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Prepared by participants in the 1968 National Defense Education Act Institute on Wood Technology, this syllabus is one of a series of basic outlines designed to aid college level industrial arts woodworking instructors in improving and broadening the scope and content of their programs. The manual consists of a brief introduction followed by seven major unit topics, including: (1) Laminated Timbers, (2) Kerf Binding, (3) Bending of Plywood, (4) Bending Steamed or Boiled Wood, (5) Lamination Bending, (6) Bag Moulding of Plywood, and (7) Anhydrous Ammonia Bending. Most units contain descriptive and explanatory information objectives, content outlines, drawings and diagrams, suggested procedures, and uses of the materials produced. Supplementary materials include a list of films and filmstrips, a glossary, a bibliography, and reference and instructional aids. Related documents are available as VT 007 858, VT 007 859 and VT 007 861. (AW)

LAMINATING AND BENDING

A
BASE SYLLABUS
ON
WOOD TECHNOLOGY

Prepared by
INSTITUTE PARTICIPANTS

EASTERN KENTUCKY UNIVERSITY
UNITED WE STAND ★ DIVIDED WE FALL
FOUNDED 1906
RICHMOND

N.D.E.A. INSTITUTE
for advanced study in
INDUSTRIAL ARTS
June 10 - August 2, 1968

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EASTERN KENTUCKY UNIVERSITY

June 10 - August 2, 1968

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PREFACE

Recently, the area of woodworking has come under much criticism as being too limited in scope and not fully abreast of an advancing technology. Some people have gone as far as to seek its abolition from the industrial arts program in the secondary schools. In reality, however, the importance of woodworking as a phase of industrial arts is probably greater now than ever before. It is conceded, nevertheless, that the scope and content of industrial arts woodworking programs needs to be improved.

Traditionally, a typical woods program is centered upon the use of hand and machine tools with little or no emphasis given to the problem of familiarizing students with technical knowledge of the material itself.

To assist in the upgrading of present programs, students and teachers should, in addition to the use of wood as lumber, be made aware of the various properties of wood and wood products. Of equal importance is a knowledge of new processes and materials used in conjunction with the fabrication, manufacture, and application of wood and wood-related products.

The purpose of the NDEA Institute in Wood Technology held at Eastern Kentucky University during the period June 10 - August 2, 1968, was to provide college level industrial arts woodworking instructors with the opportunity to receive information in depth which they might use to broaden the scope and content of their programs. To this end, the participants have prepared this series of Basic Outlines which attempt to record their experiences during the period of the institute. The "Base Syllabus" prepared by the participants in the 1967 Wood Technology institute was used as a guide in developing the format of this series.

It is hoped that the material covered herein will be applied to the improvement of each participant's woodworking program and lead their students to a greater understanding of wood and wood products.

Jack A. Luy

Institute Director

TABLE OF CONTENTS

LAMINATING AND BENDING WOOD

Introduction

Laminated and/or bent wood products have become a commonplace product of modern industry. Furniture, sporting goods, boats, and even large buildings are made in part or wholly of laminated or bent wood.

Wood can be bent quite easily by softening it with boiling water, steam or ammonia. It can also be bent by cutting saw kerfs on the back side or by laminating thinner pieces that bend more readily into larger units with the use of glue and clamps. Regardless of what process is used, the end product can result in shapes and sizes that cannot be made of solid stock.

The wood laminating and bending industry has been steadily increasing not only in quantity, but also in application. The development of new processes and materials has made it possible to fabricate consumer items that could not be produced of solid wood because of size or bending problems and also items that had to be made of solid wood or other materials.

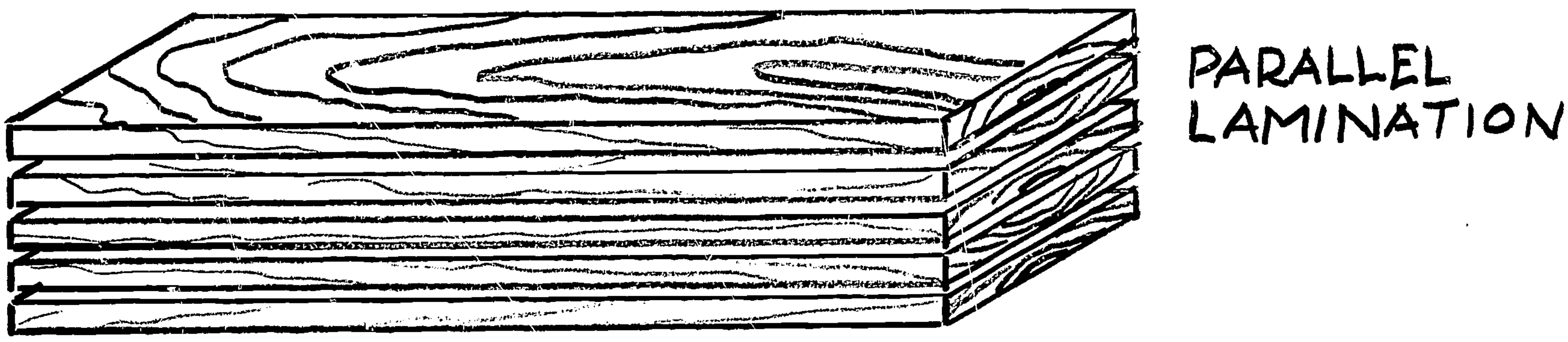
UNIT I

LAMINATED TIMBERS

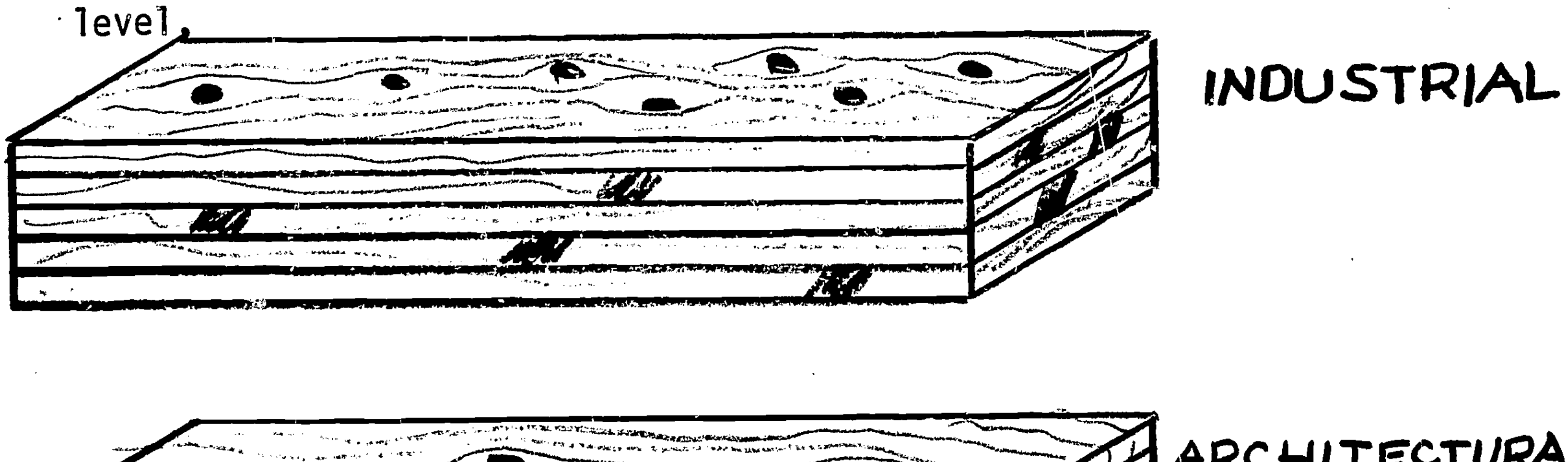
Introduction

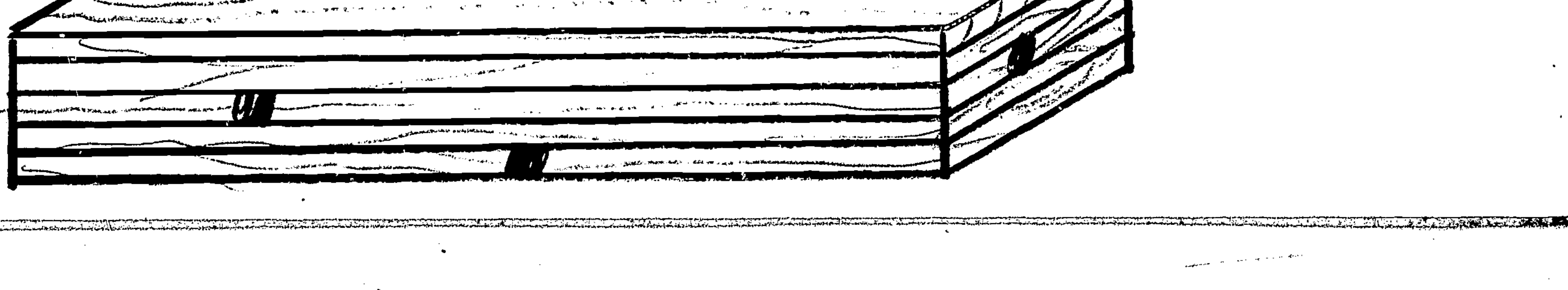
Laminated timbers have been in use to a limited extent since the early 1900's. However, their use did not become popular until just after World War II. Since that time architects have recognized their usefulness not only for structural support, but also for the aesthetic beauty that can be achieved through their use. The endless possibilities of design and size of laminated timbers have made them increasingly popular in structures of all kinds and sizes. The stresses and sizes necessary in some structures make it impractical to use solid timbers, and the nature of steel does not give the aesthetic beauty possible with laminated timbers.

For the purpose of this discussion a laminated timber is defined as solid timber that has been glued together to form desired shapes and sizes, with all members having their grain running in the same direction. They are glued together with the grain of all pieces running approximately parallel to each other in order to achieve maximum strength factors and optimum bending contours.

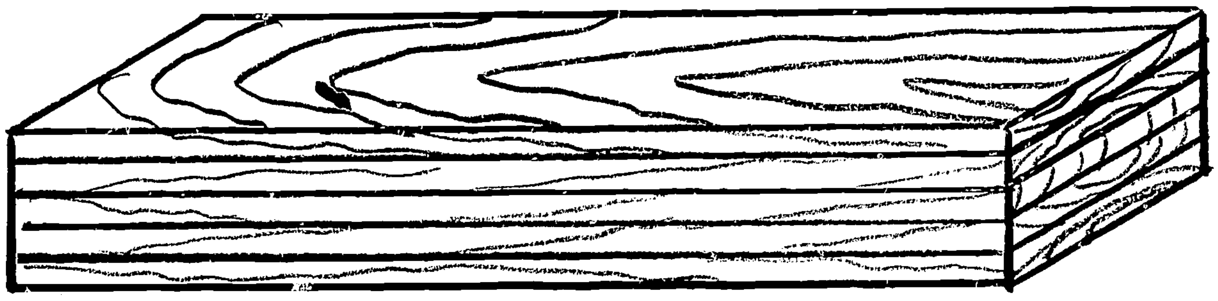


Grading and testing is a continual process throughout the manufacture with relation to the engineered design of the laminated timber. However, once the product is ready for use, the timber must meet standards which would place it in one of three pre-specified appearance grades, namely (1) industrial grade, where surface appearance is not of prime importance, (2) architectural grade, where the maximum number of surface defects, including knots, is specified and inserts or plugging is permitted to achieve the required appearance level,





and (3) premium grade where all exposed surfaces are to be clear.



I. Laminated timbers have several distinct advantages over solid timbers and metal girders.

A. Size: laminated timbers can be built-up to practically any thickness, width, and length necessary to meet the specifications called for. The only exception would be that the timber was too large and heavy for the purpose it was intended for the strength factor involved.

B. Shape: laminated timbers can be formed into practically any shape desired.

C. Drying: the individual laminates can be dried in a relatively short time before they are laminated, as opposed to the length of time necessary to dry large solid timbers.

D. Large natural timbers are more susceptible to checking and shrinking.

II. In general, only softwoods are used in the construction of laminated timbers.

A. Approximately 95% of all wood used in making laminated timbers is either douglas fir or southern pine.

B. Larch, hemlock, and other softwoods constitute the other 5%.

C. Hardwoods are seldom used in laminated timbers because:

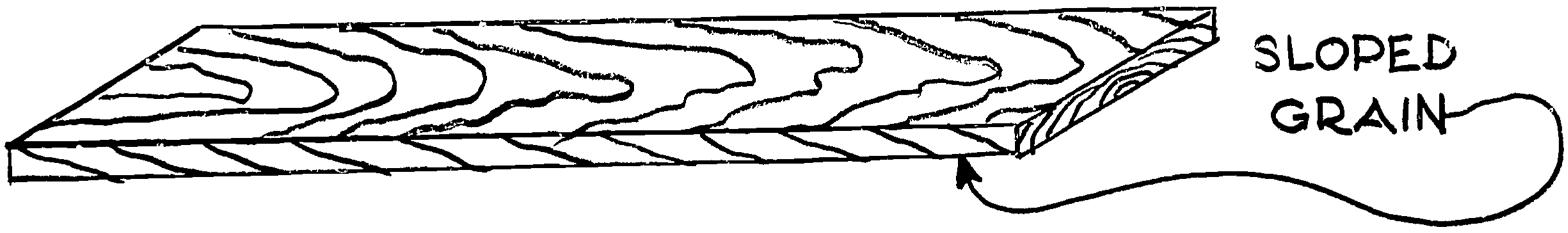
1. large clear laminates are hard to find.

2. the cost is much greater.

III. Grading species, number of laminations, ultimate use, etc. dictate the specific grades of timbers that must be used, and references for specific uses must be made to American Institute of Timber Construction Commercial Standard Publications. General rules for laminated timbers are:

A. All individual boards used in laminated timbers must be of medium grade or better.

B. Some slope of grain is permitted.



C. More splits are allowed in laminated timbers than are allowable in solid timbers.

D. Shakes not more than 1/4" deep, and not more than a 45^{0} slope, are permitted.

E. Thickness of the individual laminates must be within a plus or minus .008" tolerance.

IV. Adhesives for structural laminating: advancement of industrial technology in the formation of synthetic adhesives, and the improvement of the bonding qualities of natural based adhesives has promoted an ever increasing expansion in the utilization of glued laminated structural timbers as a building medium. In the adoption of any form of adhesive for use as the bonding agent in the fabrication of laminated timbers, two factors other than cost are of primary concern: (1) use of the laminated timber, and (2) set time of the adhesive.

A. Use of the laminated timber:

1. Dry use (water resistant adhesives): for interior locations with environments having a moisture content of 16% or less. At present, casein type adhesives are generally used for this purpose.

2. Wet use (waterproof adhesives): for all locations, but specifically for environments having a moisture content of 16% and above. Included in this area would be exterior use of timbers exposed to weather, marine uses, and where pressure treatment (wood preservatives and fire retardants) of the lumber is used either before or after gluing. Resin based adhesives of phenol, resorcinol, and melamine types adhesives are generally used for this purpose. The exception would be that melamine type adhesives are not to be used with treated lumber.

B. Set time (working life) as it relates to assembly time required in fabrication is important. Other factors affecting the working time of the adhesive must also be considered. These are moisture content of the lumber, air temperature, temperature of the lumber and fabrication room, and the curing system to be used.

1. Assembly time is the time elapsed from the initial spreading of glue on the first piece of lumber through the final application of pressure, and is divided into two parts, open and closed.

   a) Open assembly time: the time elapsed between spreading the adhesvie and assembling the spread surfaces in contact with one another.

   b) Closed assembly time: the time elapsed from the assembly of the first laminations of the package into laminate contact until final application of pressure or heat, or both to the entire package.

2. Moisture content of the wood will affect the set time and working life. Generally a moisture content of 16% is specified.

3. Temperature of the lumber and plant can affect set time.

   a) Extreme cold temperature retards setting time.

   b) Extreme hot conditions can cause pre-set.

4. The pressure application technique and type of heat curing apparatus used will have implications on the set time of the adhesive.

C. Other factors influencing the selection and utilization of a specific adhesive are:

1. Strength and stress properties.

2. Type of adhesive spreading system and its requirements.

3. Specifications as to delamination tests.

4. Type of internal jointery of the timber.

   a) Scarf joints

   b) Finger joints

   c) Mechanical joining systems

V. Hardware: the design of structural hardware for laminated timbers may be furnished by the architect or engineer, or it may be the responsibility of the timber fabricator. Sometimes the hardware may be designed and fabricated by an associated metal manufacturing company. (For types of hardware see <u>Typical Construction Details</u>, <u>AITC 104-65</u>).

VI. Manufacture of laminated timbers: the unlimited number of sizes, shapes and designs of laminations, lumber species, and glues combined with differences in facilities within the industry, is apparent. Therefore, the following steps of procedure will apply generally, but not specifically, to any one size, shape, design, or manufacturer.

A. Grading: the lumber will be graded in respect to lamination grades on arrival at the fabrication plant.

1. L1, lamination one: knots equal to 1/4 of width or less permitted.

2. L2, lamination two: knots or defects up to 1/3 the width of the finished timber permitted.

3. L3, lamination three: permits core materials with knots or knot clusters within a specified length to width ratio, not to exceed 1/2 the width of the finished timber.

B. Drying: depending on the plant facilities, lumber may arrive kiln dried, or it may be dried at the laminating plant to 12% moisture content. A moisture sensor checks each piece of stock as it enters the rough mill, and rejects for redrying those pieces that do not meet minimum standards.

C. Surfacing: all stock must be surfaced to plus or minus .008" tolerance of specified thickness.

D. Ripping: each piece of stock is ripped to specified width plus 1/4". This 1/4" will be removed after gluing.

E. Regrading: at this point the lumber is regraded, the moisture content is again checked, and the thickness is rechecked. The lumber is then placed into specified lamination grades according to species, i.e. douglas fir, southern pine, larch, oak, etc.

F. End Jointing: there are three basic methods of end jointing used.

1. Scarf joints: the length to thickness ratio of the scarf should fall within a range of 1-8 to 1-12, with the usual ratio being 1-10.

2. Finger joints: with the fingers going from edge to edge or from face to face. (Finger joints are also used in some cases to build up wider members)

3. Butt joint: not recommended.

G. Pattern: a full size pattern of the timber to be fabricated is made up (usually of plywood). It is used to align the press to the desired shape of the timber and to mark the timber for trimming.

H. Lay-up: the individual boards are laid-up in sequence exactly as they will be in the finished timber. Preliminary clamp alignment may occur at this time.

I. Glue: the glue is spread on both the top and bottom at the same time by mechanical glue spreaders.

J. Clamping: the individual laminated boards are placed into the clamping form.

1. Clamps are placed on a maximum spacing of 18" between centers.

2. If a straight beam is being laminated, the clamps are aligned to form the specified camber.

3. The clamps are usually tightened mechanically with an air torque wrench to a minimum pressure of 100 psi and to a maximum of 250 psi.

4. A visual inspection of the glue line or uniform beading of glue is made at this time.

5. The clamps are retightened after 30 minutes because initial curing will reduce the pressure. (If the dielectric glue setting process is used, the retightening step is not necessary)

6. The glued timber is removed from the clamps for total curing after it has set.

K. Surfacing: the laminated timber is surfaced on top and bottom simultaneously.

1. It is recommended that the timber be surfaced to the final plus or minus 1/16" tolerance by making two passes through the surfacer.

2. The top and bottom boards are planed to match the templet.

L. The ends are cut to proper length and contour, and any necessary tapers are included. (The end cuts are used for lab test samples)

M. Surface defects are filled to meet the visual grade standard for architectural and premium grades.

N. Sanding: the surfaces are sanded to meet specifications.

O. Hardware fitting: all members are trimmed and cut for pre-fitting of hardware.

P. Treatments and preservatives: it is recommended that when specifications require wood preservation treatments, this operation should be completed before lamination. Fire retardants are applied after lamination.

Q. Inspection and certification of the completed timber is made at this point.

R. Packing and shipping: all architectural and premium grade timbers are wrapped. If wrapping should come loose, then all of the wrapping must be removed or sunburn on the exposed surfaces will cause an uneven coloring on the finished surface.

S. Erection: the actual installation of the timbers may be part of the fabrication firm's responsibility, or it may be done by the general contractor. Adequate bracing must be kept in place during erection until all lateral members are in place and fastened.

VII. Quality Control: the quality of laminated timbers is controlled by both visual inspection and by testing that is conducted before fabrication, during fabrication and after fabrication. This inspection and testing includes items such as:

A. Lumber grading: the lumber is graded before it is delivered to the manufacturer, and again before it is used in fabrication.

B. Moisture content: all lumber is kiln dried by the timber manufacturer, and all pieces that do not meet the minimum moisture content standard (16%) are redried.

C. Thickness control: all individual timbers must be within plus or minus .008" tolerance (most producers try to stay within plus or minus .005" tolerance).

D. Viscosity of glue: glue viscosity is controlled according to type, working life necessary, temperature and humidity conditions, etc., and specific recommendations may be found in AITC Inspection Manual #200

E. Glue spread: glue spread is inspected by gummed tape patches. The tape is weighed dry and then placed on the surface to be glued, and then the tape is weighed again after the glue is spread to determine the amount of glue spread.

F. Shear test of glue line: in order to be considered a good glue line, at least seventy per cent of the failure must be in the wood itself, with a maximum of thirty per cent in the glue line. In general and through necessity, the test sample for shear must come from the end of the beam. However, a "core barrel" may be taken near the center of the beam; however, this tends to cause a weak spot and the beam must be heavy enough to compensate for this weak end spot.

G. Delamination test (inadequate glue line): this test is used to determine whether or not the glue has been properly applied and cured.

1. The test is composed of three cycles of rapid wetting and drying.

2. All checking due to this wetting and drying should appear in the wood. If any checking occurs in the glue line it is considered delamination, indicating that the glue line is inadequate.

H. End joints: end joints are subjected to stress and bending tests. All joints must withstand a stress of more than 8,200 psi.

I. Glue line thickness: glue lines are checked with a fifty-power microscope calibrated to measure the line thickness in thousandths of an inch.

J. Miscellaneous visual inspection:

1. Dimensions

a) Thickness, width, length

b) Squareness.

c) All holes for fastening and erection are complete.

2. Overall appearance is good.

K. Apply official inspection approval stamp.

UNIT II

KERF BENDING

Introduction

Kerf bending is a method of bending solid wood that is used to a limited extent in modern wood products industries. It is the simplest and quickest method of bending, requiring no special equipment. Two significant disadvantages limit this method of bending. These are: kerfs cut across the grain produce a weak member, and saw kerfs may telegraph (show through) on the outside surface.

I. Types of Kerf Bending

A. There are two types of kerf bending: bending with kerfs cut across the grain, and bending with kerfs cut parallel to the lumber face.

1. Cross grain kerf bending.

   Solid wood can be bent easier if a series of saw kerfs is across the grain on the concave side of the bend. The part produced in this manner is weak and should be used only in assemblies where it can be securely attached to other supporting members.

2. The following is a suggested procedure for producing cross grain bent parts.

   a) Determine the radius of the bend.

   b) Determine the length of the bend.

   c) Determine the spacing for the saw kerfs. This can be done by measuring the radius of the circle to be bent from the end of the stock and make a saw kerf at this point. Fasten the stock to a table top with a clamp,then raise the free end of the stock until the kerf closes. The distance the end of the stock is raised above the table is the distance needed between kerfs.

   d) Now lay off the second kerf and continue cutting kerfs until the length to be bent is covered. The kerf should be cut to within 1/16 to 1/8 inch of the board face.

   e) Fill the kerf with glue, bend to the required curvature, and clamp until dry.

3. Kerf cut parallel to the face.

   Occasionally a part is needed that is straight for most of its length but curved at the end as in a water ski.

The easiest method of producing this kind of bend is to make saw kerfs from the end grain parallel to the face surface.

4. The following is a suggested procedure for producing bent parts using kerfs parallel to the face.

    a) Determine the curvature of the bend.

    b) Determine the length of the bend.

    c) Cut the kerf or kerfs from the end grain parallel to the face surface to the end of the bend.

    d) Cut sheets of veneer slightly wider and longer than the kerfs.

    e) Apply a good grade of glue to both surfaces of the veneer and to the inside surfaces of kerf.

    f) Slip the veneer in place.

    g) Fasten the end to be bent in a suitable mold and clamp until dry.

    h) Remove from the mold and trim off the excess veneer and cut the part to its finished shape.

    i) If extremely thick material is to be bent it may be necessary to steam or soak the ends to make the wood more plastic before the veneer is inserted.

II. Common Uses of Kerf Bending

Wooden parts produced by kerf bending are used for some furniture parts (chair parts, table aprons, etc.), kitchen cabinet work, water skiis, and snow skiis.

UNIT III

BENDING PLYWOOD

Introduction

Extensive use is made of molded plywood in today's furniture industry, especially in the construction of chairs and commercial seating. There may also be times when plywood is selected because of stability and more uniform strength. Because of the expensive equipment used in industry, the transfer of this type of molding to the industrial arts program has been limited.

I. Bending of standard plywood

A. Reasonable radii may be bent with certain species, depending on thickness. Refer to Table 1.

Table 1. Bending Properties

The following table indicates radii to which birch and mahogany veneer core plywood panels can be bent in a dry condition. (Source: "Plywood" by Louis H. Meyer.) Values are for dry bending. Type 1 (waterproof) panels soaked or steamed average approximately 50% greater flexibility.

	Thickness	Lengthwise of panel	Crosswise of panel
Birch (Poplar core)	1/16"	7.6"	4.1"
	1/8"	13.3"	8.3"
	1/4"	28.0"	20.9"
	3/8"	39.6"	34.4"
Mahogany (Poplar core crossband)	1/16"	5.9"	4.1"
	1/8"	10.2"	8.3"
	1/4"	21.5"	20.9"
	3/8"	30.3"	34.4"

B. Another method is to cut saw kerfs through all plies to bottom of face veneer. See figure A.

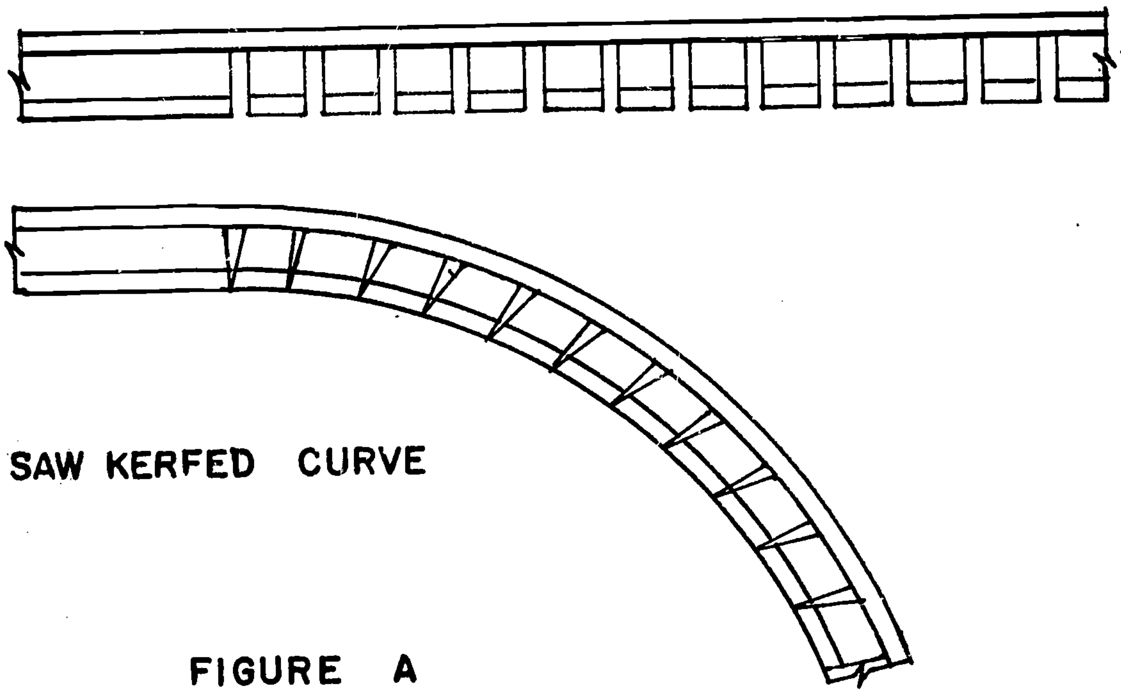


FIGURE A

1. The saw kerfs should be as thin as possible and spaced so that the kerf closes when placed in the desired convex shape.

2. If the surface veneer is to have a concave shape, use a double thickness of plywood and cut kerfs on the interior plys. See figure B.

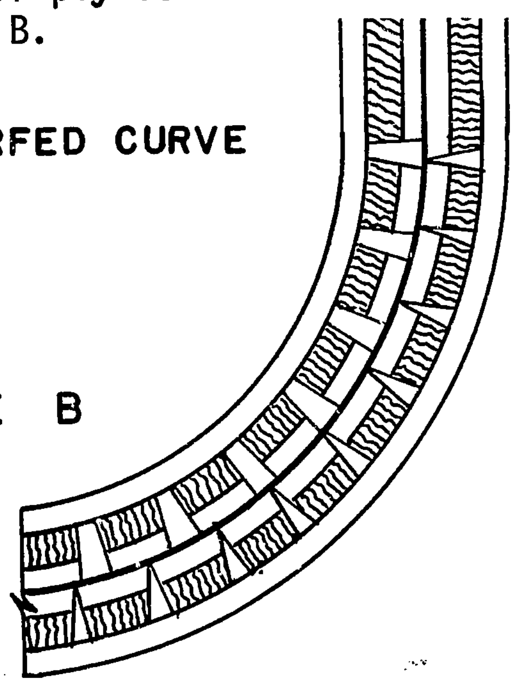


FIGURE B

C. Most types of bends require heavy molds and special clamping techniques.

II. Bending of non-standard plywood.

A. Special bending stock of two or three ply unbalanced construction is often used. Figure C illustrates several examples.

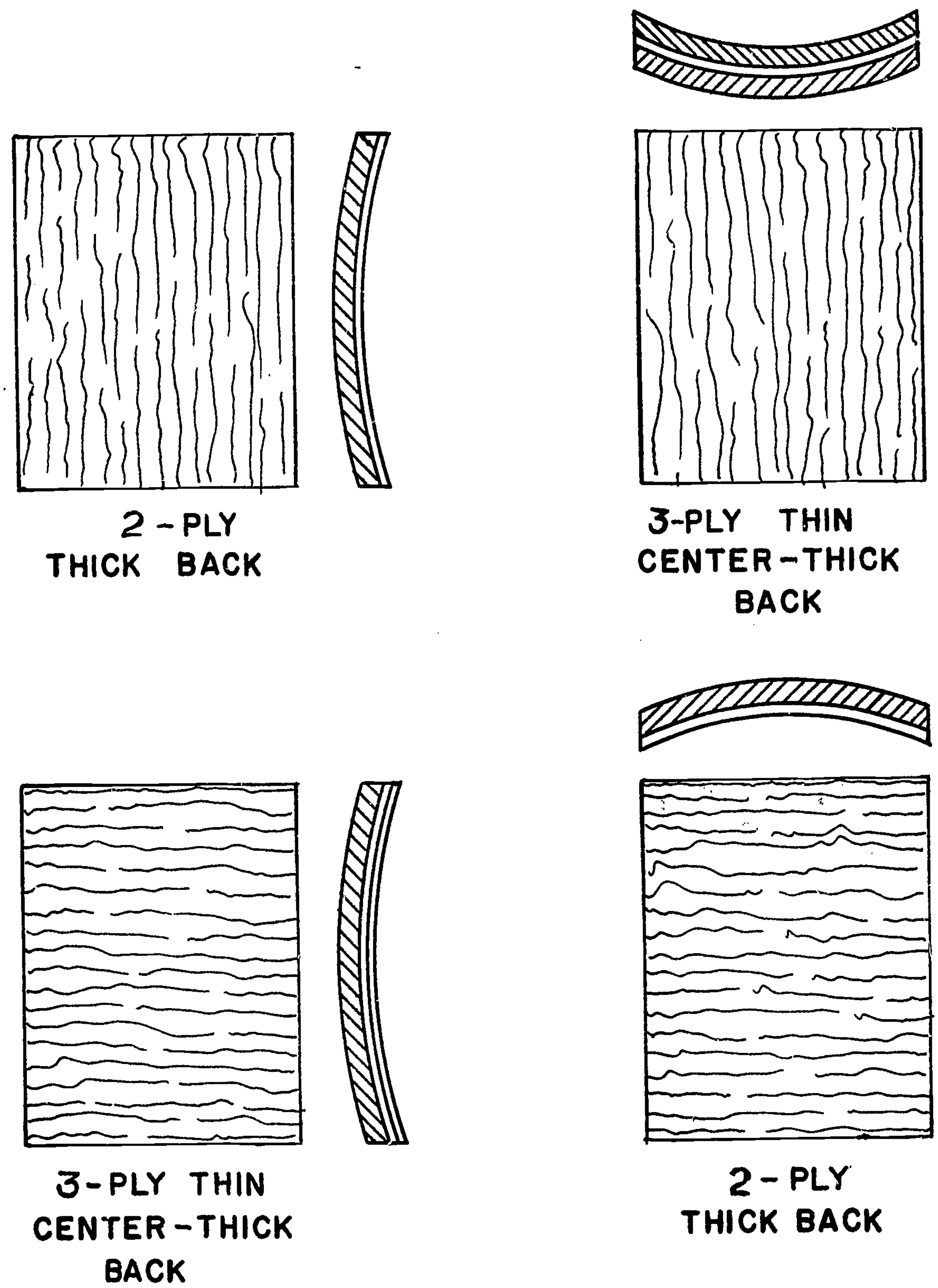


FIGURE C

B. For best results, separate layers should be assembled with the face ply grain running parallel to the bend.

C. Any number of layers may be used to build up the proper thickness.

III. Use of heat and wetting agent.

A. Soaking in hot water greatly improves the bending characteristics and is preferred over the use of a wetting agent.

1. Wetting agents are used to help plasticize the wood.

2. Several commercial wetting agents are available.

a) "Hydrodyne" manufactured by the Aquadyne Corporation, New York.

b) "Drench" produced by the National Foam System, Inc.

IV. Use of pressure molding systems.

A. The Dia-Press molding process is perhaps the most sophisticated molding process used in the industrial arts laboratory.

B. There are various types of shop produced molding systems which are used in the laboratories.

1. A "Bag Molding" system constructed with a football or basketball bladder, automobile or bicycle inner tube, or a fire hose may be used.

2. Jigs or forms using mechanical pressure may also be used.

V. Use of dielectric curing in fabrication of laminated shapes.

A. Commercially, the material is often pressed between platens which are used to form the material to shape as well as provide for radio frequency curing.

B. The radio frequency glue welder may be used for spot curing the glue line in order to speed up some lamination projects in the industrial arts program.

UNIT IV

BENDING STEAMED OR BOILED WOOD

Introduction

Steaming and boiling of wood is one of the oldest methods of bending wood to shape. A cooper in the sixteenth century used a steam process to soften the lumber for bending barrel staves. By 1893, new techniques for wood bending were perfected and the furniture industry made a more definite move to the bent chairs. In 1900, rounded chair backs and rocking chairs had an influence on wood bending.

Of all the methods used to produce curved furniture parts, bending is not only the most economical, it also offers maximum wood utilization and high strength. Solid wood bending is a craft operation that involves the bending of wood in hot presses or over unheated forms, either mechanically or by hand. Hand bending is usually confined to severe or compound curves.

Today the use of wood bending is prevalent in such industries as furniture manufacturing, boat and ship building, agricultural implements, tool handles, arch beams, sporting good equipment.

I. Principles of Bending

A. Wood of certain species steamed in boiling water can be:

1. Compressed by as much as 25 to 30 per cent parallel to the grain.

2. Stretched only 1 to 2 per cent.

B. Because of the relation between attainable tensile and compressive deformation, it is necessary, if bending involves severe deformation, that most of the deformation be forced to take place as compression.

1. The inner or concave side must assume the maximum amount of compression.

2. The outer or convex side must have zero strain or a slight tension.

a) To accomplish this, a metal strap equipped with end fittings should be used. The strap makes contact with the outer or convex side and, acting through the end fittings, places the whole piece of wood in compression. The tensile stress that would normally develop in the outer side of the piece of wood during bending is borne by the metal strap.

II. Selection of Bending Stock

A. Selection of stock to be bent is limited by the woods used in furniture construction plus the wood's bending properties.

1. Hard woods bend better than soft woods.

2. Heavy woods better than light woods.

3. Second growth woods bend better than old growth.

B. Bending quality is assessed by

1. Tension and compression strains applied in bending without wood failure.

2. The retaining of the wood strength properties after it is bent.

C. The degree of bending ability and efficiency among hard woods will vary to a great extent.

D. According to the Forest Products Laboratory, wood for bending may be selected for bending quality in the following order: hackberry, white oak, red oak, chestnut oak, magnolia, pecan, walnut, hickory, beech, elm, willow, birch, ash, sweet gum, soft maple, yellow poplar, hard maple, chestnut, buckeye, bass wood and mahogany.

E. Soft woods are not often used in bending operations; exceptions to this rule are:

1. Yew and yellow-cedar.

2. Douglas fir, southern pine, the cedars, and redwood are used for ship and boat planking.

   a) Soft woods are bent to moderate curvature after being steamed or soaked.

F. Bending stock should be free from serious cross grain and distorted grain, such as may occur near knots.

1. The slope of cross grain should not be greater than 1 to 15.

2. Decay, knots, shake, pith, surface checks, and exceptionally light or brashy wood should be avoided. Such irregularities may cause wood to fail during bending, particularly if:

a) They are on the face that is to be the inner or concave side at the time of bending.

b) The piece is to be bent to a sharp curvature.

G. Seasoning bending stock is pertinent to a successful bend.

1. Green stock has a tendency to wrinkle along the inside of the bend, to check and split in hot press bending, and to involve excessive shrinkage, defect, and time in the drying process.

2. Kiln dried wood has a brittleness even when it is softened prior to bending and generally cannot be bent successfully in production operations.

3. Air-dry moisture content standards vary with species, bending methods, the average range is 12 to 30% moisture content.

a) Hand bending 20 to 30% moisture content.

b) Machine bending 15 to 20% moisture content.

c) Hot press bending 12 to 15% moisture content.

(1) For hot pressing without conditioning, the range becomes 15 to 20% and as high as 30% for woods not susceptible to checking and splitting.

III. Preparation of the stock before bending.

A. Stock to be bent should be prepared in the form of blanks for individual parts of rough dimension and multiple-width plates that will be ripped into individual parts after bending.

B. Best results are obtained by keeping the thickness of the part as close as possible to its finished dimension.

C. Provide greater width than thickness to prevent lateral buckling.

D. Cut the stock accurately to fit bending straps, pans, or other bending apparatus.

E. If possible, do not shape parts until after they are bent.

F. Do not drill, carve or cut joints on the material to bend because this will cause possible distortion or failure in bending.

G. Seal coat the ends.

1. This prevents excessive moisture absorption.

2. It minimizes end checking during drying process.

IV. Conditioning.

A. Conditioning is to soften or plasticize the wood, making it compressible for bending to a desired curvature without failing.

1. This may be accomplished by

a) Steaming

b) Hot water

c) Commercial chemical softening agents

B. Treatment is critical because

1. Wood too soft will wrinkle.

2. Wood not soft enough will sliver and split.

C. Plasticizing with chemicals such as glycerine, tannic acid, phenol, ferric acid, and urea has been extensively explored.

1. Recent experimentation reports good results using dimethyl sulfoxide, and ammonium salts solution, but the hazardous nature and offensive odor prevent its commercial use to date.

D. Heat and moisture of steam or of hot water treatments produce degrees of platicity measuring about 10 times that of wood at normal temperatures.

E. Plasticizing apparatus.

1. The steam chest, any container in which it is possible to hold wood and apply steam or boiling water.

2. Types of apparatus

a) Aluminum foil containers heated over open flames.

b) Form bending machines with steam heated platens.

c) Pressure steam retorts.

(1) Steam conditioning may be exhaust or atmospheric pressure, live steam without pressure, live steam under pressure, or a steam water combination.

(2) High pressure steam shortens the conditioning period, but pressures in excess of 35 psi may cause case-hardening.

(3) Steaming time is also critical.

d) Boiling wood directly in water container. Conditioning with boiling or near boiling water (up to 210° F) approximates exhaust steam treatment at atmospheric pressure.

(1) Conditioning schedules, 1/2 hour per inch of thickness for wood at 15 to 20% moisture content and 1 hour at 12 to 15% or lower for hot water treatment. High pressure steam may reduce conditioning time by 50% and combination steam-water treatment as much as 25%.

(2) Some wood benders apply a thin coating of linseed oil to the conditioned wood to minimize possible breakage during bending.

V. Bending Fixtures

A. After wood is conditioned for bending, it can be stretched or lengthened very little, but it can be compressed, upset, or shortened considerably.

B. Two classifications of bending techniques:

1. End pressure

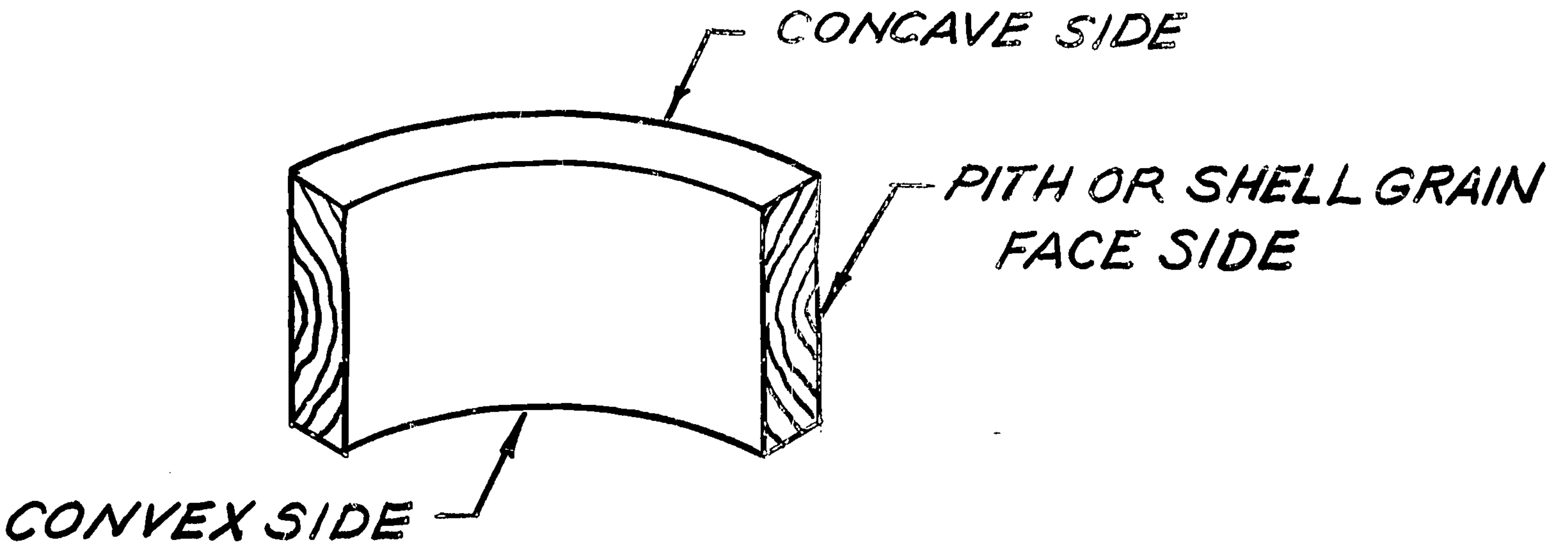
a) Considering the difference in length of bent wood convex and concave faces, bending with minimum failure requires stretching as little of the wood as possible on the convex side while reducing the length of the concave surface through compression. This is accomplished by using retaining straps or pans with end fittings attached.

b) These fittings permit compressive force (and pressure) to be applied to produce necessary upset and to prevent tension failure along the convex surface.

c) Bending stock should be located in relation to the form over which it is to be bent, allowing wood to bend with the grain.

d) The most critical part of the bend is the concave or outside surface so the defects of the wood should not be on this face.

e) The pith or shell grain face side of the wood should be oriented to the concave side of the bend.



f) Bending straps should be as wide as the stock being bent and can be made of brass, copper, aluminum, or stainless steel.

(1) Hand bending straps are fastened to bending forms by special hooks, lugs or clamps.

(2) Machine straps carry end fittings designed to receive rods.

g) The metal strap is applied to the convex side of the material.

h) The strap reduces the tendency of the bend to to spring back after removing it from the clamps.

i) The metal strap is used when a curvature requires more than 3% difference between the length of the inner and outer face.

2. Small curvature bends may be made without end pressure control if good bending woods are selected and properly conditioned, providing the radius of curvature approximates eight times the thickness.

VI. Setting the Bend

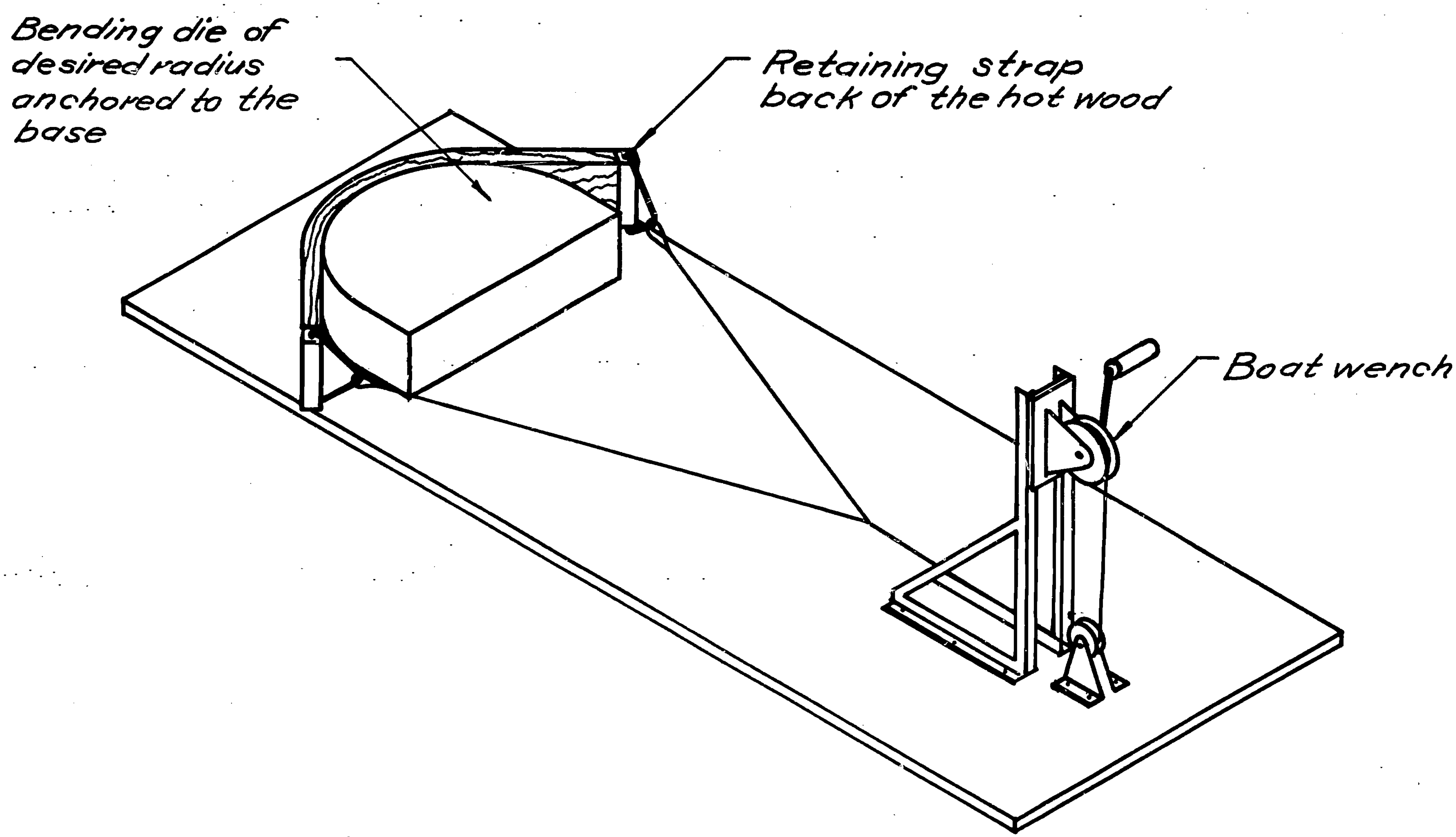
A. Bends must be set to prevent change in shape when freed from restraining straps, etc.

B. Drying is required to set the bend.

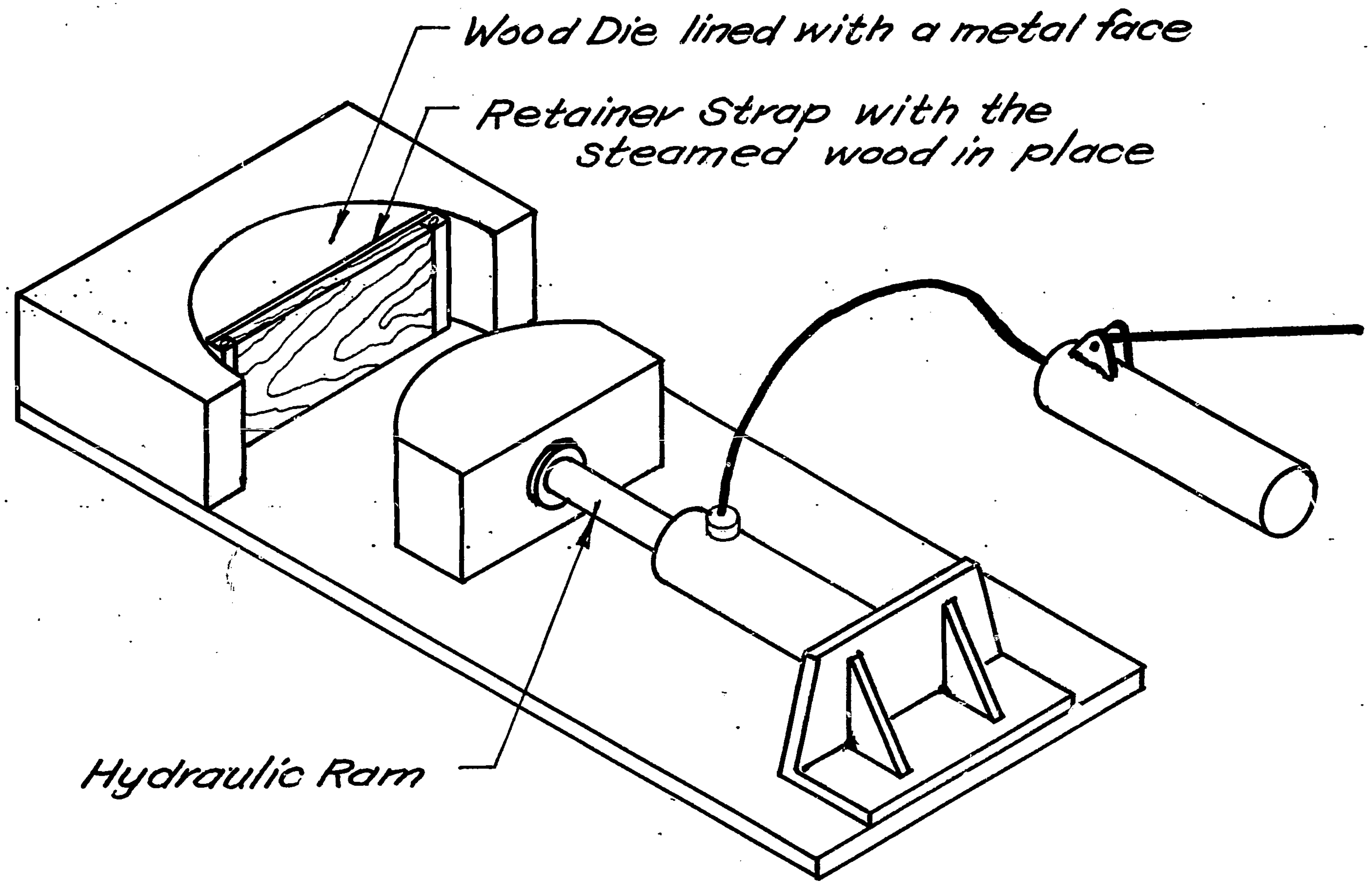
C. Cooling may set the bend long enough to allow removal of the strap within an hour after bending

D. Most bentwood will straighten out somewhat by the absorption of moisture.

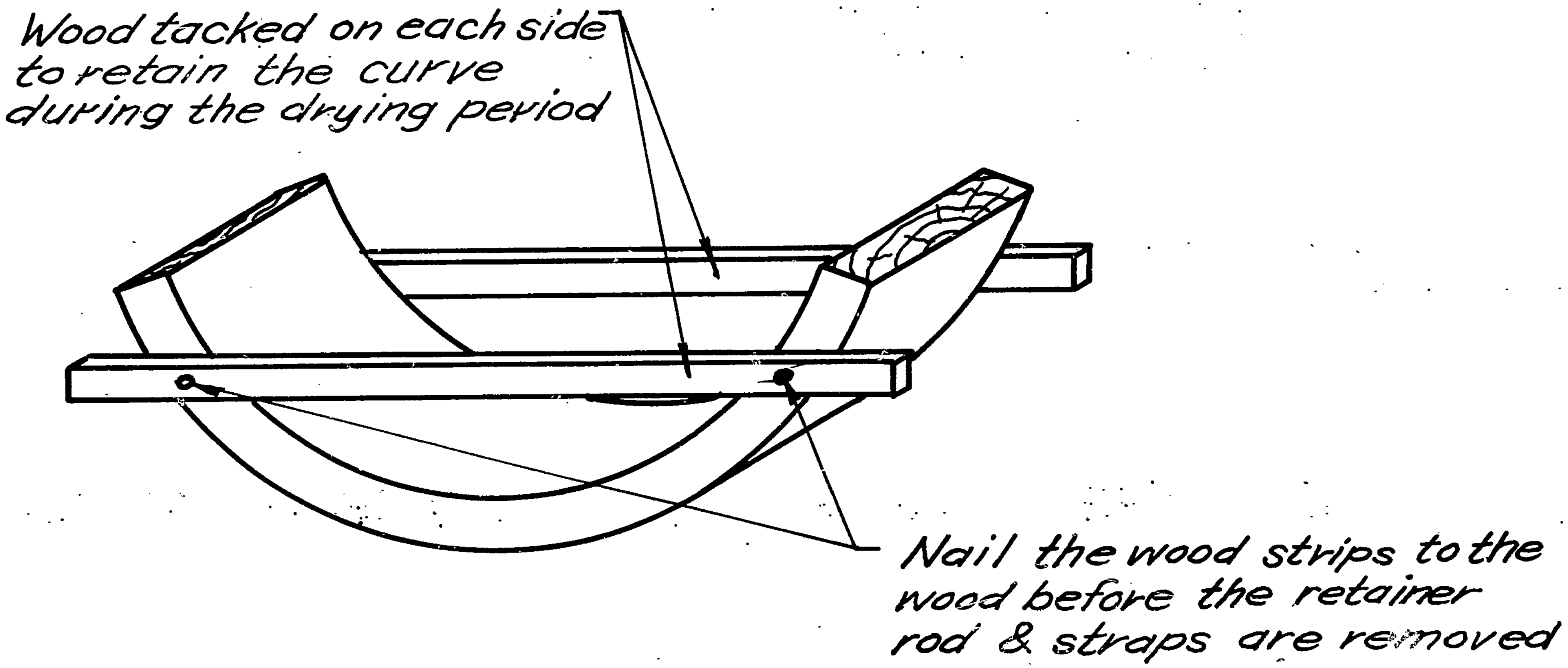
SOLID WOOD BENDING JIG



HOT WATER BENDING JIG



HOLDING METHOD FOR SETTING BENT WOOD



UNIT V

LAMINATION BENDING

Introduction

Lamination bending is a significant part of modern wood production industries. Laminations serve more purposes than any other type of wood bending. Bent lamination applications range from complex arches used in heavy construction to simple salad forks. The purpose of this section is to provide an introduction to the area of wood lamination bending.

I. History of Wood Lamination

A. The wood laminating process was developed in Germany by Hetzer in the early part of this century.

B. Glue laminated arch construction was used in Europe for framing churches, railroad stations, factories, and warehouses for some time before it was introduced in America. In 1934 the Forest Products Laboratory constructed the first building using wood laminates in the United States.

C. Since 1934, laminates have been widely used in the construction of churches, gymnasiums, factories, ships, etc.

D. The development of modern wood adhesives has greatly expanded the use of laminated products.

II. Characteristics of Wood Laminations

A. Parallel-grain or laminated construction refers to two or more layers of wood glued together with the grain of all layers approximately parallel. The laminations may vary as to species, number, size, shape, and thickness.

B. Basically the process of lamination involves the development of a mold, the selection of the wood species and thickness, the selection of the type of glue to be used, providing adequate clamping pressure for the mold and laminates, and providing adequate curing time and facilities for the product being made.

C. Wood laminates may be used where other materials are not suitable because of their strength-weight ratio and adaptability.

D. The Forest Products Laboratory states that the following are the most significant advantages of laminated products over solid lumber.

1. Laminations are essentially unlimited in size.

2. Laminations improve utilization of our timber resources.

3. Laminated products are free from severe checking.

4. Architectural effects not possible with solid wood can be achieved with lamination.

5. Laminations open the possibility of designing constant strength members. It is possible to vary the cross section of the members to fit varying stress requirements at different points.

E. The following are characteristics of woods used in lamination:

1. Hardwoods bend better than softwoods. The following United States hardwoods are listed in order of good bending quality: American elm, white oak, locust, American beech, yellow birch, red oak.

2. Industrial used woods for bending are: white oak, red oak, elm, hickory, ash, cherry, beech, maple, walnut, sweetgum, and mahogany. Mahogany from Central America has moderately good bending quality while African mahogany does not.

3. Only two softwoods, yew and the yellow-cedars, possess good bending qualities.

4. When selecting the wood species for lamination choose woods having the same shrinkage and swelling characteristics to avoid or control stresses in wood when the lamination is subject to moisture changes.

5. Woods that have an excessive amount of cross grain or compression wood should not be used.

6. The principal causes of weakness in laminates are knots, cross grain, and end-joint deficiency.

7. Veneer thickness, moisture content, resin content, rate of compression, and rate of heat penetration have been found to be important in determining the strength of the finished product.

8. Using hard close-grained species will lessen the chance of deformities in the finished lamination. Species such as hard maple and oak absorb less moisture.

F. To what extent does moisture content influence the fabrication of laminated products?

1. Theoretically wood bends best when the moisture content is at fiber-saturation point. Wood this high in moisture is likely to check, split and shrink excessively.

2. Generally most kiln-dried lumber is too dry for good bending.

3. The ideal stock for bending is air-dried stock with a moisture content of 12 to 20 per cent.

4. When glues such as casein or urea resin are used, the water in the glue raises the moisture content in the wood around the glue joint. This added moisture must be considered during both the bending and the curing stages in lamination.

G. What factors determine the amount of curve that may be attained in lamination?

1. The minimum radius to which a dry, clear, straight-grained laminate can be bent without breaking is approximately 40 to 60 times its thickness. This varies with the species.

2. White oak 1/4 inch thick will bend to an 18 inch radius while Douglas-fir or white pine of the same thickness will bend not more than 31 inches.

3. Moisture content of the laminates is an important factor in determining bending radius.

III. Types of Glues Used in Lamination Bending.
(For more information see the unit on wood adhesives)

A. Proper gluing depends largely upon the use of the completed object.

B. At all times the glue used should be as durable as the wood, moisture resistant, and durable to heat. For this reason, thermoplastic glues are not recommended for lamination.

C. The following glues are used in lamination products: casein, urea-resin, phenol-formaldehyde resin, resorcinol-formaldehyde resin, melamine-formaldehyde resin glues, and epoxy glues.

1. Casein glues are not suited for exterior use or where moisture content is high.

2. Urea-resins are suitable for wood laminations where moisture conditions are high, but hot water and high temperature will cause delaminations.

3. Extreme heat is required to cure laminated glue with phenol-formaldehyde resin.

4. Resorcinol-formaldehyde resin glues have moderate temperature curing requirements and high quality and durability characteristics.

5. When using melamine-formaldehyde resin glue clamping must be completed before the glue becomes too tacky to permit free slippage of the lamination.

IV. Types of Molds, Jigs, and Fixtures Used in Lamination Bending.

A. A suitable mold or gluing jig must be obtained to draw the curved assembly into the desired shape and to hold it in that shape under pressure until the glue is set and cured. However if straight laminations are used, they can simply be clamped until the glue is cured.

B. The gluing of curved assemblies may be done on either a male-female mold or on a male-female jig. (See Figure 1).

C. Since pressure is not applied to every square inch of the surfaces when the jig is used, the laminations must be thick enough to maintain equal pressure by the strength of the wood itself. Thicker laminations are sometimes placed on the inside and outside face of the assembly in order to maintain this pressure.

D. When developing jigs and molds to be used for curved assemblies, it is usually advisable to carry the line of the curve well beyond the net length of the finished product.

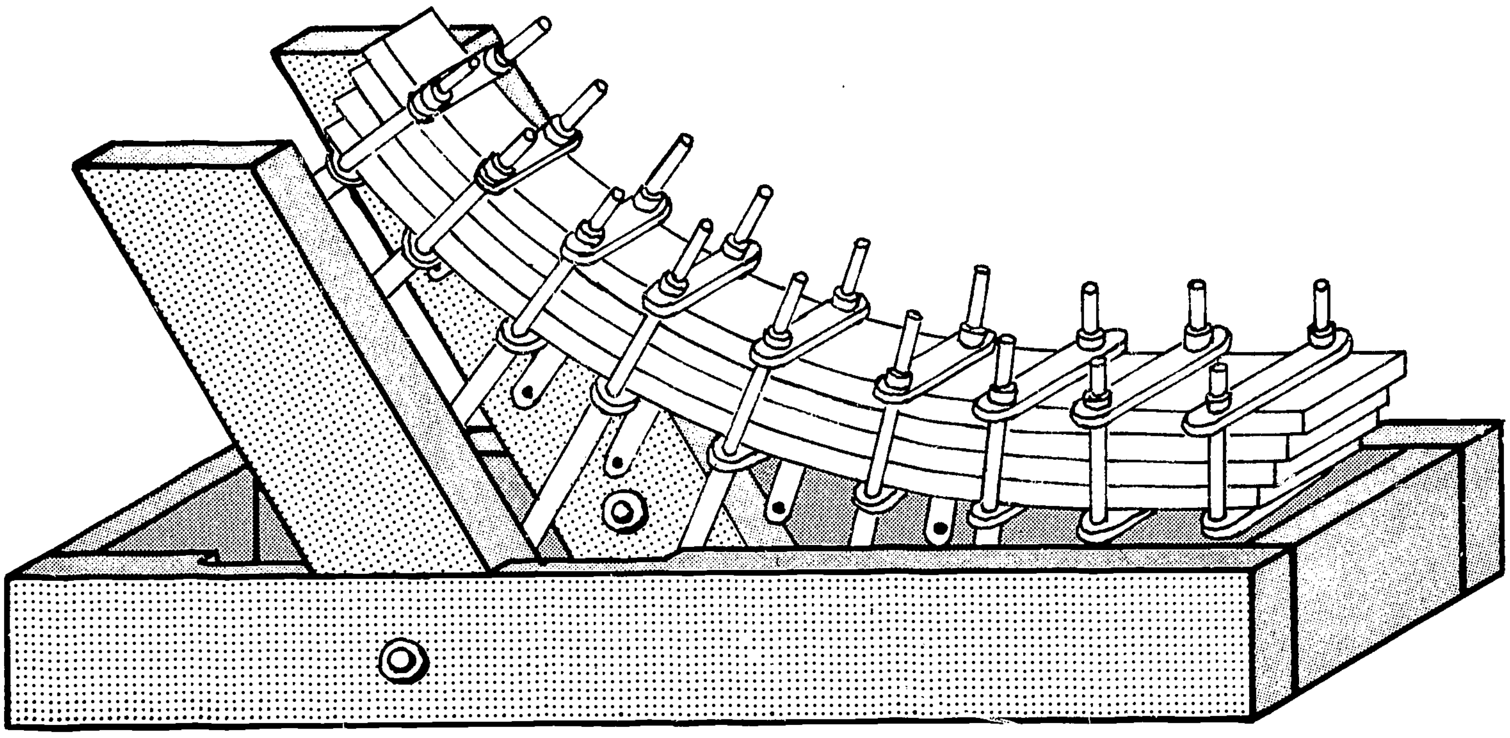
E. If thin laminations are to be used in the assembly, the male-female mold must be developed. Figure 2 illustrates the construction of a male-female mold.

F. A variety of presses and clamps have been developed for exerting pressure on glued laminated assemblies.

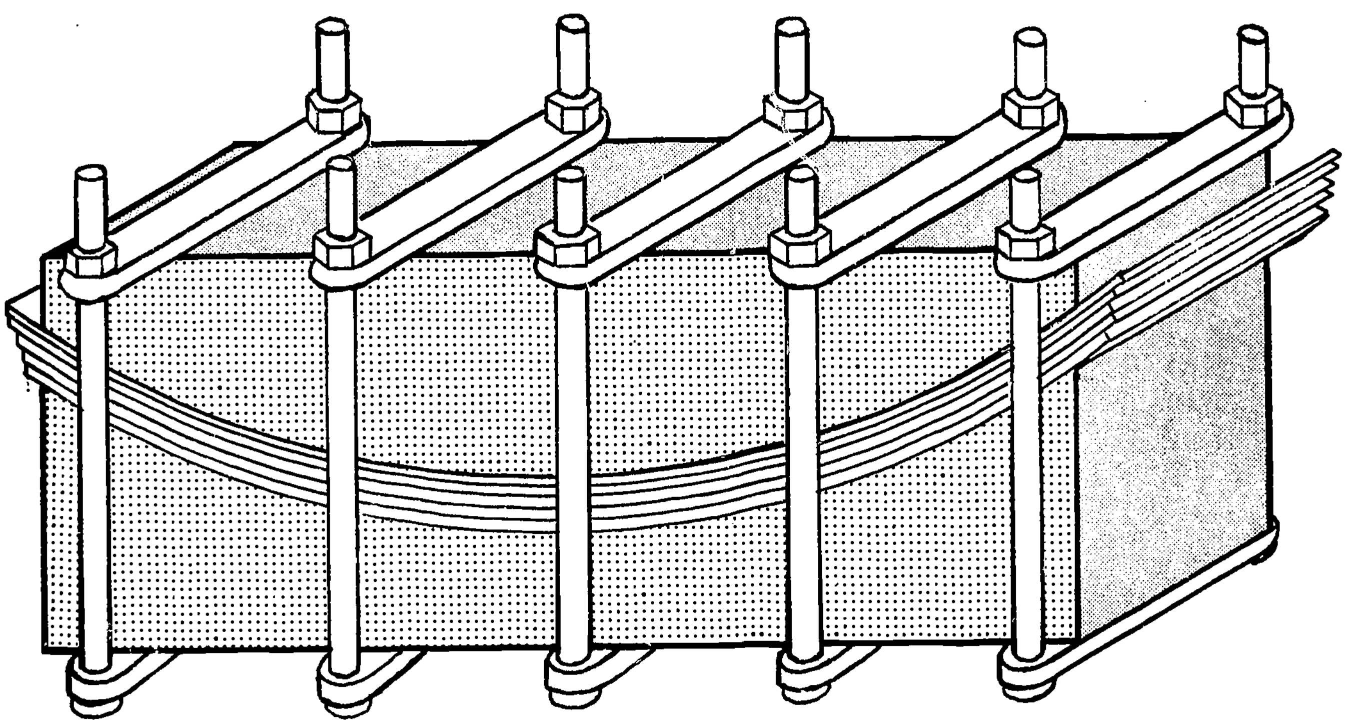
1. Hydraulic and screw presses are used for end-joining and for exerting pressure on male and female molds.

2. A standard "C" clamp, a modification of the carriage clamp, and fasteners using threaded bolts that protrude from the bending jig are also used to hold laminations against the form.

3. Some commercial wood laminators use the fire-hose clamping method. This method utilizes an inflated fire-hose to apply pressure to the glue joints.



CURVED LAMINATED ASSEMBLY IN AN ADJUSTABLE JIG



CURVED LAMINATED ASSEMBLY IN A MALE - FEMALE MOLD

Fig. 1

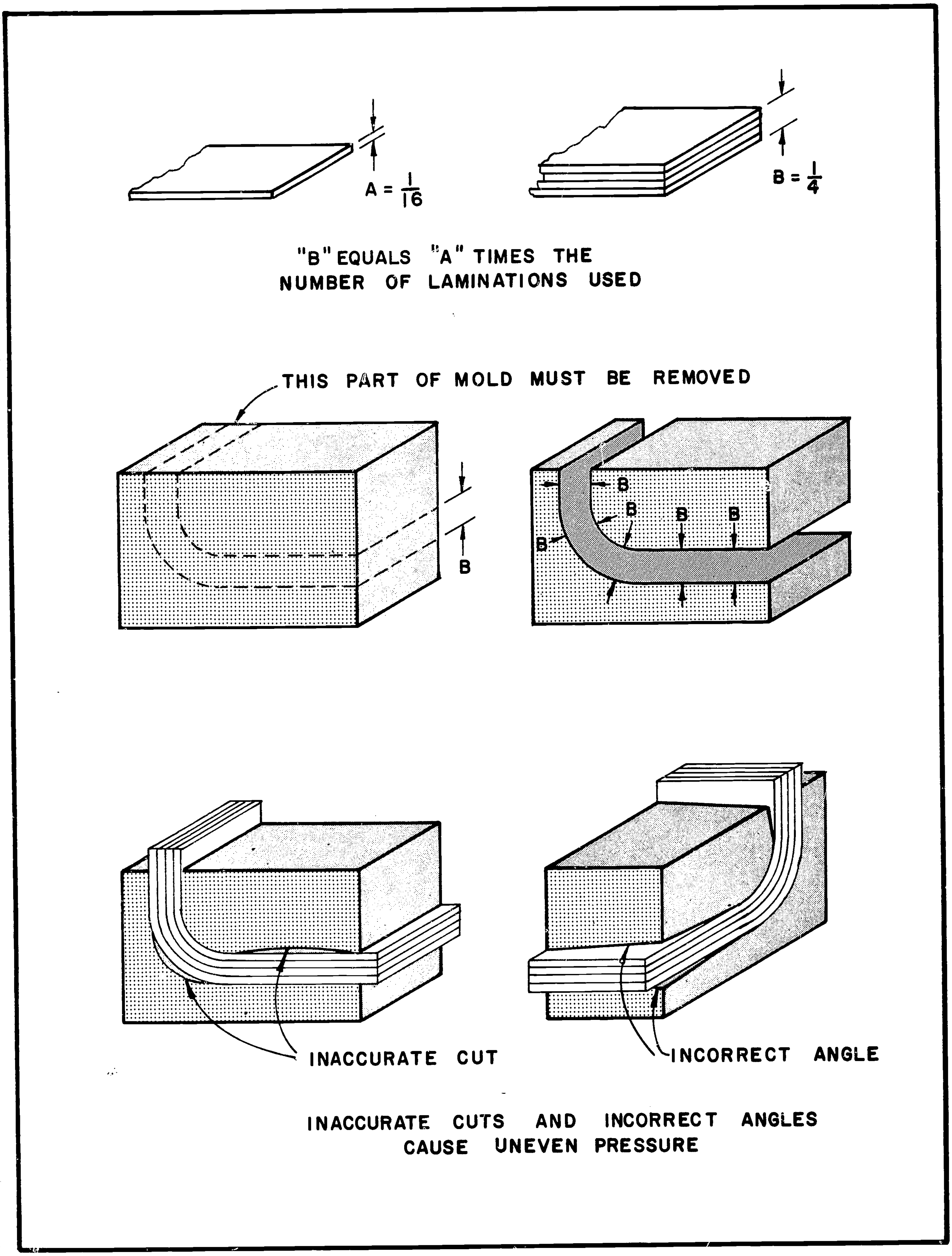

A = 1/16
B = 1/4
"B" EQUALS "A" TIMES THE NUMBER OF LAMINATIONS USED
THIS PART OF MOLD MUST BE REMOVED
B
B
B
B
B
B
INACCURATE CUT
INCORRECT ANGLE
INACCURATE CUTS AND INCORRECT ANGLES CAUSE UNEVEN PRESSURE

Fig. 2

a) The following are some advantages of this clamping system:

   (1) It applies continuous pressure along the laminate.

   (2) It makes it possible to hold any desired pressure on the glue joints during the curing cycle.

V. Steps in Making a Laminated Wood Project. (Project ideas are included in Appendix).

A. The following is a suggested procedure for student constructed lamination projects.

1. Develop the project design and make sketches.

2. Make a full size drawing of the curve for use later in mold development.

3. Select lamination thickness and species of wood. The total thickness of the project is the sum of all laminations. Usually an odd number of veneers (3, 5, 7, etc.) is used.

4. Lay out the curve on the mold blank from the full size drawing.

5. Cut out the mold very carefully.

6. Line the mold with plastic laminate if desired and/or coat the mold surface with paraffin.

7. Select the proper glue and apply it with a brush or roller to each side of all laminations except the two surface laminations. Glue should be applied to only one side of the surface laminations.

8. Place the laminations in the mold and apply even clamping pressure. The mold may be protected from glue by placing wax paper between the veneer assembly and the form surfaces.

9. Allow the lamination to remain under pressure until the glue has cured. The amount of time will vary with glue type and lamination thickness.

10. Remove the project from the mold and trace the outline of the object on the laminated veneers.

11. Cut the project to finished shape on a band saw or jig saw.

12. Sand and apply the finish desired.

UNIT VI

BAG MOLDING OF PLYWOOD

Introduction

Bag molding of plywood and laminated veneer members probably had its origin in the vacuum-bag process that was introduced into the furniture industry several years ago. While the vacuum-bag depended upon atmospheric pressure to form the project, and room temperature to cure the glue, the newer techniques employ considerably higher fluid or air pressure and varying degrees of heat.

Molded plywood is produced by various techniques often referred to as the Duramold, Vidal, Aeromold, or vacuum-bag processes. There are other terms which are used to describe the technique and they are "bag-molding", "autoclave-molding", or "tank-molding." A more inclusive term would be "air or fluid pressure molding."

I. Principles of molding plywood.

   A. Temporarily attach super-imposed layers of strips or sheets of glue-coated veneers to a mold of the desired shape with staples, tape, clips, or by some other means.

   B. Apply heat and pressure through a flexible, impermeable bag or blanket in order to mold the unit structure. (When air pressure is used, heat must be from some other source).

   C. It is recommended that bag-molding be limited to the production of strategic molded parts that cannot be manufactured by any other practical means such as:

      1. A project with appreciable compound curvatures.

      2. A project with a variable thickness.

      3. Projects with single curvature bends approximating or exceeding 180 degrees.

      4. Pieces which are too thick to be bent from flat plywood.

      5. Parts which are too large to be made practicably by mating dies.

      6. When small quantities are needed and therefore mating dies are not justified.

   D. The molded structure must have balanced construction, the same as flat plywood.

1. For maximum resistance to warping, all plywood should be symmetrical about the center plane of thickness.

2. Symmetry in balanced plywood may be maintained in the following ways:

   a) The same species of wood should be used on both sides of the center.

   b) The same number of plies should be used on both sides of the center.

   c) The thickness of the plies should be the same on both sides of the center.

   d) The direction of the grain in the various plies should be the same on both sides of the center.

3. In pieces with pronounced compound curvature it is not always possible to alternate plies at 90 degrees to each other.

E. It is impossible to make flat strips of veneer conform to appreciable compound curvature before the application of fluid pressure; therefore, the greater the compound curvature at right angles to the grain of the strips, the narrower the strips must be to avoid wrinkles.

II. Preparation and conditioning stock before molding.

A. For boat, aircraft building, and other high quality molding heat and pressure are required.

   1. An autoclave or cylindrical pressure tank which will withstand working pressures of 30 to 120 pounds per square inch may be used. Figures A and B.

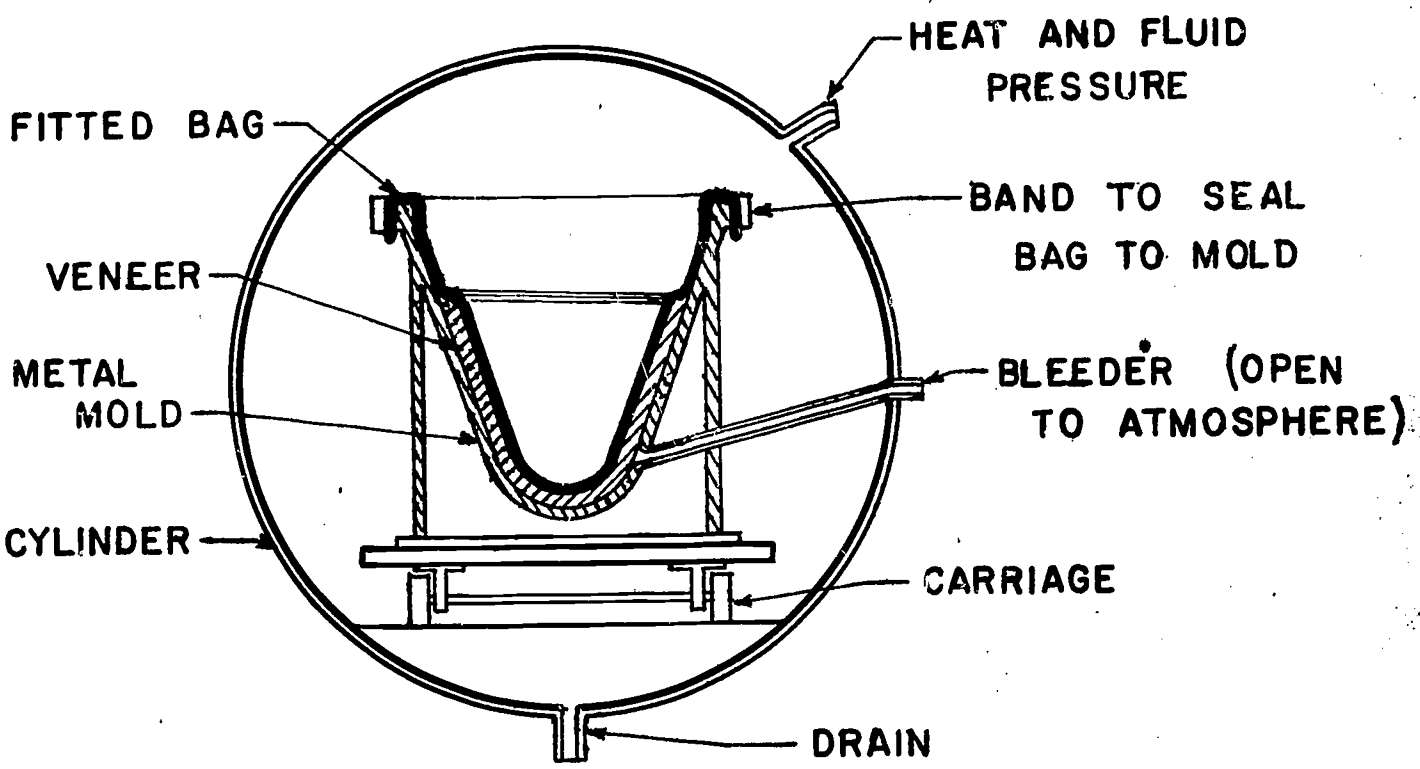


FIGURE A

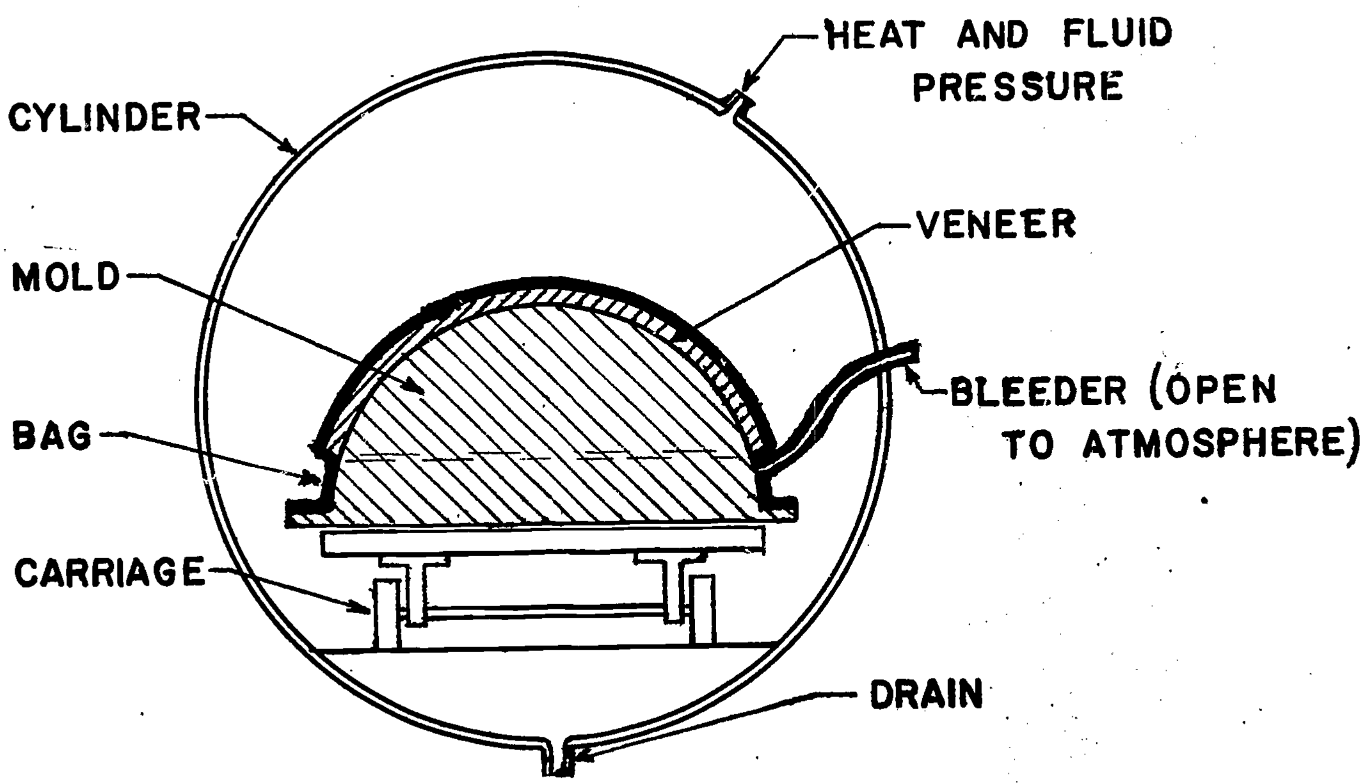


FIGURE B

2. An economical method of supplying heat may be steam which is supplied either directly or indirectly by heating water or air, hence a boiler or an adequate supply of steam from an existing steam line is necessary. Figure C shows a hot water apparatus.

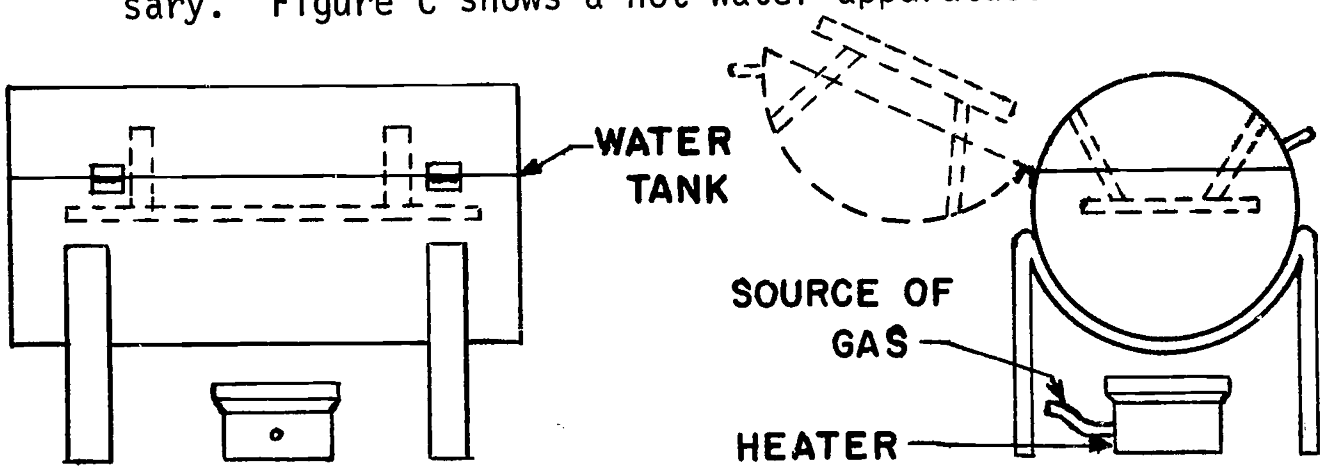


FIGURE C

3. In some bag-molding operations careful control of the moisture of the veneer throughout the process is desirable.

III. Molding Jigs and Fixtures.

A. All plywood formed by the bag-molded process requires a mold of some type, sometimes called forms, dies, or mandrels, which may broadly be classified as male or female.

1. Male molds are normally made of wood and have the obvious advantage of presenting a tacking surface often necessary to temporarily attach strips of veneer. Figures B, D, and E.

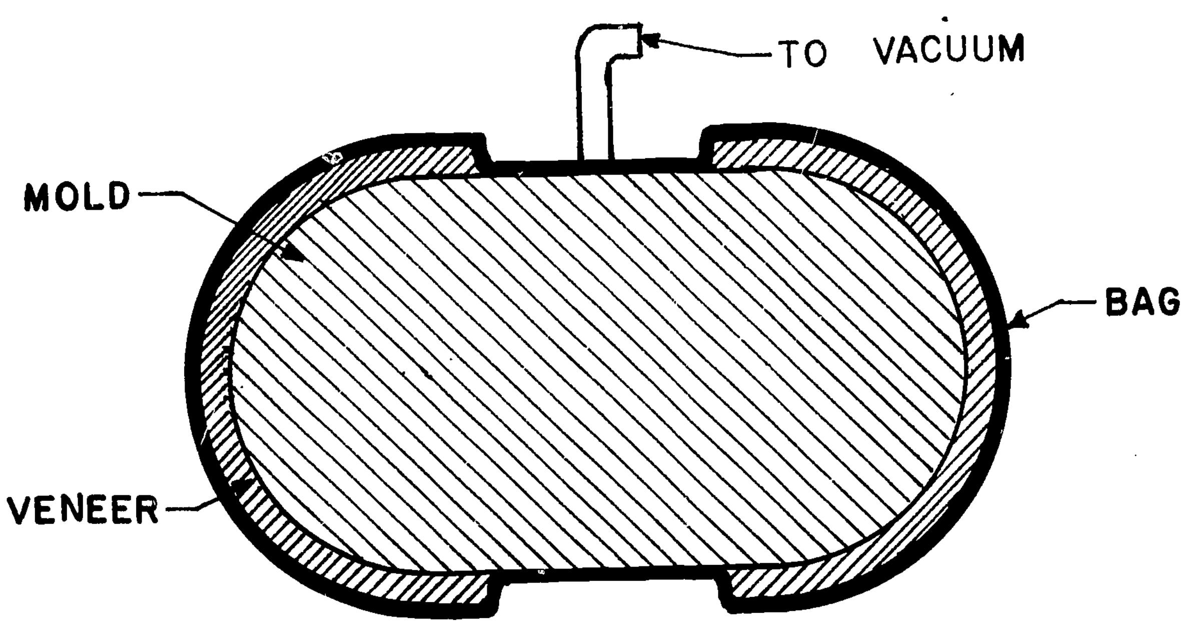


FIGURE D

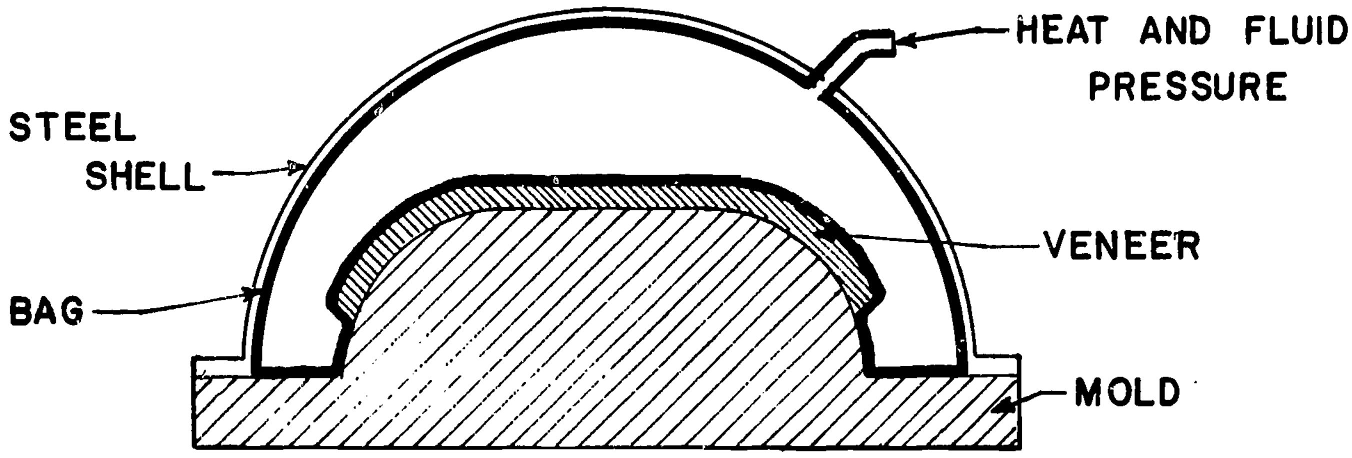


FIGURE E

a) Wood molds are prone to distort somewhat after repeated heating and cooling, particularly if they are allowed to become wet as a result of a leak in the bag.

b) The temperature penetration in wood molds is relatively slow as the mold is usually several inches thick, and the molded plywood must be heated essentially from the bag side.

2. Female molds are usually made of metal, which gives them longer life and greater stability. Figures A and F.

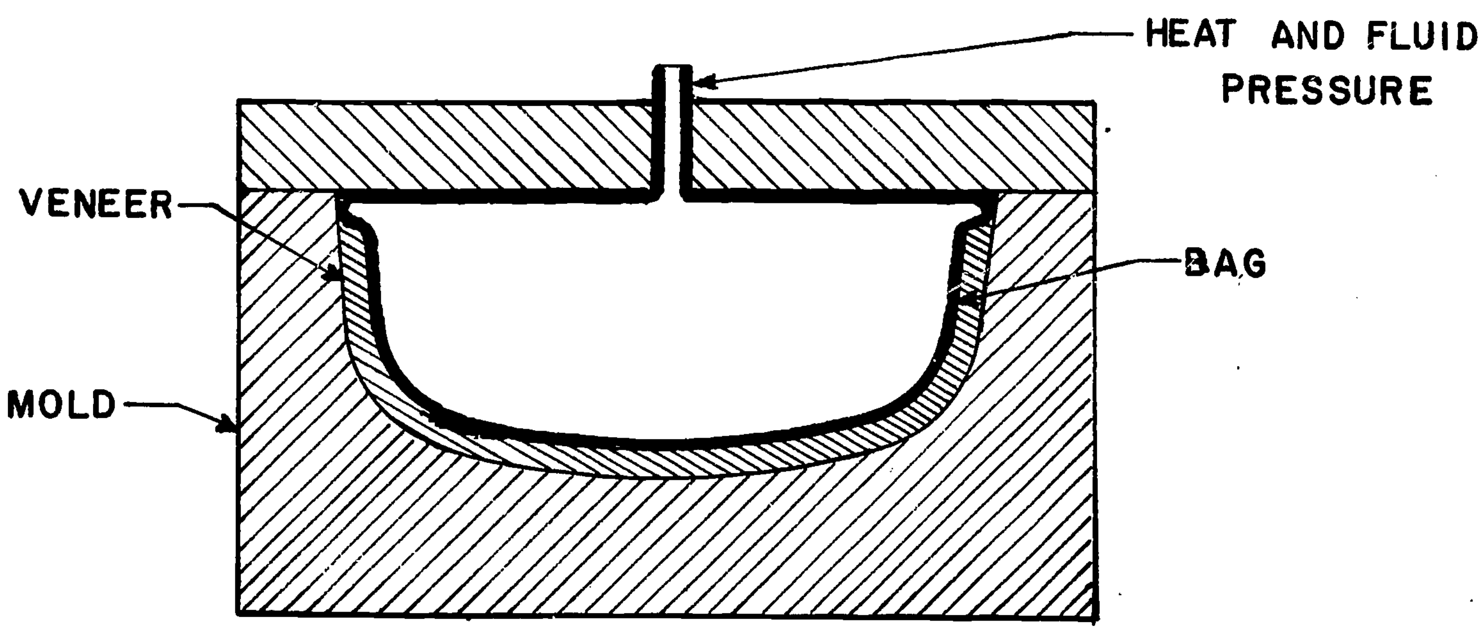


FIGURE F

3. Some attempts have been made to use concrete, cements, and casting resins in mold construction, but to date these materials have proved practicable in relatively few uses.

4. The purpose of the bag is to provide a flexible, impervious barrier between the fluid under pressure and the mold.

   a) Bags are classified as full or half bags (blankets).

      (1) A full bag is a complete envelope of impervious flexible material clamped shut at one end or side and having a connection, usually called a bleeder, to allow the entrapped air to escape to the atmosphere. Refer back to Figures D and F.

      (2) A half bag is a sheet which normally fits the mold without wrinkling and is sealed by some temporary means to the edges of the mold. Refer back to Figure A.

B. A fire hose clamping system may be used to laminate small projects such as salad sets, etc., and large projects such as a bow. Figure G.

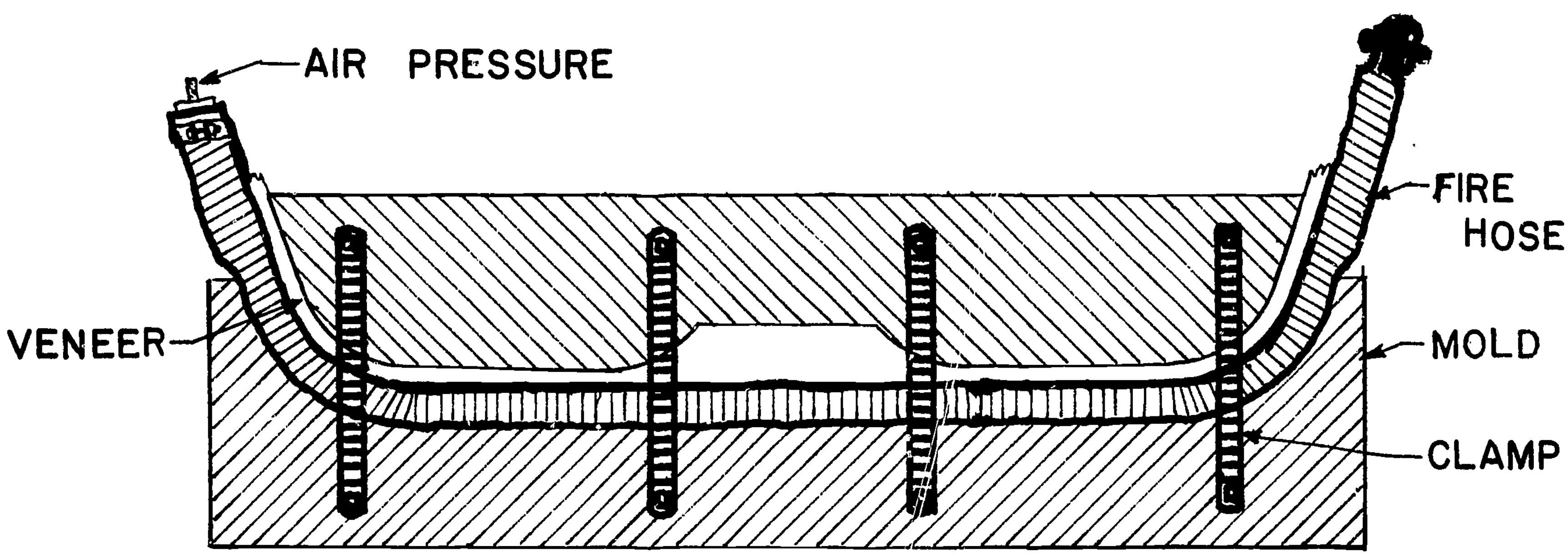


FIGURE G

IV. Glues which are used for bag molding.

A. For commercial operations a hot-setting resin type is generally used, one which is dry at the time the veneer is assembled on the mold.

B. For the school shop, glue should be selected according to the use of the finished project.

1. Resorcinol glue may be used for a waterproof bond.

2. The two common natural glues are hot animal and casein, neither one of which is waterproof.

3. Epoxy may be used in places where wood and plastic are joined or combined.

UNIT VII

ANHYDROUS AMMONIA BENDING

Introduction

Anhydrous ammonia is produced commercially from the synthesis of nitrogen and hydrogen. Under normal conditions of temperature and pressure, it is a colorless gas having a distinctive odor. It is used by farmers to fertilize their fields; thus, it can be found at a farm supply dealer.

When wood is subjected to anhydrous ammonia in either the liquid or gaseous form, a swelling and softening condition results. This condition is due to the breaking down of the hydrogen bonds within the lignin of the cell walls and in the crystalline lattice of the cellulose. This breaking down of the hydrogen bonds enables the micromolecules to move past one another, enabling the wood to be bent without fracture. When anhydrous ammonia evaporates, the hydrogen bonds are permanently re-formed into the new shape.

This process is still in its developmental stages and very dangerous. Consequently, it is not recommended for actual use or demonstration in a junior or senior high school industrial arts shop.

In addition to bending applications, anhydrous ammonia can be used for pressing, stamping, shaving, and fibrilizing of wood and wood products.

I. The gas process.

A. The gas process can be accomplished through the use of a few inexpensive materials and facilities. The three main components necessary for a working apparatus are:

1. A tank of anhydrous ammonia.

2. A small, pressurized treatment chamber.

a) The tank must be constructed of steel, since ammonia will have a corrosive effect in any ferrous metal.

b) The chamber must be constructed to withstand pressures up to 150 p.s.i.

c) There must be an efficient means of opening and closing, with the retention of the pressure seal.

d) The chamber must include a steel valve for both introducing and disposing of the gas.

e) The chamber should include a resettable steel safety valve at 150 p.s.i.

f) The chamber, ideally, should include a pressure and temperature gauge.

3. A method of disposal - a container of water through which the anhydrous ammonia from the chamber is passed.

B. Order of Procedure.

1. Place the anhydrous ammonia tank on a stand with the valve outlet slightly elevated and facing down.

2. Secure the treatment chamber to a stand, and place it at a convenient distance from the ammonia tank.

3. Connect hose between the ammonia tank and the hand valve on the treatment tank.

4. Fasten a length of pipe to the safety valve and submerge the other end in the container of water.

5. Open the treatment chamber and insert the wood samples.

6. Close the treatment chamber half-way and the hand valve.

7. Open the anhydrous ammonia tank valve for a few seconds to flush the air from the treatment chamber, then close the chamber fully to seal.

8. Completely open ammonia tank valve and treat the samples for the specified length of time as shown by the table. (See on separate sheet)

9. At the end of the treatment, securely close:

   a) ammonia tank valve

   b) treatment chamber valve

10. Unfasten hose from the ammonia tank valve and place it in in the container of water.

11. Keeping the hose immersed in the water, open the hand valve on the treatment chamber to release the pressure.

12. Open the treatment chamber and quickly remove the wood samples and bend them to the desired shape; hold or clamp them until retention of the shape occurs.

II. Liquid Process

A. Equipment needed for the soaking process with anhydrous ammonia:

1. Tank of anhydrous ammonia

2. Dry ice

3. Acetone

4. Large container, well-insulated of a suitable material such as glass, iron or steel. (Do not use non-ferrous metals.)

5. Tongs

6. Rubber gloves

7. Gas masks, for all persons working with the process

8. Long Pyrex dish

9. A loose-fitting cover over the container to prevent contamination and direct contact with the air.

10. Strips of wood which must have a moisture content of less than 10% to prevent freezing.

11. A well ventilated room, one with an exhaust fan, or an appropriate area outside.

B. Order of Procedure

1. Prepare strips of wood. (The strips must be no longer than the soaking container, and about 1/8" thick.)

2. Place dry ice and acetone in large container.

3. Set the Pyrex dish in the middle.

4. Run ammonia gas slowly into the Pyrex dish (as the ammonia condenses into a liquid, continue to run enough to perform the process.) Have a gas mask on for this process.

5. The samples of wood should be precooled, then placed into the container of liquid ammonia using tongs or rubber gloves. (The main factor to consider is to maintain the proper temperature of the liquid ammonia. If the liquid is too warm, it will evaporate and if it is too cold, it will freeze.)

6. Remove the strips of wood when they become plasticized and bend them to the desired shape. (The plasticizing time varies with the species of wood used and the thickness of the sample.)

III. Solvents

A. The use of solvents with anhydrous ammonia provides a means of achieving varied conditions.

B. There are two groups of solvents for anhydrous ammonia:

1. Competing: Solvents with acidic or proton donating characters, such as water, alcohols, acids, phenols--not only dilute the ammonia, but also compete for the available ammonia and reduce the ammonia activity still further.

2. Bonding: Groups act only as proton acceptors. They therefore do not compete with the cellulose for ammonia. (See chart)

IV. Safety

A. Anhydrous ammonia fumes are extremely toxic. Individual should have a thorough knowledge of the hazards involved in working with the gas before any attempt is made to use it.

B. The apparatus must be used in a well-ventilated location, preferably outdoors.

C. The body must be protected by wearing long-sleeved cotton clothing and rubber gloves.

D. A well-fitted gas mask should be worn by each person working with the equipment.

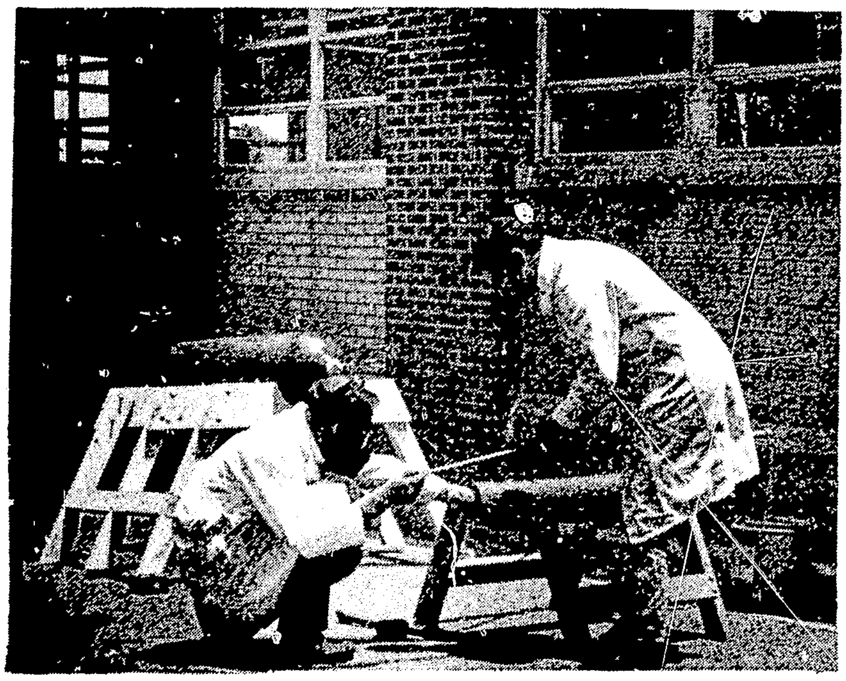
E. A convenient method of disposing of the gas after treatment is by passing it through water, which transforms it into ammonium hydroxide, which is relatively harmless.

F. It is recommended that anyone attempting such experiments should first review the National Safety Council's pamphlet on anhydrous ammonia.

Table

Approximate Plasticizing Time
For the Anhydrous Ammonia Gas Apparatus

Size	Time
1/4" x 2" x 24"	1 1/2 - 2 hours
3/16" x 1" x 24"	30 min. - 1 hour
1/8" x 1" x 24"	20 - 40 min.
less than 1/8"	20 min.

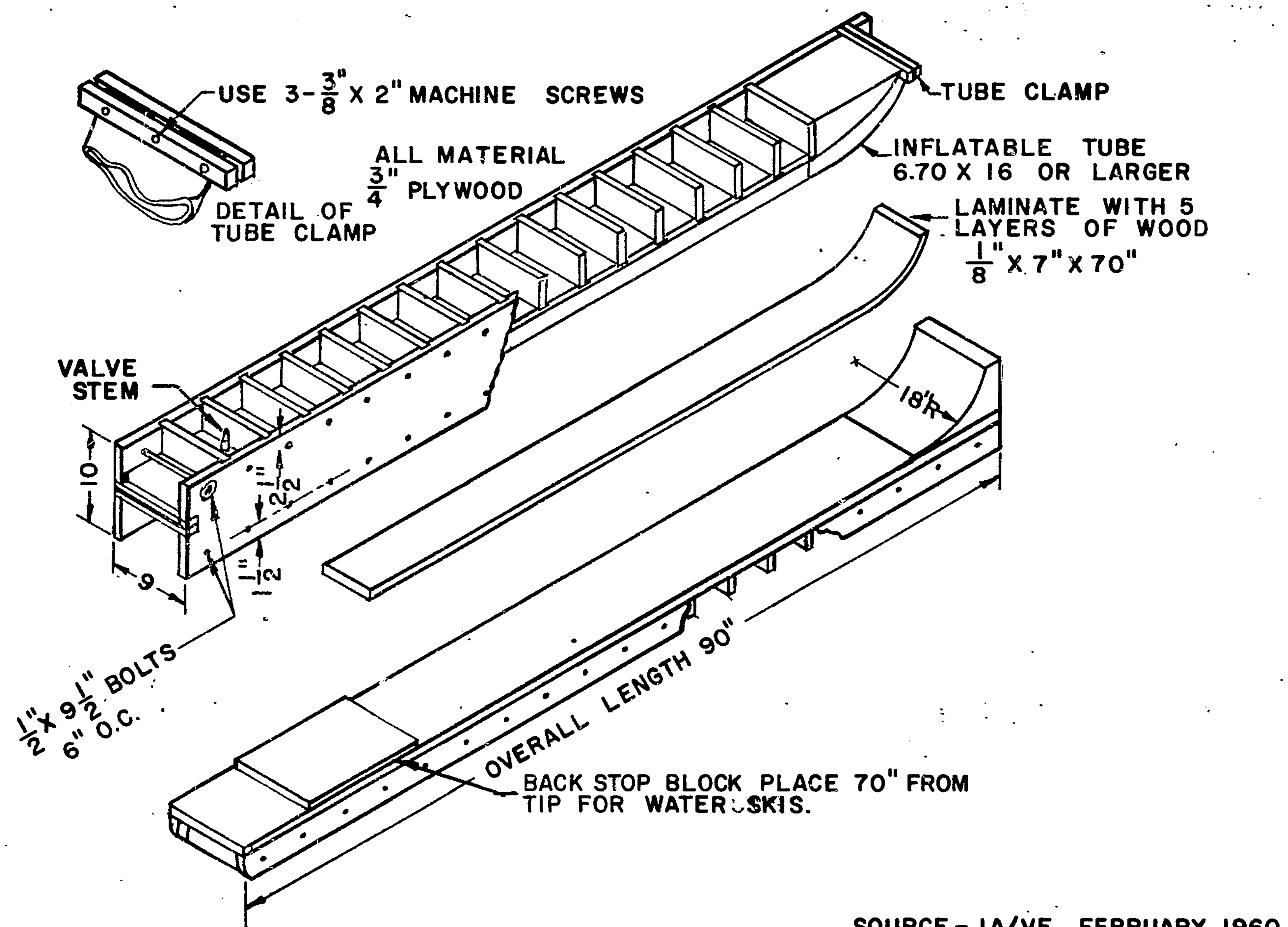


Robert Wilson and Steve Botwick demonstrating set-up of equipment for gas conditioning of wood, prior to bending.

Bob Tate, East Carolina University, demonstrating the bending of wood after it has been conditioned under 150 psi of anhydrous ammonia.

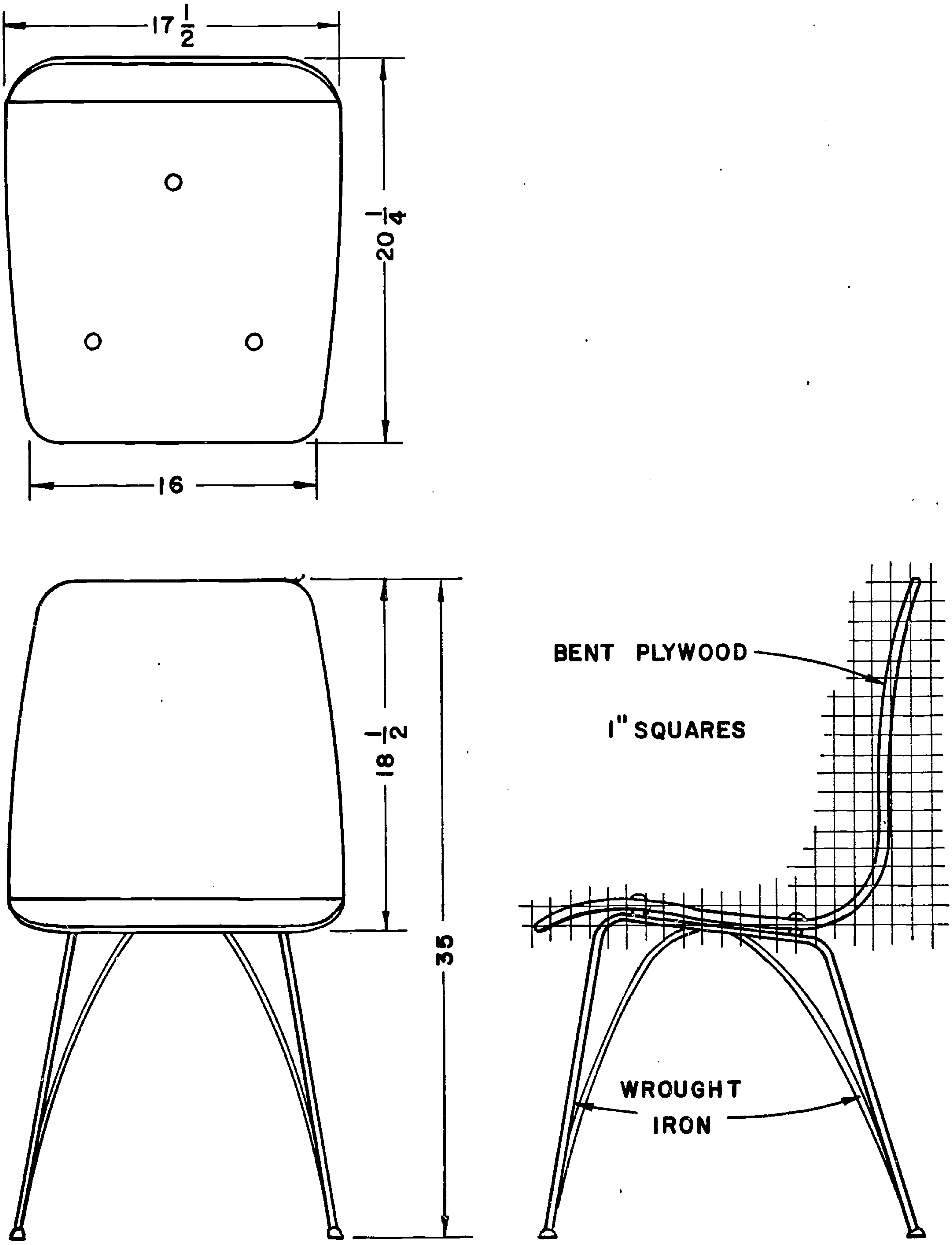
ANHYDROUS AMMONIA SOLVENTS

Solvent	Characteristics	Uses
Dimethylsulfoxide	Contributing factor prevents checking less ammonia need assist softening	Industrial cleaners, pesticides, paint stripping and hydraulic fluids
Carbowax 400	Less ammonia needed inhibits shrinkage	Lubricants, bases for cosmetics
Tetrohydrofuran	Less ammonia needed inhibits shrinkage	Topcoating solutions, solvent for synthetic resins
Ethanolamine	Unknown	Non-ionic detergents and in dry-cleaning, polishes, paints
Lauryl Alcohol	Unknown	Rubber, textiles, synthetic detergents
Glycerol	Unknown	Explosives, cosmetics, foodstuffs



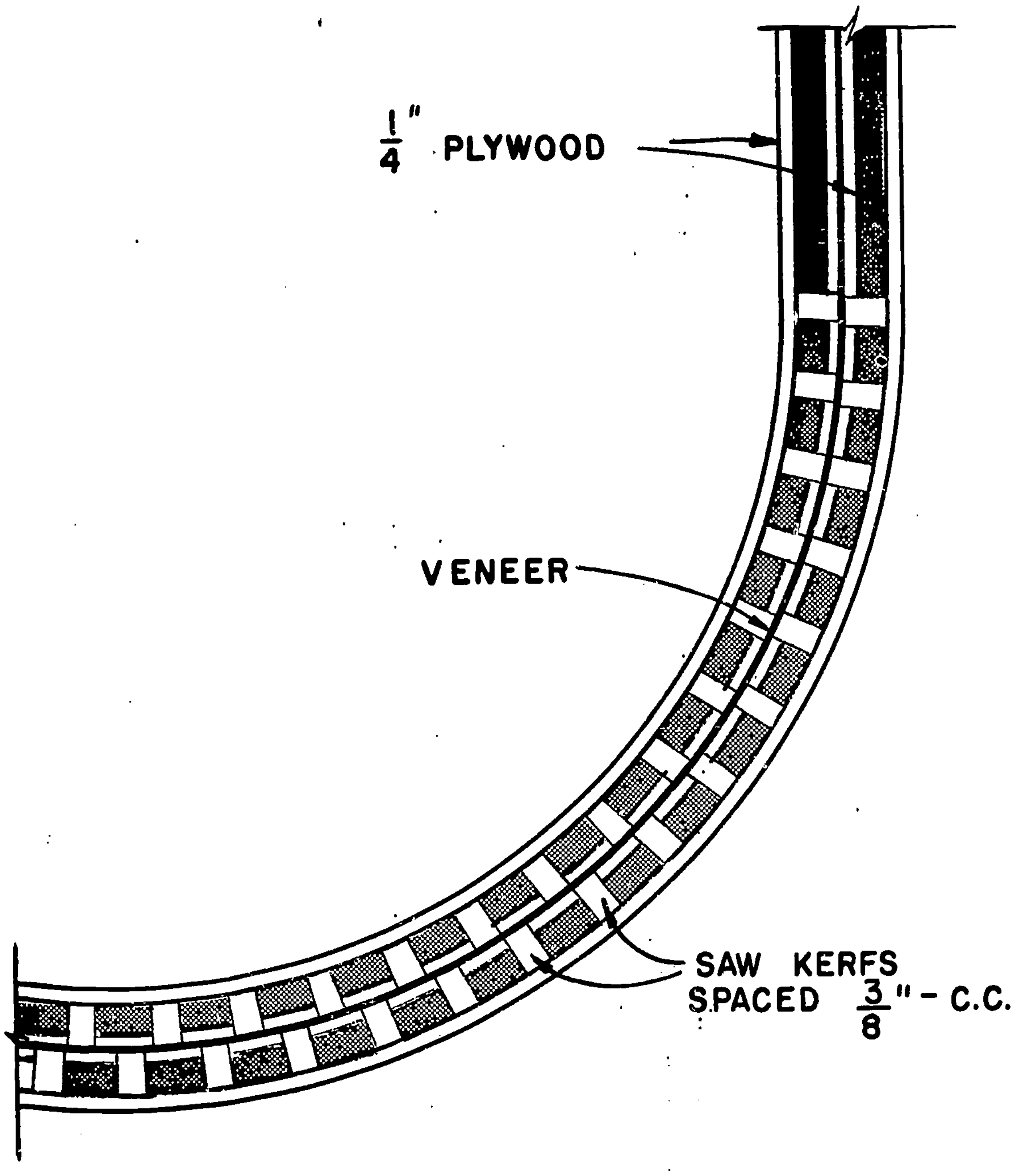
SOURCE - IA/VE, FEBRUARY, 1960

<u>PNEUMATIC</u> <u>CLAMPING</u> <u>DEVICE</u> <u>FOR</u> <u>LAMINATED</u> <u>WATER</u> <u>SKIS</u>

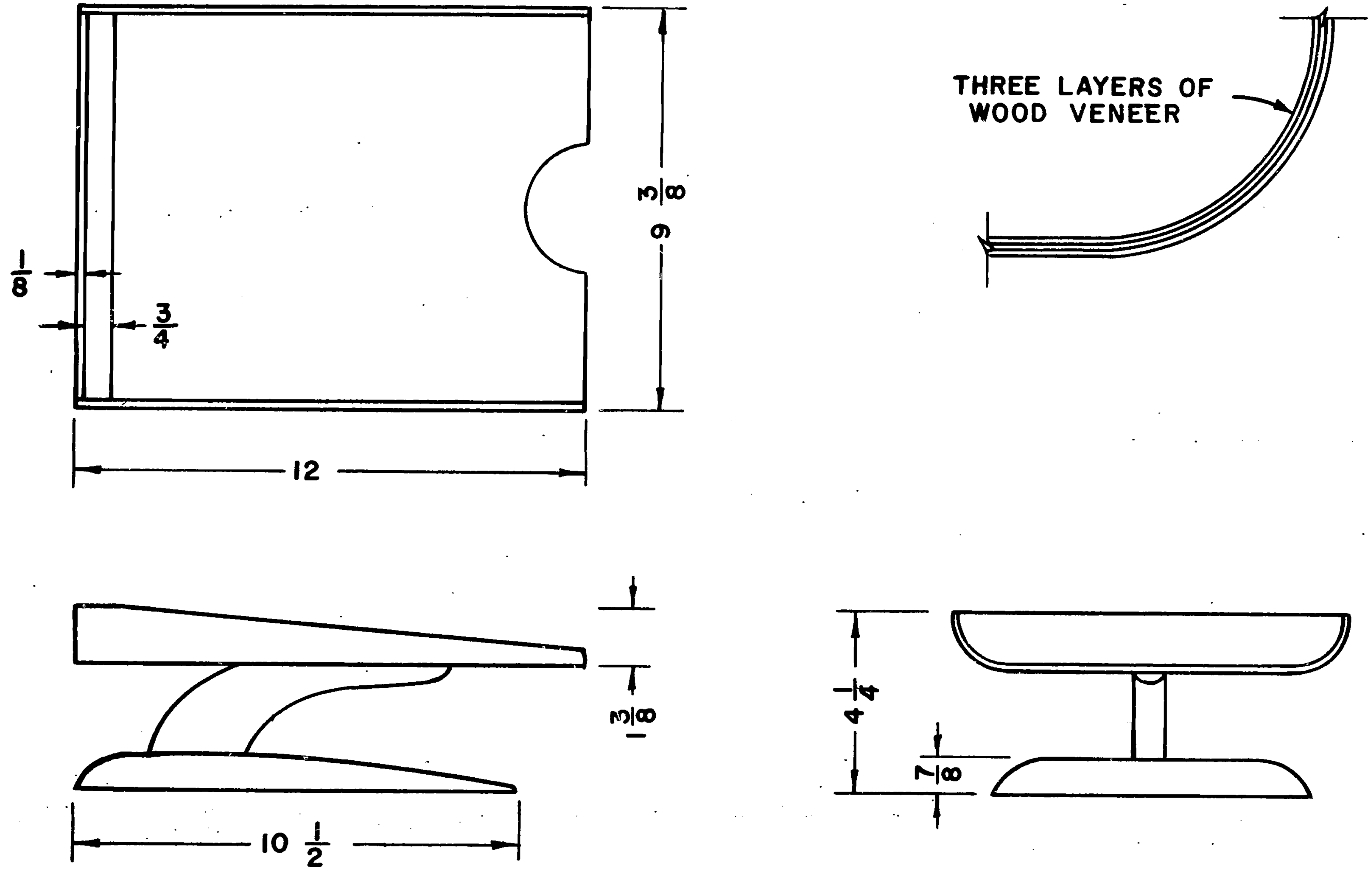


DESK CHAIR

SCALE - 1/8" = 1"

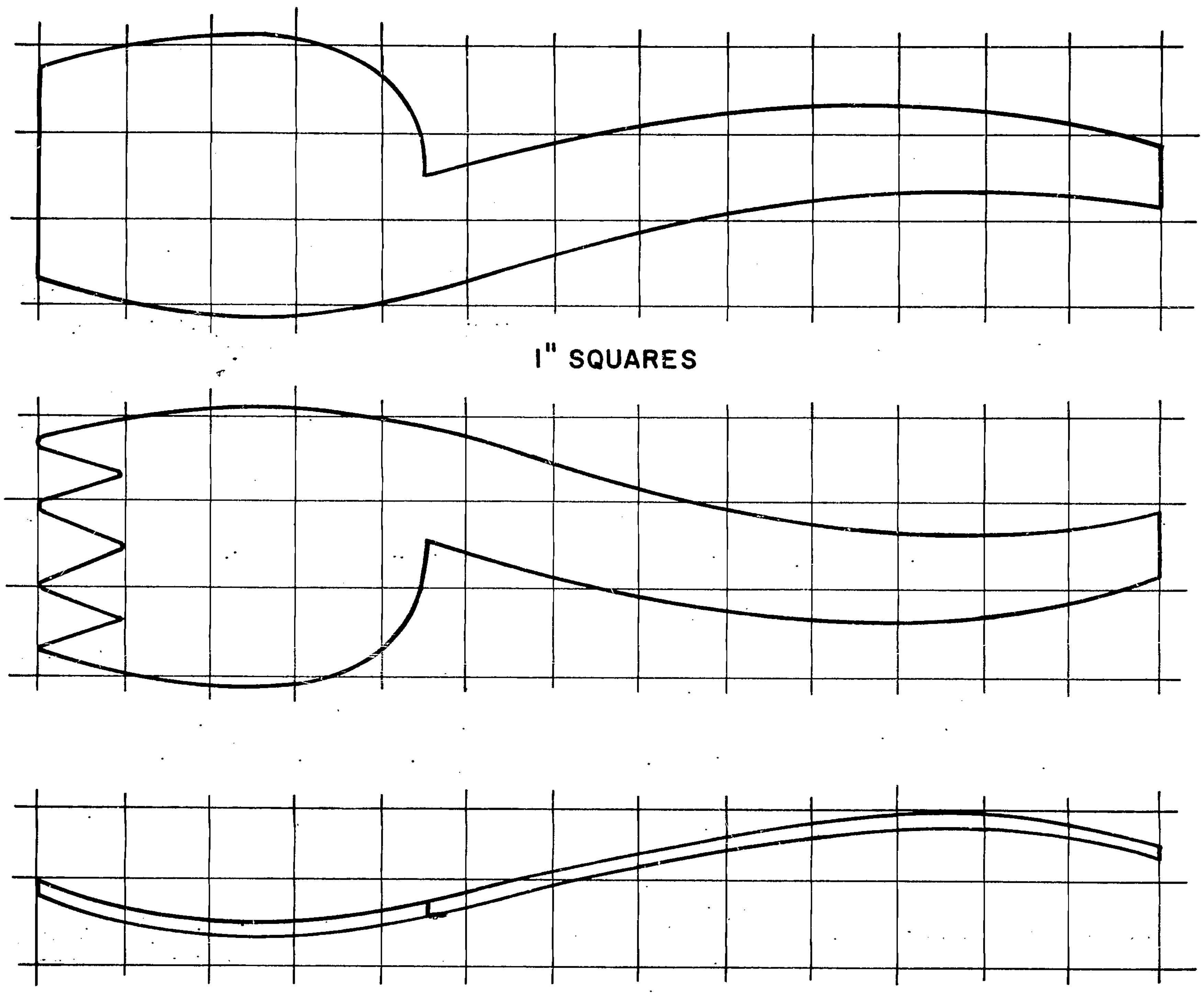


SECTION OF THE CRITICAL BEND IN DESK CHAIR



LAMINATED DESK TRAY

SCALE - 1/4" = 1"


1" SQUARES
SALAD SET
SCALE– 1/2" = 1"

FILMS AND FILMSTRIPS

American Institute of Timber Construction
1700 K. St. N.W., Washington, D.C. 20006
"The Wood That Could"
"Modern Timber Construction"

Koppers Company, Inc.
Koppers Building, Pittsburg, Pa. 15219
"Laminated Beams Idea Kit"

Southern Pine Association
Box 52468, New Orleans 50, La.
"The Lasting Gift" "Glued Laminated Wood Arches"

National Lumber Mfg. Association
1619 Massachusetts Ave., N.W., Washington, D.C. 20036
"Blueprint for Better Schools"
"Comparative Fire Test on Timber and Steel Beams"

Timber Structures, Inc.
P.O. Box 3782, Portland, Oregon 97208
"Buildings for Tomorrow"

Pettibone-Muliken Corporation
4700 W. Division St., Chicago 51, Illinois
"The Enchanted Forest"

U.S. Department of Agriculture
Motion Picture Service, Washington, D.C. 20250
"A Piece of Wood"

Indiana University
Audio-Visual Center, Bloomington, Indiana 47405
"The Woodworker"

Stephen F. Austin State College
Department of Forestry, Nacagdoches, Texas
Bulletin 7 lists film and filmstrip on Forestry

GLOSSARY

Adhesive: A substance capable of holding materials together by bonding of contact surfaces.

Adhesives, dry-use: Adhesives which perform satisfactorily when the moisture content of the wood does not exceed 16% for repeated or prolonged periods of service.

Adhesives, wet-use: Adhesives which perform satisfactorily for all conditions of service including exposure to weather, dry use, marine use, and pressure treatment.

Ambient: Surrounding or encompassing.

Assembly: The process of fastening together, by means of hand or portable tools, fabricated components of structural timber framing with nails, bolts, connectors, and/or other fastening devices to form larger components or subassemblies of a structural frame.

Assembly Time: The time interval between the spreading of the adhesive on the laminations and the application of final pressure or heat or both to the entire assembly. Assembly time is composed of two parts, open and closed.

1. Open Assembly Time: The time elapsed between spreading the adhesive and assembling the spread surfaces into close contact with one another.

2. Closed Assembly Time: The time elapsed from the assembly of the first laminations of the package into intimate contact until final application of pressure or heat or both to the entire package.

Batch: A term generally used by adhesive manufacturers to identify a "lot" of adhesive.

Board: Lumber less than 2 in. thick and 1 or more inches wide.

Bonding: Joining materials together with adhesive.

Bracing: Structural elements installed to provide restraint, support, or both to other members to enable them to function so that the complete assembly will form a stable structure.

Break: A fracture of the wood fibers across the grain caused by external forces.

Buyer: The purchaser.

Check: A separation of the wood grain due to internal stresses caused by severe moisture cycling or seasoning.

Clamp: A device for application of uniform pressure on a laminating package.

Curing Time: The period of time which an adhesive takes to attain its full strength.

Delamination: The separation of layers in an assembly because of failure of the adhesive.

Depth: The dimension of the cross section which is measured parallel to the direction of the principal load on the member in bending.

Fabricated Structural Timber: Engineered load-carrying elements of wood (including sawn lumber and/or timber, glued laminated timber, and mechanically laminated timber) which are shop-fabricated for use in frames of all kinds including but not limited to trusses, arches, beams, girders, and columns for use in schools, churches, commercial, industrial, and other buildings and for other structures such as bridges, towers, and marine installations.

Gluing: The operation of edge, face, or end joining together of pieces or laminations with adhesives.

Hot Service: Normal use conditions in which the wood members may remain at temperatures of 150° F or above, continuously or for prolonged periods of time.

Joint,Area: The area of the glue line, usually expressed in square feet of glue spread to 1,000 feet square of joint area.

Joint, Bolted: A joint in which bolts transmit load and hold members in position. Includes wood-to-wood and wood-to-steel assemblies.

Joint, Edge: A side joint in laminations formed by the use of two or more widths of lumber to make up the full width of a lamination.

Joint, End: A joint formed by joining pieces of lumber end to end with adhesives.

Joint, Finger: An end joint made up of several meshing tongues or fingers of wood. Fingers are sloped and may be cut parallel to the wide faces or to edge faces of laminations or other single members.

Joint, Scarf: An end joint formed by joining with adhesive the ends of two pieces of lumber, which have been tapered to form sloping plane surfaces.

Laminating: The process of bonding laminations together with adhesive. The operations to which it applies include preparation of laminations, preparation and spreading of adhesives, assembly of laminations in packages, application of pressure, and curing.

Lamination: A wood layer contained in a member comprised of two or more layers bonded together with adhesive or fastened together with mechanical fastenings. It is considered to extend the full width and the full length of the member. It may be composed of one or several wood pieces in width or length but only one in depth. Wood pieces may or may not be end- or edge-glued.

Laminator: A company which performs laminating operations.

Piece Mark: A mark placed on an individual piece of timber framing to designate its location in the assembly as indicated in the shop drawings.

Plasticizing: A treatment to soften wood sufficiently so that it will bend easily.

Relative Humidity: Ratio of actual pressure of existing water vapor to maximum possible pressure of water vapor in the atmosphere at the same temperature, expressed as a percentage.

Split: A separation of the wood fiber caused by external forces.

Spread: The quantity of adhesive per unit joint area applied to a lamination. It is preferably expressed in pounds of liquid or solid adhesive per thousand square feet of joint area.

Spread, Double: The application of adhesive to both surfaces of a joint.

Spread, Single: The application of adhesive to only one surface of a joint.

Squeezeout: The adhesive extruded from glue lines when pressure is applied.

Submerged Service: Normal use conditions in which timbers in service will be continually submerged in water.

v

Wet Use: Normal use conditions where the moisture content of the wood in service exceeds 16%, as it may in exterior construction.

Width: The dimension of the cross section which is measured normal to the direction of the principal load on the member in bending.

Wood Failure: The rupturing of wood fibers expressed as the percentage of the total area involved that shows such failure.

Working Life: (pot life): The period of time during which an adhesive, after mixing with catalyst, solvent, or other compounding ingredients, remains suitable for use.

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I. Instructional Aid - "Mini-jig" clamping device

A. Function

1. Introductory aid - wood bending and lamination

2. Facilitates teaching of broad concepts

B. Advantages

1. Efficient use of time and material

2. Readily available

3. Easily manipulated

C. Description

1. 3/4" x 2 1/2" x 8 1/2" piece of hardwood (cherry works well).

2. Profile is centered and cut with the bandsaw.

3. The two parts are joined at each end with 3/16" x 3 1/2" carriage bolts centered 1" from ends.

4. Use of wing nuts make the unit entirely self-contained, requires no tools for manipulation - washers used with wing nuts distribute pressure and prevent excessive wear.

5. A demonstration is readily set up with the jig, a number of 1/16" x 3/4" x 6" veneers and a small bottle of glue.

6. A sealer should be applied to the jig - cooking wax rubbed in the bending area or wax paper placed between the laminate and the jig will facilitate removal of the laminated unit.

7. Drawer pulls could be fashioned from the lamination - may easily be finished with 2/0 and 4/0 garnet paper.

II. Suggested studies for laboratory work and related information

A. Bending characteristics of different kinds of wood

1. Tangential cut
2. Radial cut
3. Kiln or air dried
4. Veneers or solid stock
5. Macro-identification of kind - structural comparisons
6. Techniques for conditioning

B. Properties of different kinds of glue

1. Natural - synthetic
2. Source - drying time - pressure required - color
3. Glue line - strength - moisture resistance - curing
4. Choice of proper glue for a given purpose

C. Clamping devices

1. School laboratory devices
2. Industrial devices - hydraulic - air pressure
3. Custom designed jigs
4. Innovations

D. Trim and dress techniques

1. Cutting tools and machines
2. Smoothing tools and machines
3. Sanders - abrasives used - grades - source
4. Carriages - handling of large units - safety

E. Laminating industry

1. Furniture - structural
2. Design - selection of material
3. Job analysis
4. Production - shipping - utilization
5. Comparison with other products
6. Employment opportunities
7. Educational requirements
8. Outlook for the future