutively produced scarf joints should be evaluated to show that the equipment and the methods can consistently produce high quality scarf joints in the species of wood intended to be used in production.

60.3 Testing proficiency of cabinet surfacer. - Twelve boards of the species intended to be laminated in production should be used for checking machining performance. The boards should be nominal 1-inch, approximately 6 inches wide, and at least 6 feet long. At a given thickness setting, one board should be run through the center of the surfacer, one through the left side, and one through the right side. This procedure should be followed four times. Each board should be thoroughly identified. All boards should then be measured for tolerances with a micrometer, accurate to the nearest 0.001 inch. Measurements should be taken at the center of the length of each board and at both ends. Two measurements should be taken at each of the three locations on the board to measure variation in thickness across the width of a given board. By this procedure machining variation in thickness can be determined along the length of a board, across its width and at various planer bed locations. This data should be presented in a table similar to Figure 3. Throughout the length or width of a board no two measurements taken should exceed the maximum tolerance permitted by the applicable laminate specification. In addition, surfaces should show no manufacturing defects such as skip, torn grain, raised grain, chipped grain, and chip marks, to an extent which will prevent sufficient contact between gluing surfaces for complete adhesion.

60.4 Testing distribution and adequacy of temperature and humidity conditions in a curing chamber.-

60.4.1 Test procedures and results.-

60.4.1.1 Place at least three laminated assemblies at various locations in the curing chamber, inserting thermocouples at the innermost glue line of each assembly. This should preferably be done when the chamber is full.

60.4.1.2 Insert at least three temperature and humidity recording or indicating devices in various parts of the curing chamber.

60.4.1.3 Make a drawing of the setup showing distribution of samples and instruments.

60.4.1.4 Submit samples and chamber to a full curing cycle, being careful that in the heating and cooling periods the ambient chamber temperature is not increased or decreased by a rate faster than that permitted by the governing specification. During the required curing period, no glue line temperature

in any sample should be less than that required for the particular approved adhesive appearing on Qualified Products List QPL-397 under Type II, Class 2 requirement of Military Specification MIL-A-397. The maximum variation in glue line temperature in the various samples should not exceed 9° F. At no point in the curing chamber or glue line should the temperature exceed 215° F. Further restrictions may be required on curing chamber temperature, glue line temperature, and curing period conditions when bonding wood treated with preservative.

60.4.1.5 Throughout the curing process relative humidity conditions should be uniformly maintained throughout the curing chamber which will keep the average moisture content of the wood essentially the same as it was before the curing process was begun. The samples should also show no signs of warp, casehardening, checking, or other degrade as a result of the curing process.

60.4.2 Difficulty in maintaining proper relative humidity conditions in curing chambers. - Discussions with a number of laminators have indicated that a better understanding of procedures to maintain proper relative humidity conditions in curing chambers is desirable.

60.4.2.1 Available literature on maintaining suitable relative humidity conditions in curing chamber to keep wood at a given moisture content condition. - A number of charts and graphs are available which show the correct relative humidity conditions which must be maintained in a curing chamber for a given chamber temperature condition to hold wood at a given moisture content. Unfortunately, many of these tables or graphs have been misinterpreted. A good source of practical, understandable information on the subject is Forest Products Laboratory Bulletin No. 1651 of October 1952 entitled, "Relative Humidity and Equilibrium Moisture Content Graphs and Tables for use in Kiln Drying Lumber." Table I of the referenced bulletin shows relative humidity conditions which must be maintained at a given temperature condition to reach a given equilibrium moisture content in wood. As noted in the table, different temperature conditions generally require different relative humidities in a chamber to maintain the same equilibrium moisture content condition in wood. Therefore, during the varying temperature cycle followed in curing laminate assemblies, it is also necessary to vary relative humidity conditions in the curing chamber, if the wood is to remain at essentially the same moisture content throughout the curing process.

60.4.2.2 Difficulty in maintaining enough relative humidity in the curing chamber. - At times laminators have had difficulty in maintaining high enough relative humidity conditions in the curing chamber. This problem usually originates when steam humidification is used. A common error in the use of steam humidification has been the straight injection of steam from steam heating system into the curing chamber. The line pressure of the steam is usually 10 to 30 p.s.i. On leaving the line the pressure is quickly reduced, and often the result is superheated or dry steam, which will actually reduce the relative humidity of the air in the chamber instead of increasing it. This difficulty can be avoided by either using fine water sprays or installing a system in the steam spray line which will completely saturate the steam as it leaves the pressure system.

60.4.2.3 Condensation in the curing chamber. - In maintaining proper relative humidity conditions in the curing chamber during the curing cycle, some firms have experienced difficulty with heavy condensation. Heavy condensation can usually be attributed to one or more of the following:

60.4.2.3.1 Trying to lay up laminated assemblies at too low temperatures.

60.4.2.3.2 Inadequate insulation and vapor barrier materials in the curing chamber walls.

60.4.2.3.3 Insufficient air circulation in the chamber.

60.4.2.3.4 Increasing the temperature in the curing chamber at too rapid a rate. Heating a chamber slowly will avoid condensation particularly at the higher temperatures where a greater actual amount of water is present for a given relative humidity condition. For example, if air at a temperature of 80° F. and 67 percent relative humidity (approximately 7.8 grains per cubic foot of water) was cooled to 60° F. (by chamber walls, clamps, etc.) approximately 2 grains per cubic foot of water would condense. This is a relatively small amount and could be eliminated by using slightly less than equilibrium moisture content conditions in the curing chamber during initial part of the heating period. However, if the air temperature was maintained at 160° F. and 79 percent relative humidity and if the chamber wall was at 140° F. temperature approximately 14 grains per cubic foot of water would condense. This is about 7 times as much condensation as would occur with the same 20° F. temperature spread at the lower temperature range. It is therefore obvious that if heavy condensation is to be avoided at the higher temperatures, better circulation, more adequate chamber insulation, and slower heating conditions are necessary. A graph showing these temperature-humidity relationships is shown in Figure 4 of the above referenced Forest Products Laboratory Bulletin No. 1651.

70. PROFICIENCY IN CONDUCTING BLOCK SHEAR TESTS

70.1 Correlation tests with a laboratory approved by the Bureau are required to show that results of block shear tests conducted at the laminator's plant in both shear strength and percent wood failure are essentially the same. The correlation tests should be conducted in a manner similar to that described below using the species of wood intended to be laminated in production:

70.2 Preparation of test specimens. - In order to effectively correlate block shear tests conducted at two testing stations, samples must be matched. This is most easily accomplished by cutting two closely adjacent full cross sections from a laminate. Enough cross sections shall be cut from laminates so at least 15 glue lines are represented. These laminate sections should be long enough and wide enough that they can be cut into 4 quarters; each quarter having large enough dimensions that a staircase specimen representing all glue lines can be easily prepared from it. Figure 4 shows an example of a wood laminate section. Each laminate section shall be carefully indentified as follows: A, B, C, D, etc. The four quarter sections in each laminate section shall be identified as follows: I, II, III, and IV. Quarter I in a given laminate section shall be diagonal to Quarter III, and Quarter II diagonal to Quarter IV. Individual glue lines in a given laminate section should be clearly marked 1, 2, 3, 4, etc., so that their position identification will not be lost. After full identification marking has been made, the laminate sections should be cut into quarters as marked (See Figure 4.) The cut quarter sections from the various laminate sections should then be separated so that Quarters I and III are included in one group and retained by the preparing activity for cutting of block shear test specimens and testing. The other group, containing Quarters II and IV, should be sent to the other activity for cutting block shear test specimens and testing. For better correlation, the activity preparing samples should place its specimens in a polyethylene bag or equally effective moisture barrier package and store. The other samples should also be packaged in the same manner but forwarded to the approved laboratory. On mutually agreed-on date, both activities should cut specimens for test and conduct tests.

70.3 Test procedures. - Block shear test specimens should be prepared and tests conducted, in accordance with the applicable laminate specification. In conducting tests, glue line 1 should be tested first, other glue lines being tested in numerical sequence. The block shear test specimens should be evaluated in both shear strength and accompanying percent wood failure.

70.4 Results. - The results of tests should be analyzed by suitable statistical methods to determine whether both activities are producing comparable results.

70.5 Methods for testing edge joints. - The cyclical exposure test as outlined in applicable military wood laminate specifications is considered a suitable method for evaluating adequacy of edge joint glue lines (provided all process requirements have been met). A preliminary method which indicates whether or not individual edge joints will meet the exposure test requirement is a block shear test as outlined below:

70.5.1 Preliminary testing of edge joints by the block shear test method. - For preliminary testing of edge joints full length boards containing at least two edge joints should be produced on regular production equipment in accordance with specifications. The boards prepared should be of at least two thicknesses, 1/2" and of a large thickness, and at least 7 boards of each thickness should be prepared. At least seven samples should be taken at random from each edge joint of each edge glued board and tested in block shear. The block shear strength must be not less than that specified in the particular laminating specification for the species of wood listed for block shear strength between laminations. The accompanying percent wood failure shall be not less than 75 percent. These tests should be conducted at a laboratory by qualified personnel on standard test equipment and in accordance with standard test procedures except for width of test specimen.

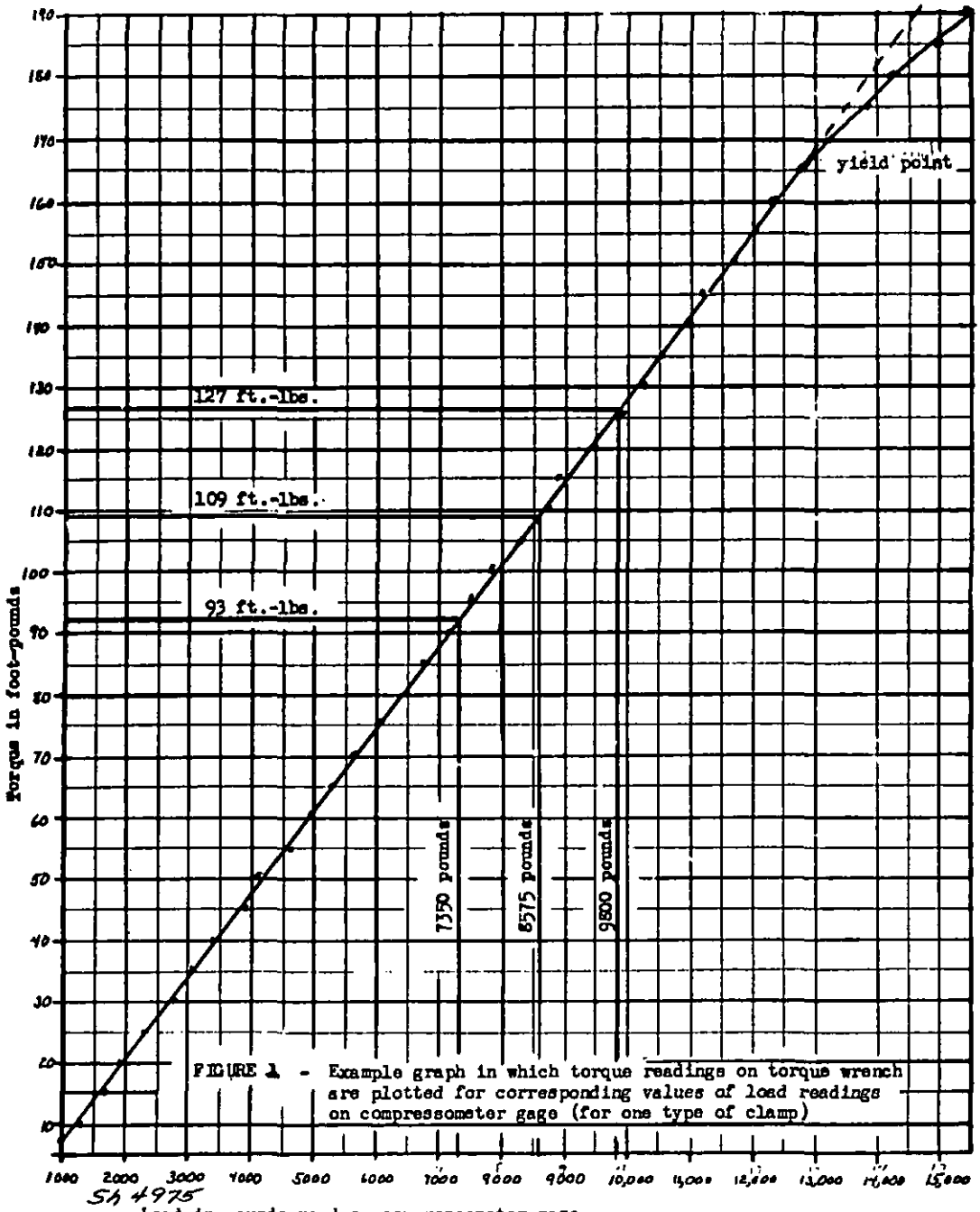


FIGURE 1. - Example graph in which torque readings on torque wrench are plotted for corresponding values of load readings on compressometer gage (for one type of clamp)

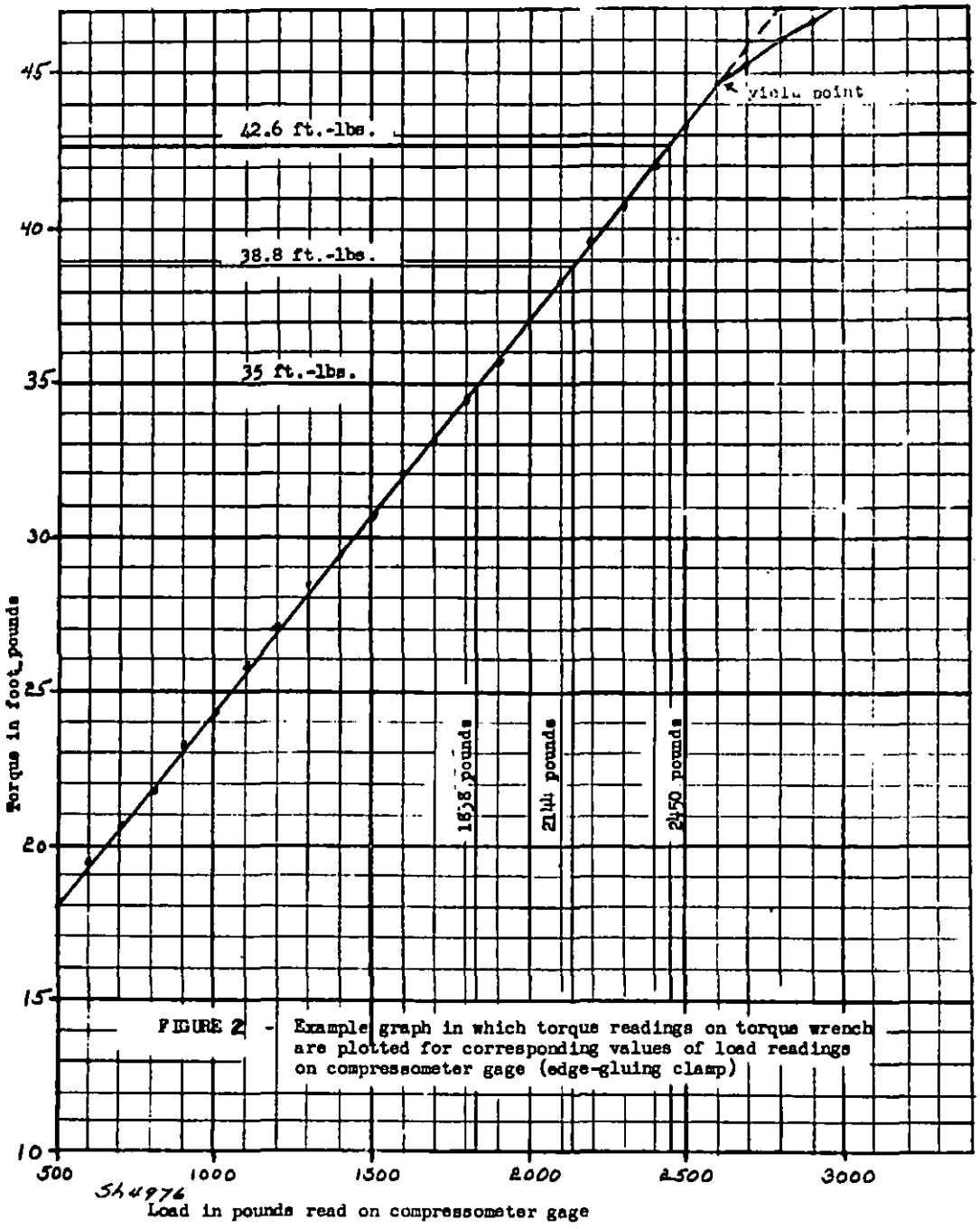


FIGURE 2 - Example graph in which torque readings on torque wrench are plotted for corresponding values of load readings on compressometer gage (edge-gluing clamp)

Boards through left side of surfacer (inch)						Boards through center of surfacer (inch)						Boards through right side of surfacer (inch)					
Leading End		Center		Aft End		Leading End		Center		Aft End		Leading End		Center		Aft End	
Left Side	Right Side	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side	Left Side	Right Side
0.750	0.751	0.749	0.751	0.750	0.752	0.752	0.751	0.749	0.748	0.748	0.750	0.746	0.748	0.747	0.749	0.750	0.748
0.757	0.752	0.754	0.753	0.751	0.750	0.753	0.752	0.748	0.746	0.748	0.749	0.749	0.750	0.748	0.749	0.750	0.749
0.753	0.752	0.751	0.754	0.751	0.752	0.752	0.753	0.750	0.747	0.749	0.750	0.747	0.749	0.749	0.750	0.747	0.750
0.751	0.753	0.752	0.750	0.752	0.751	0.751	0.752	0.750	0.751	0.750	0.751	0.749	0.748	0.750	0.749	0.750	0.748

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FIGURE-3. Sample chart showing thickness tolerances of boards run through a surfacer.

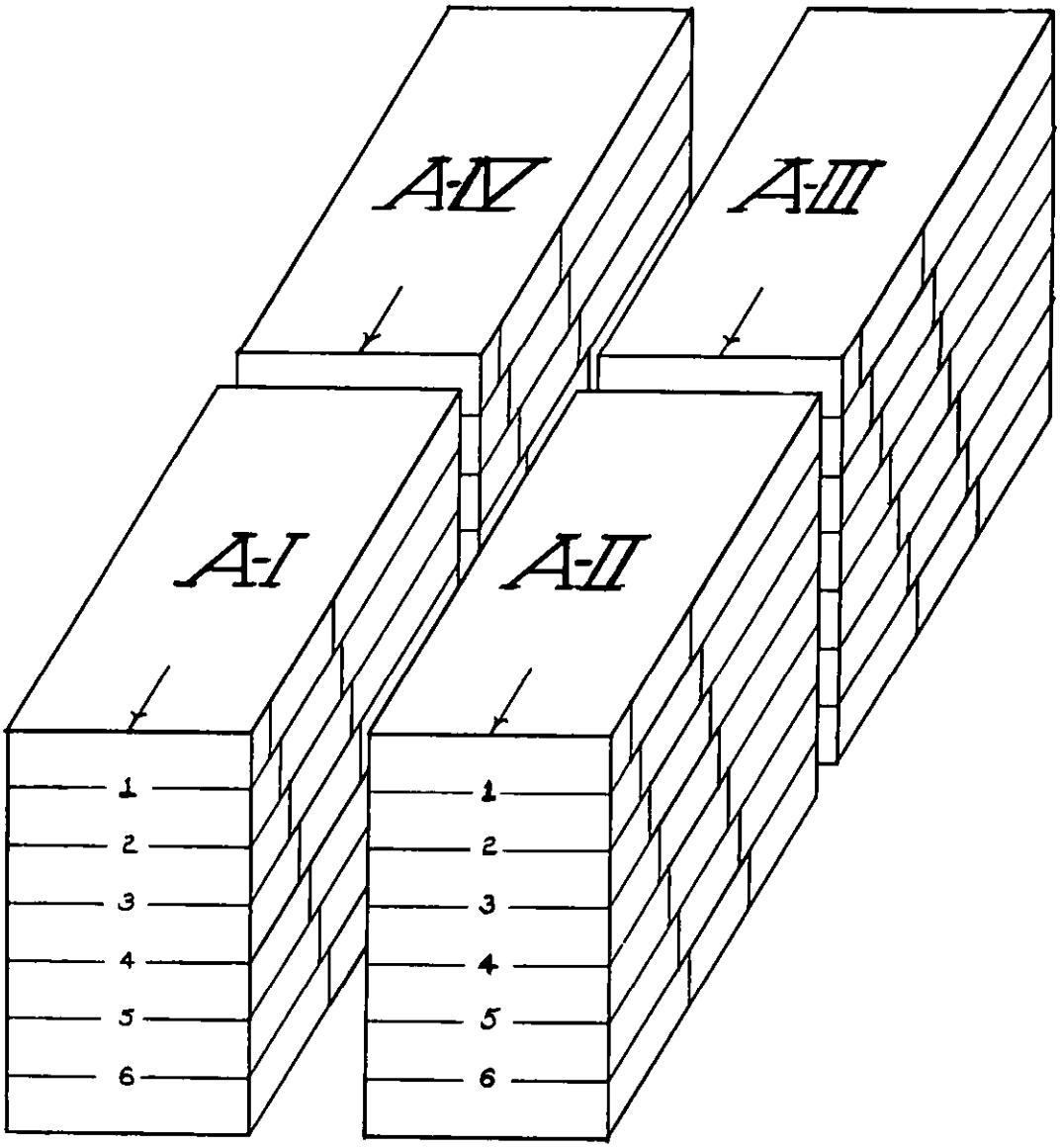

Figure 4 - Example of a Wood Laminate Block Shear Test Correlation Sample.