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AN APPROACH TO THE SOLUTION OF TWO INDUSTRIAL PROBLEMS

A Dissertation Submitted In Partial Fulfillment To The School Of Forestry and Conservation In Candidacy For The Degree of Master Of Wood Technology.

BY

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FOREWORD AND ACKNOWLEDGMENTS

The research presented in this thesis was conducted at the Wood Utilization Laboratory of The School of Forestry & Conservation of the University of Michigan. The laboratory work was carried out under the supervision of Mr. Louis A. Patronsky, Instructor in Wood Technology.

The author intends to show how industrial problems and the approach to their subsequent solutions might take place in a research laboratory of any typical wood fabricating plant.

The author is indebted to Mr. L. A. Patronsky for his interest and suggestive criticisms. Special thanks is hereby extended to other members of the laboratory staff for their cooperation and helpful information.

INTRODUCTION

The first part of this investigation was undertaken as the result of a discussion with representatives of the Michigan State Department of Health. In the extensive research indulged in by the Department in obtaining further information on the subject of Virus Diseases, there arose the problem of obtaining a centrifuge capable of extremely high speeds necessary to isolate specific viruses.

In use at the time was an ultra-centrifuge whose speed was far too low to properly separate the viruses. The Department had tried a Magnesium alloy casting, Dural and Alloy Steel. All these were incapable of allowing speeds over 40,000 r.p.m. The Department had visions of a centrifuge capable of running at speeds from 60,000 - 100,000 r.p.m. With the former materials for the centrifuge casting, as the speed approached 40,000 and somewhat higher, the centrifugal force exerted on the outer areas of the casting became so great that stress cracks occurred.

After trying the three castings of Magnesium alloy, Dural, and Alloy Steel, with the same apparent undesirable results, the Michigan State Department of Health representatives brought the problem to the Wood Technology laboratory at the University of Michigan, School of Forestry & Conservation.

The discussion centered around the possibility of using a wood rotor in the centrifuge. All concerned fully realized the high tensile strength exerted by wood in relation to its density.

The problem centered around finding a suitable material with a high tensile strength and a low density. This ratio of Tensile Strength over Density became the important equation.

Wood is relatively high in the classification of Tensile Strength (p.s.i.) of the various materials in use today.

	Tensile Strength P.S.I.
Alloy Steel	189,000
K. Monel	185,000
Structural Steel	85,000
Dural	55,000
Polyamide (Nylon)	50,000
Aluminum die cast	29,000
Aluminum	22,000
Wood	16,000
Plywood	9,600
Fiber-Glass	54,720

With the above in mind it seemed that "Compreg" might possibly be the much sought after material.

According to Forest Products Laboratory Bulletin R-1268 "Resin Treated, Laminated Compressed Wood", a few samples of parallel laminated resin-treated compressed Spruce with a specific gravity of 1.30 gave maximum tensile parallel to the grain of over 40,000 p.s.i. and modulus of elasticity values ranging from 4,000,000 to 5,000,000 p.s.i. (1) (2)

As the specific gravity of Compreg is increased, the tensile strength and the modulus of elasticity are increased.

An example of this is found in an American Society of Mechanical Engineers paper entitled "Resin-Impregnation of Wood" by Ralph Casselman (2). The following is the data reported in the paper (3).

Specific Gravity	Tensile Strength	Mod. of Elast.
1.1	28,000 p.s.i.	3,350,000 p.s.i.
1.2	30,000 "	3,500,000 "
1.3	32,000 "	3,700,000 "
1.4	34,000 "	3,850,000 "

It seems from Mr. Casselman's article that an increase of 0.1 in the specific gravity of the panel of Compreg gives a corresponding increase of 2,000 p.s.i. in the tensile strength and about 150,000 p.s.i. increase in the modulus of elasticity. This may erroneously indicate that the problem could be solved quite easily. Merely increase the specific gravity to a point where the ratio becomes satisfactory. However, this cannot be accomplished because the specific gravity of dry wood sub-

(1) Literature cited in bibliography

stance is about 1.46. This means that theoretically there is absolutely no air space whatsoever. The cell walls are completely compressed. The specific gravity of the phenol-formaldehyde resin is about 1.28. From this information it is evident that a specific gravity of much over 1.40 is impossible.

One of the possible advantages in using Compreg that could possibly enter into the solution is the fact that the density of the Compreg could be varied. Where the greatest stresses occurred, the specific gravity could be increased (4).

The methods involved in arriving at a solution to the problem were numerous. It seemed very feasible to try parallel laminations of the veneers first. The procedure to use parallel laminations was very logical because wood is strongest in the direction parallel to the grain. After laying up these parallel laminations the procedure was to alternate the grain of adjacent layers 5°, 10°, and 15° prior to compressing in the hot press. The desirability of offsetting the grain at the various angles would redistribute the stresses over a greater area and therefore result in a higher tensile strength.

Three panels were to be made. The first was to have the grain of each succeeding ply of veneer offset 5° from the previous sheet of veneer. The second panel was to be built up similarly, only the grain of each succedding ply of veneer was to be offset at a 10° angle. The third panel was to be built up in similar fashion with alternating grain deviating at a 15° angle.

These panels were to be cut up into test specimens for a standard tensile strength test. The data from these tests on the various specimens was to be used in determining which method of the three used in laying up gave the highest ratio of tensile strength to density value.

For each of the panels to be made for the tests, the pressure to form the Compreg was also to be varied. For each layup of parallel laminations, 5° grain deviation, 10° grain deviation, and 15° grain deviation, there was to be made a panel under the following pressures: 800 p.s.i., 1000 p.s.i., and 1500 p.s.i. Since the high speed of the rotor would necessitate a material having a high value for toughness, the increased pressure would impart greater toughness qualities. These pressures were to be used because any increase in pressure makes the resulting panel have a higher specific gravity value (L). Also, under these varying pressures the optimum ratio of tensile strength to density might be found.

To summarize the general procedure, the final panels were to be composed of the following: one panel for each grain angle deviation and one panel of parallel laminations with one panel for each pressure. Thereby making a total of 12 panels from which to cut the tensile strength specimens.

The following table will show how the panels were to be numbered:

No. of Panel	Bonding Pressure P.S.I.	Grain angle
1	800	Parallel
2	800	5°
3	800	10°
4	800	15°
5	1000	Parallel
6	1000	5°
7	1000	10°
8	1000	15°
9	1500	Parallel
10	1500	5°
11	1500	10°
12	1500	15°

MATERIALS

1. The species used for impregnation was Yellow birch veneer 1/16" thick. The veneers, prior to the impregnation process had a moisture content between 6% and 8%.
2. The resin used as the impregnant was an alkaline catalyzed unpolymerized phenol-formaldehyde resin-forming mix with a pH of 7.7 and a solids content of 61%. This Resinoid R5995 manufactured by the Bakelite Corporation is miscible with water in all proportions (1).

3. The veneers were treated with a 50% aqueous solution of the Resinoid BR5995 so as to give the desired resin content of 30% of the weight of the wood.(5)(6) When resin-treated veneer is highly compressed in making parallel laminated Compreg, it is not necessary to use a bonding glue between the plies provided the resin content exceeds 30% on the basis of the dry weight of the untreated wood.(5)

The solution for the first bath was made up in a metal container sufficient to cover the necessary number of veneer sheets. This bath consisted of 3725 cc. of Bakelite Resinoid BR5995 and 3725 cc. of cold tap water. The temperature of the treating bath was 65°F.

Impregnation, due to the size of the metal container, was done in stages. The veneers were allowed to remain under the surface under non-drying conditions to allow the resin-forming constituents to become uniformly distributed by diffusion throughout the structure.

The time required for the veneer to take up the desired amount of resin-forming constituents will vary directly as the square of the thickness of the veneer, directly as the specific gravity of the wood, and inversely with the moisture content of the wood and the temperature.

It has been shown that the extent to which wood swells in a resin forming solution beyond the swelling in the solvent alone is a good indication of the affinity of the wood for the resin-forming constituents. Aqueous phenol-formaldehyde resin-forming solutions cause considerably more swelling of wood beyond the swelling in water than is caused by any of the other resin-forming systems tried.(1)(4)

After impregnation for 48 hours at atmospheric pressure and room temperature, the veneers were taken out and placed between small stickers to allow better circulation through the plies in drying. The veneers were then slowly dried so that the resin-forming constituents were able to diffuse from the fiber cavities into the cell walls as water was removed from the fiber cavities. In four days, the plies reached a moisture content of approximately 6% to 8%.

Sample plies from each batch prior to impregnation were weighed and then later weighed again after reaching a moisture content of 6% to 8% to determine the amount of solid resin absorbed by the veneer sheets. The following table shows the results of these weighings.

Wt. Prior to Impregnation	Wt. after drying	Increase	% Increase
Ply No. 1- 82 gr.	121 grams	39 grams	32.2%
Ply No. 2 88 gr.	132 grams	44 grams	33.3%
Ply No. 3 86.5 gr.	131 grams	44.5 grams	33.9%
Ply No. 4 83 gr.	123 grams	40.0 grams	32.5%
Ply No. 5 87 gr.	130 grams	43 grams	33%

Average Percent of Increase = 32.98%

Temperature and Pressing

After drying, the plies were assembled and readied for the hot press. The bonding pressure used on the first panel was 800 p.s.i. The temperature used was 285°F. for fifteen minutes.

From past experience it has been shown that the higher the temperature of pressing, the greater will be the tendency to check. This is due to the embrittlement of the treating resin. The best results for bonding have been obtained by pressing at 285 to 300°F. (5)

When heating from the press platens, the time of pressing depends on the thickness of the panels. If all the heat came from the platens, the time for pressing would vary as the square of the thickness. However, in the case of the resin-forming mixes, there is an appreciable amount of exothermic heat resulting from the reaction within the wood structure. Because of this fact, the pressing time required for thick specimens of Compreg is somewhat reduced because of the fact that the internal temperature is built up more rapidly than by conduction alone. By this reduction in pressing time, the heat from the center of the plies to the surfaces is kept steady enough to avoid over-curing or burning at the center. Should a higher temperature be used, the dissipation of heat from the center could hardly keep up with the heat being evolved at the center by conduction.

By using a bonding temperature of 285°F. the exothermic reaction was sufficiently slow that the generated heat could be conducted away as rapidly as it was generated, thus avoiding the undesirable building up of heat at the center. This latter occurrence is further reason for avoiding bonding temperatures appreciably above 285°F.(5)

To check on the platen temperature so that a higher temperature than was desirable would not occur, a thermocouple was inserted into the press.

Total pressing time ranged from 15-30 minutes per inch of original thickness of the wood.

After the proper amount of pressing time, the panel was allowed to remain under pressure in the press with the heating elements turned off. This procedure is very important in the forming of Compreg. The panel should be cooled to approximately 180°F. or in general to cool the wood below the boiling point of water before removal from the press. In cooling to the above temperature, the Compreg is prevented from springing back if pressed under incomplete curing conditions. Also, the surface is vastly improved. Most important of all detrimental occurrences that might be due to improper cooling of the panel if the plies used were appreciably over 2% in moisture content is the crazing and blistering of the surfaces. With the moisture content of the veneers rather high (6-8%) steam pockets, blistering and crazing of the surfaces would occur upon immediate release of the pressure. With woods of contrasty grain, release of pressure prior to the allowance for cooling at the center of the panel brings about a phenomena known as "washboarding".

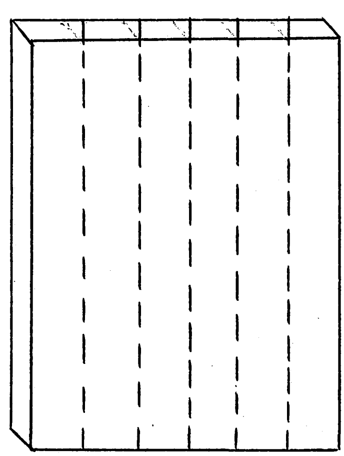
Taking all these adverse possibilities into consideration, the panels were allowed to cool to approximately 180°F. Again the thermocouple was used to check on the thermostats, connected to the heating elements.

The other panels requiring pressures of 1000 psi. and 1500 psi. were treated similarly to insure testing specimens of uniformity.

PROCEDURE FOR TESTING SPECIMENS

1. Method of preparing the specimens:

The panels were first cut up into strips 12" to 14" in length, 1/2" thick and 1" wide. The final test specimen was to be tested according to British Specifications for standard Tensile Strength Test (7).

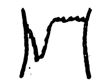
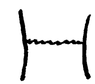
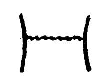
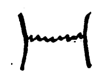
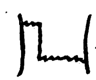
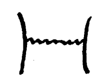
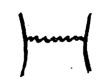
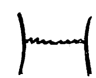
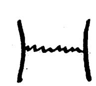


In order to get the required 12" radius, a fixture with a 12" radius was marked off and cut out. This curve was sanded down to assume a perfect 12" radius. Holding this fixture against the piece of Compreg, the radius was marked off on the 1/2" side of the specimen. Saw kerfs were cut with the band saw as close as possible to the marked off curve. After all the pieces were taken care of in this manner, they were filed down to assume the radius. This gave the piece the dimension of 1/4".

To get the radii on the opposite or 1" side of the specimens, the fixture again was employed in marking off the line of curvature. This side being more difficult to work on, the use of a lathe was employed. A sanding drum was put on the lathe and abrasive action cut down the area to the required size. The cross sectional area of the test piece was now 3/8" x 1/4" or 3/32 sq. in.

The tests were conducted on a Riehle testing machine. The head speed of the testing machine was approximately 4000 to 8000 p.s.i. per minute.

The table on the following page shows the results of the tests.

Spec. No.	Pressure PSI	Total Load lbs.	Tensile Stress	Sketch of Failure	Remarks
1.	800	3750	40,000		Double failure occurred. Center ply had crossed & interlocking grain.
2.	800	3785	40,500		Perfect tension failure, straight across.
3.	800	3860	41,250		Perfect failure -across the reduced area.
4.	1000	3675	39,200		Tension failure across center.
5.	1000	3785	40,500		Very poor failure
6.	1000	3550	38,000		Failure at center
7.	1000	3830	40,900		Failure at center
8.	1500	4510	48,200		Failure at center
9.	1500	4500	48,000		Failure not straight across center.
10.	1500	4795	51,200		Tension failure at center.
11.	1500	4675	49,990		Tension failure at center.

To get the specific gravity of the panels, pieces were cut from the remains of the panels after cutting for the tensile strength specimens.

The pieces were cut to weigh approximately 5 grams each. The pieces were first weighed in air on the analytical balance. After weighing the three pieces in air, they were weighed in distilled water with a temperature of 72°F. The specific gravity was found by using the following formulae:

$$\text{Density} = \frac{\text{Wt. (grams)}}{\text{Volume (ccs.)}}$$

$$\text{Specific Gravity} = \frac{\text{Density}}{1 \text{ (sp. gr. of water)}}$$

The following table shows the Specific Gravity data:

Pressure PSI	Wt. in air (grams)	Wt. in Water (grams)	Sp. Gr.
800	5.1212	3.8992	1.314
1000	4.7990	1.2230	1.342
1500	5.201	1.387	1.363

From the above, as the pressure is increased, the Specific gravity is also increased. This is a step in the right direction, but since the ultimate specific gravity would be 1.46 theoretically, the consequent increase in tensile strength would have to have a very high ratio increase in proportion to obtain the desirable values.

Due to the unavailability of the resin R5995, the

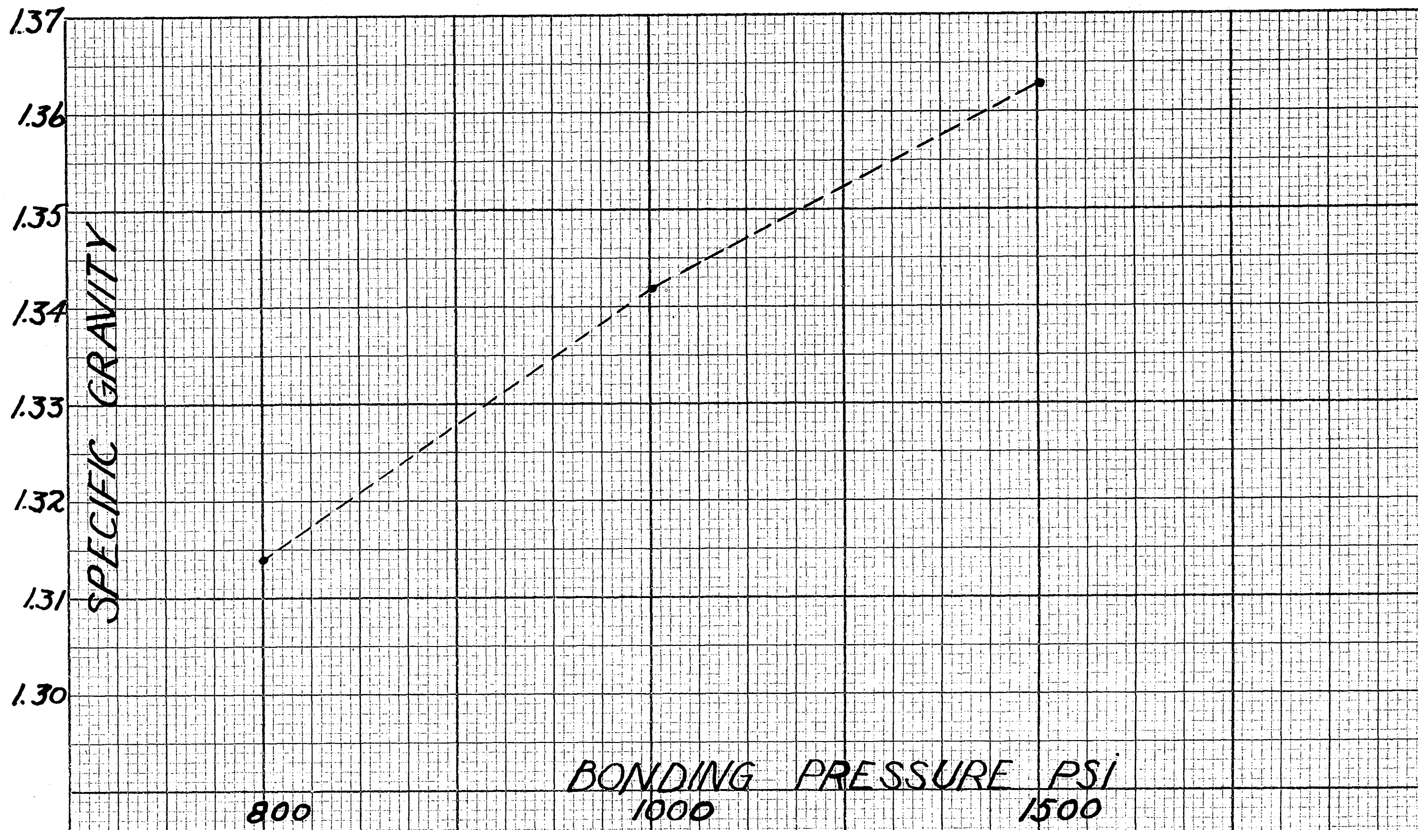
TABLE I

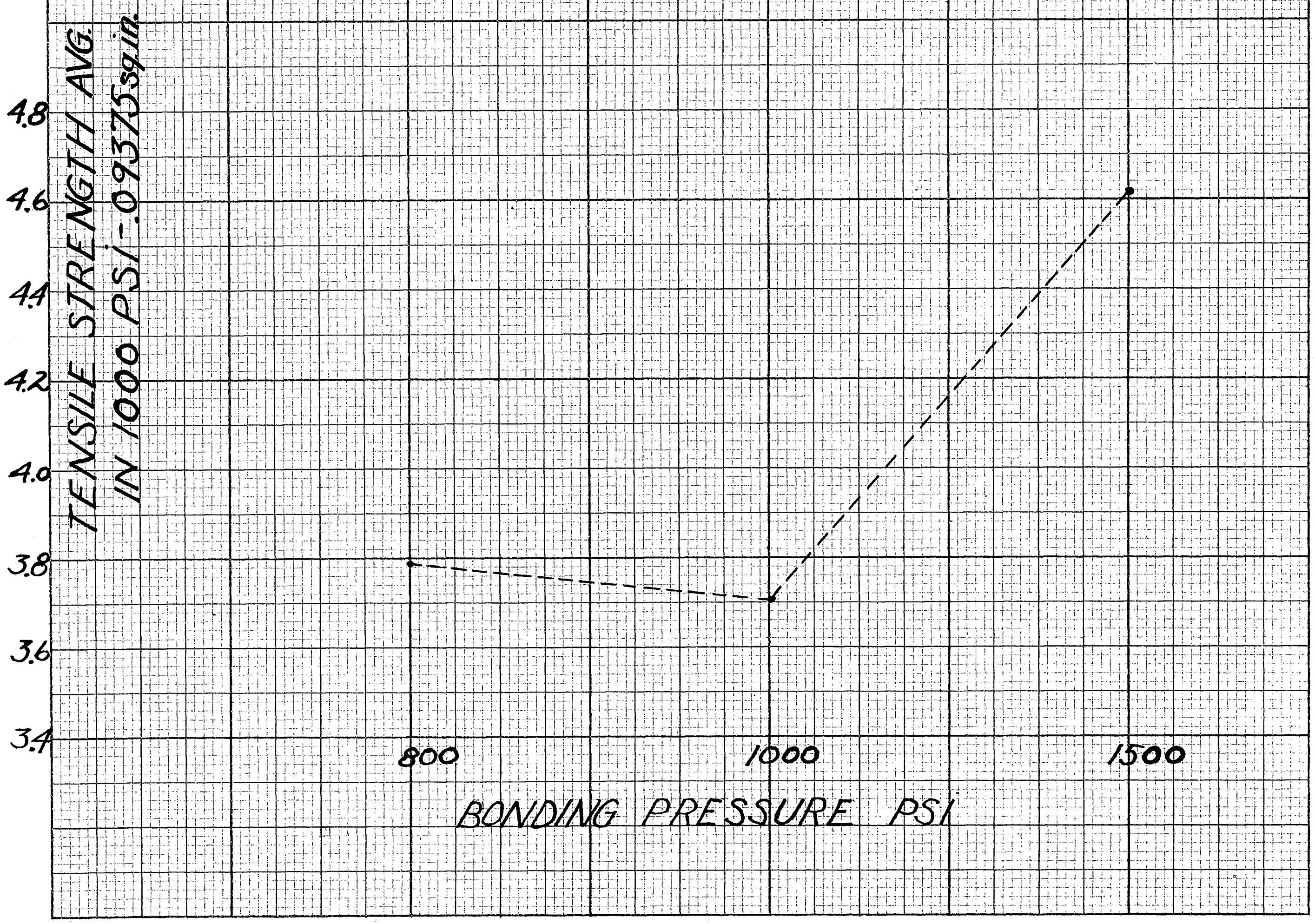
Ratio of Tensile Strength/Density of Compreg Tested

Bonding Pressure P.S.I.		Ratio
800		30,900
1000		29,478
1500		36,200
	Average	32,193

TABLE II

	Bonding Pressure	Platen Temp.	Sp. Gravity	Tens. Strength
1.	800 p.s.i.	300°F	1.314	40,000 p.s.i.
2.	800 "	"	"	40,500 "
3.	800 "	"	"	41,250 "
			Average -----	40,580 "
4.	1000 "	"	1.342	39,200 "
5.	1000 "	"	"	38,000 "
6.	1000 "	"	"	40,500 "
7.	1000 "	"	"	40,900 "
			Average -----	39,650 "
8.	1500 "	"	1.363	48,200 "
9.	1500 "	"	"	48,000 "
10.	1500 "	"	"	51,200 "
11.	1500 "	"	"	49,990 "
			Average -----	49,348


SPECIFIC GRAVITY
1.37
1.36
1.35
1.34
1.33
1.32
1.31
1.30
BONDING PRESSURE PSI
800
1000
1500

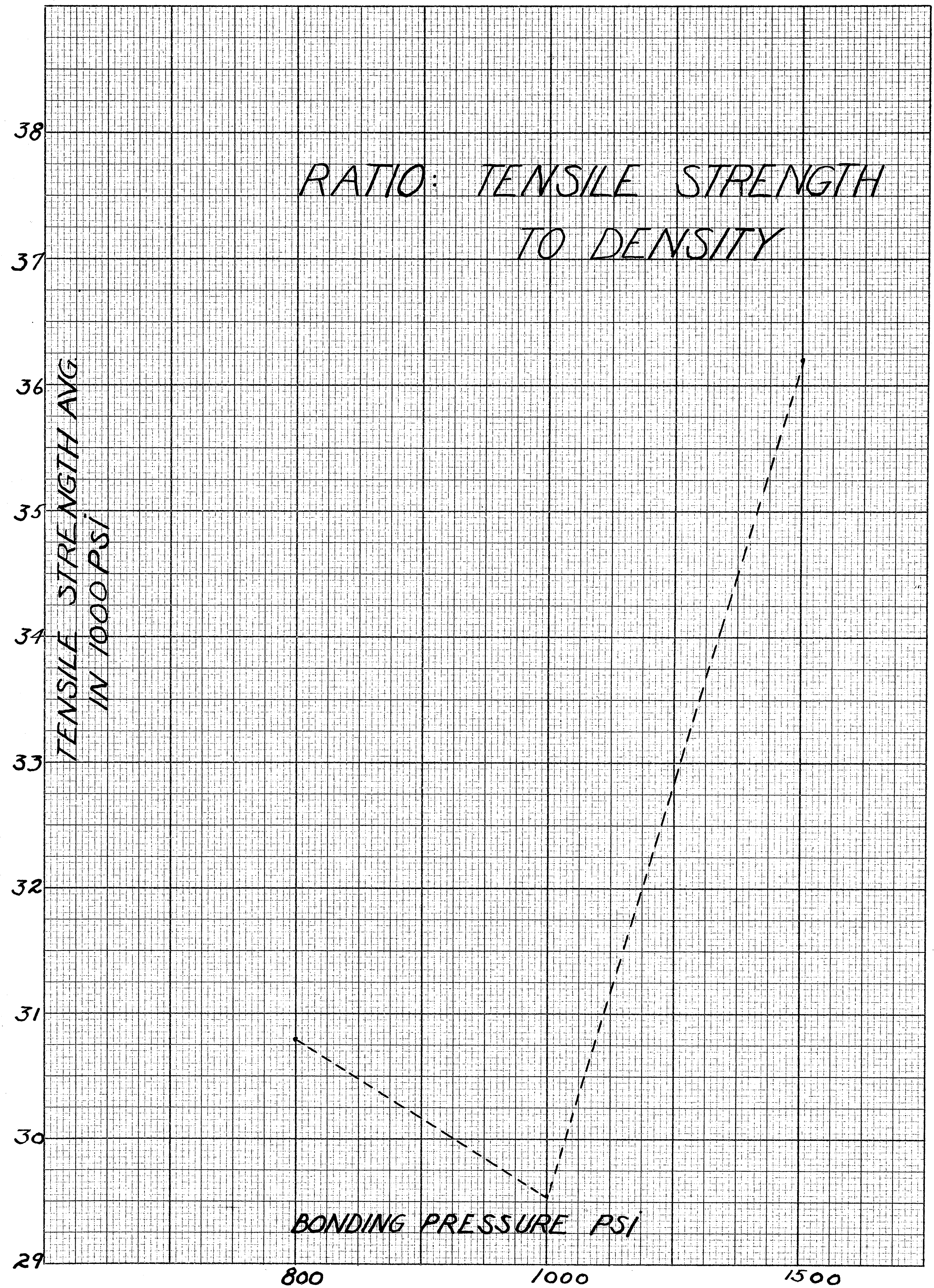

TENSILE STRENGTH AVG.
IN 1000 PSI-.09375 sq.in.
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
800
1000
1500
BONDING PRESSURE PSI

Ratio of Tensile Strength/Density of Compreg and of Other Materials

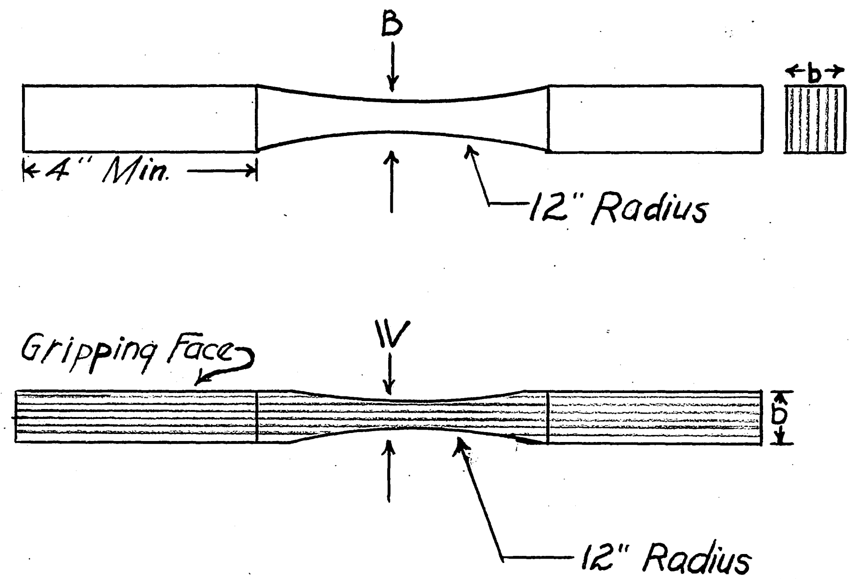
Material	Tensile Strength	Density	Ratio
Alloy Steel	189,000	7.8	24,230
K Monel	185,000	8.8	21,020
Struct. Steel	85,000	7.85	10,830
Dural	55,000	2.79	19,710
Polyamide	50,000	1.14	43,860
Alum. Die Cast	29,000	6.60	10,000
Aluminum	22,000	2.7	8,150
Wood	16,000	0.63	25,400
Plywood	9,600	0.68	14,120
Compreg	42,500	1.34	31,717
Glass Fiber	54,720	1.76	31,090

TABLE III

Bonding Pressure P.S.I.	Specific Gravity	Tensile Strength	Ratio: Tensile Strength / Density
800 p.s.i.	1.314	40,580 p.s.i.	30,900
1000 p.s.i.	1.342	39,560 p.s.i.	29,478
1500 p.s.i.	1.363	49,348 p.s.i.	36,200


RATIO: TENSILE STRENGTH
TO DENSITY
TENSILE STRENGTH AVG
IN 1000 PSI
38
37
36
35
34
33
32
31
30
29
BONDING PRESSURE PSI
800
1000
1500

panels with the grain deviations could not be made and tested for tensile strength. The remaining tests on the Compreg possibilities for the ultra-centrifuge, as laid out in the working plan could not be tested and compared to the results obtained by the parallel laminated pieces.



Cross sectional dimensions of test length:-

$W = \frac{1}{8\,t}$ (maximum = 1" minimum = 3/8")

B = t or 3/8", whichever is the smaller.

Thickness of test piece:

b = 1" or t, whichever is the smaller.

t = thickness of original material.

In piece tested, t = 1/2" $\therefore$ $W = \frac{1}{8 \times .5} = 1/4"$

B = 3/8"

Therefore piece tested has a cross-sectional dimension of 3/8" x 1/4" or 3/32 sq. in. or .09375 sq. in.

According to the British specifications, each test piece shall be pulled in an approved testing machine, the stress in the piece being increased uniformly at a rate of 4000 - 8000 p.s.i. per minute. The load shall be applied axially.*

From all the foregoing data, Mr. Casselman's article and the Compreg tested, it is very evident that a material giving a ratio of tensile strength to density anywhere from 60,000 to 100,000, which is the desirable range, would have to be sought elsewhere. ~~probably~~. The properties of Compreg could not do the job to form a rotor capable of speeds over 60,000 revolutions per minute.

Recent experimental work on the polyamides and glass fibers woven into different types of cloth have resulted in high tensile strength materials.

Work having to do with the experimentation of resin impregnated glass fiber laminates shows the possibility of forming high strength reinforced plastics. It seems that with most of the woven glass fibers worked with that on the whole they lend themselves very well to simple bends and compound curvatures. The "rotor" for the centrifuge would have a simple curve at the base and therefore the glass cloth might be applicable.

* (Ref: British Standard Specifications, 5 V. 3)

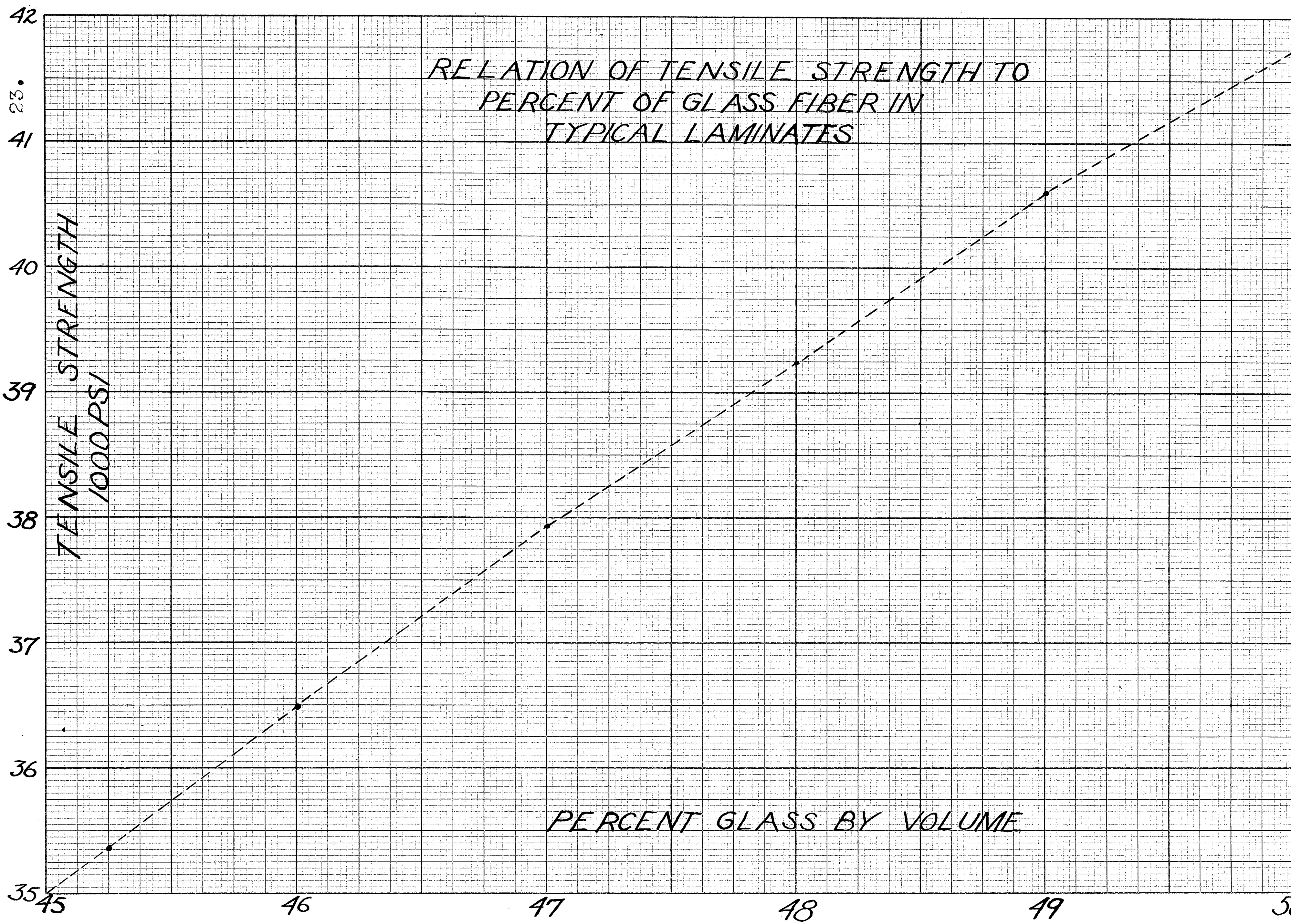
Of all the woven types of glass fiber cloths, it seems that the loosely woven cloths appear to be best for drawn shapes.(8)

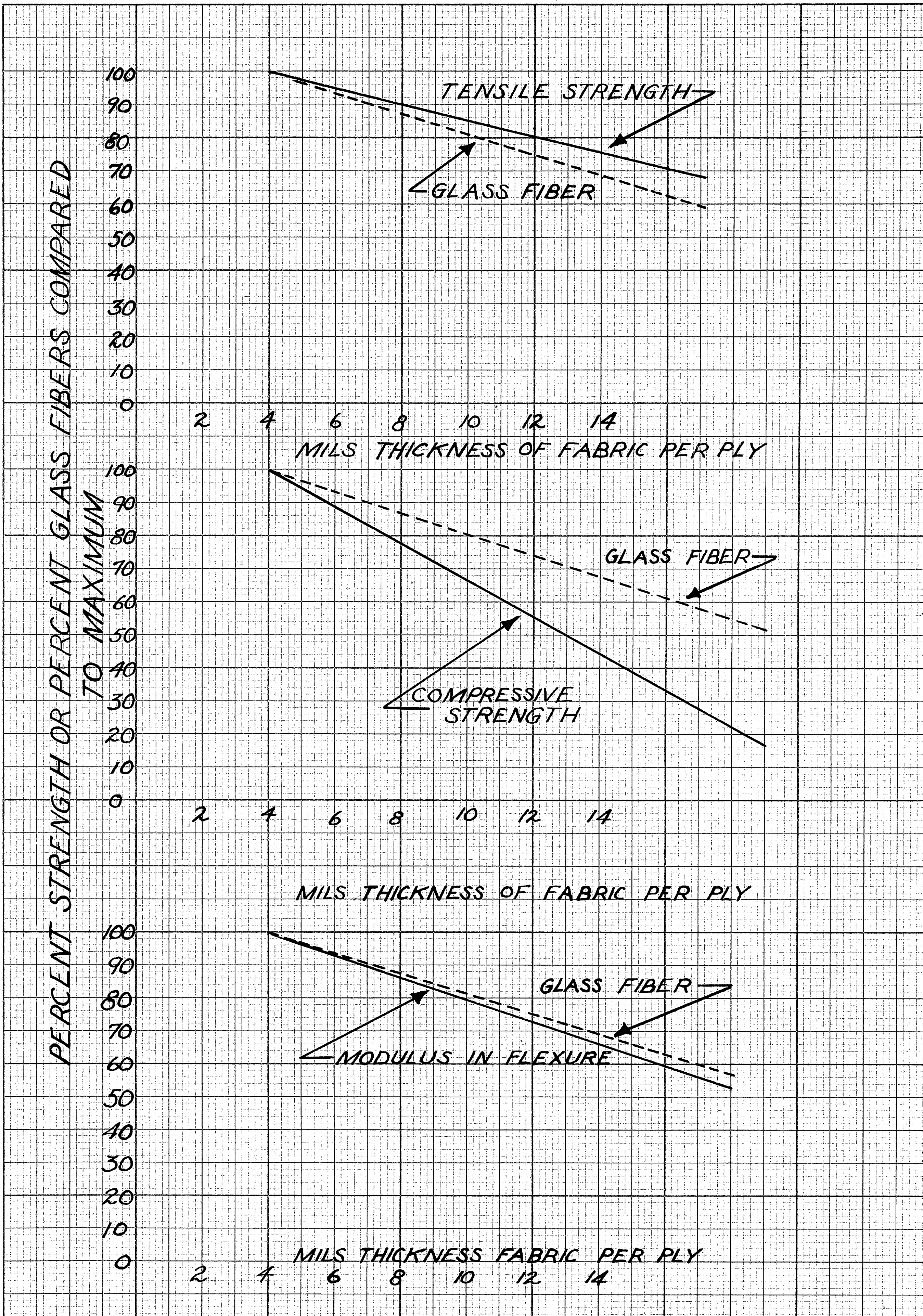
The glass fiber is resin impregnated, heat treated and formed into laminates. These cross-laminated sheets are 1/4" to 1/2" in thickness. Heat treating creates maximum adhesion of the resin to the glass.

Cross laminated glass fiber cloth combined with short fine glass fibers, known in the industry as flock-fibers, impregnated with a low-pressure thermosetting resin and heat treated gave the following values for tensile strength and density; 54,720 p.s.i. and a specific gravity of 1.76. This cloth was created in the laboratory in 1944 when the Army Air Forces were studying the possible development of glass reinforced low pressure plastics for various parts in aircraft.

However, during the past two years, continuous research on glass fiber cloth reinforced laminates has given much higher values for tensile strength.

An important factor in producing this high tensile strength fiber glass cloth is the type of resin used for impregnation. Although at the time all the various types of resins were not available in commercial quantities, it seemed that the copolymer polymerizing resins, which differ from the well-known condensation types such as urea-formaldehyde and phenol-formaldehyde in that they do not give off


RELATION OF TENSILE STRENGTH TO
PERCENT OF GLASS FIBER IN
TYPICAL LAMINATES
TENSILE STRENGTH
1000 PSI
PERCENT GLASS BY VOLUME
42
41
40
39
38
37
36
35
45
46
47
48
49
50


PERCENT STRENGTH OR PERCENT GLASS FIBERS COMPARED TO MAXIMUM
TENSILE STRENGTH
GLASS FIBER
MILS THICKNESS OF FABRIC PER PLY
GLASS FIBER
COMPRESSIVE STRENGTH
MILS THICKNESS OF FABRIC PER PLY
GLASS FIBER
MODULUS IN FLEXURE
MILS THICKNESS FABRIC PER PLY
100
90
80
70
60
50
40
30
20
10
0
2
4
6
8
10
12
14

Explanation of Graphs on Strength Characteristics and Percent Glass Fibers

Tensile Strength

The tensile strength of glass cloth laminates is closely related to the glass content. As the percent of glass fiber is decreased, the tensile strength decreases proportionately.

Compressive Strength

Compressive strength of glass cloth laminates drops sharply with reduced glass content. To assure high compressive strength there should be a high ratio of glass to resin.

Modulus of Elasticity

Modulus of Elasticity of glass cloth laminates is in exact proportion to the glass content, decreasing as the glass percent decreases. There are slight variations as the ply thickness of the laminates increase.

water and a gaseous by-product in curing, gave the best results. The fact that the copolymers cure without the elimination of gas & water means that higher curing temperatures can be used. Another important item is the elimination of "blistering". (5)

Other factors affecting the strength characteristics of the glass-fiber cloth besides curing conditions & the type of resin are; fiber diameter, closeness of the fiber weave, direction of the fibers, and the glass to resin ratio.

From the graph showing the relation of tensile strength to the percent of glass fiber it will be noticed that the tensile strength increases as the percent of glass fibers increase. However, there is a limiting point where this ceases. The graph would level off when the glass volume approached 50%.

The strength of the glass laminates can be varied in many ways. The properties of unidirectional glass cloth in the direction of the fibers are approximately double of those of cross laminated glass cloth. The strength can be varied by using a cloth with a tight or open weave, by varying the number of plies of cloth for a given thickness, or by dispersing glass flock in the resin to serve as lateral reinforcement. As in the Compreg, alternating of the grain direction distributes the stresses and makes the material stronger. All these variables make it possible to cover a wide range of Strength.

Exhaustive studies of glass fibers have been conducted, to determine their physical properties. A great deal of new apparatus has been designed and built. Today, experimental fibers have been produced in the laboratory with a tensile strength exceeding 2,000,000 p.s.i. in a diameter range smaller than the standard textile fibers.

Since the wood utilization laboratory does not have the facilities to test fiber glass and the polyamides, no actual testing and experimentation could be performed.'8' (9)(10)

The polyamide resins are commonly known as nylon. This is a generic term for any long-chain synthetic polymeric amide which is capable of being formed into a filament in which the structural elements are oriented in the direction of the axis. The name nylon does not refer just to yarn but includes an entire family of polyamide resins.

The high polymeric materials such as the polyamides are made up of long molecular chains. Application of a constant load to such a material produces an instantaneous deformation due mainly to the straightening of the primary valence chains. As a consequence, deformation under loading tends to take place in the direction of the chains, corresponding to an increase in deformation. However, upon removal of the load, the elastically deformed structure tends to return to its original unstrained form. (12)(13)

No definite information on woven polyamide could be found either laminated or otherwise. However, the physical properties of the polyamide fibers, namely density and tensile strength are fairly well established in the literature. The strengths can be altered by the granular size of the polyamide powder. The physical properties of a certain type of polyamide filament fiber is density, 1.14 gm/cm^3 and a tensile strength of 10,530 p.s.i. tested at 77°F. and a relative humidity of 55%. (9)(10)(11)

Discussion of Results

From the above, it is evident that without any information on the strength characteristics of polyamide woven fibers this material would have to relinquished from further experimentation in favor of the glass fiber cloth. The strength properties of woven impregnated glass fiber cloth seems to indicate that this material might possibly solve the problem. Further intensive study should be made of this material until an optimum tensile strength to density ratio could be obtained.

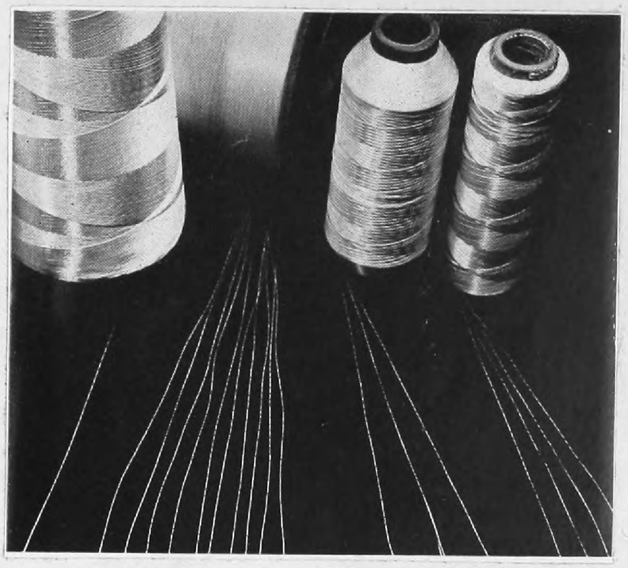


FIGURE I

In Figure I is shown one of the two basic types of glass fiber yarns. Shown are single end and multiple wound continuous filament yarns on various types of packages.

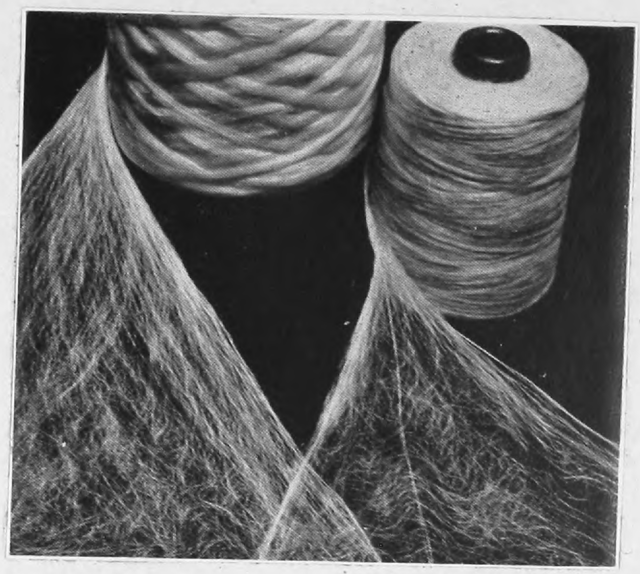


FIGURE II

Figure II shows plain staple fiber at the left, while a low twist staple yarn, reinforced with continuous filament yarn is shown at the right.

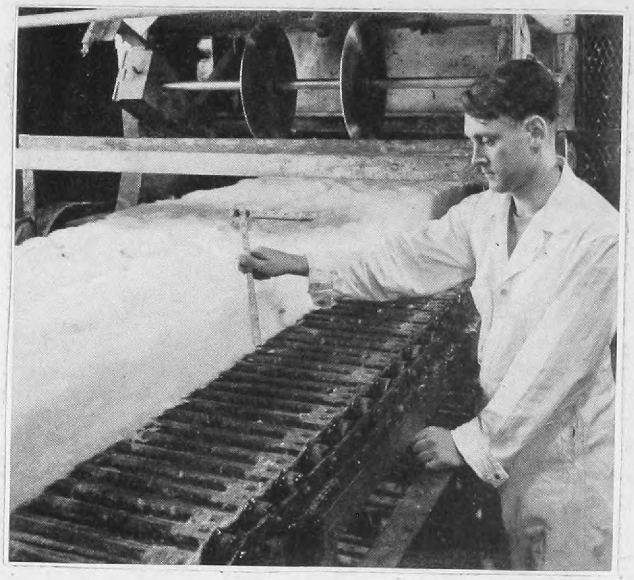


FIGURE III

In figure III is shown the glass fibers forming on a conveyor belt in a wool-like resilient mass.

FIGURE IV

In figure IV is shown the glass marbles that are molded from the raw materials. These marbles are inspected for flaws that might affect the tensile strength properties of the fibers. These marbles are later re-melted in small electric furnaces, each of which have many small holes in the base of the melting chamber through which the molten glass flows in fine filaments.

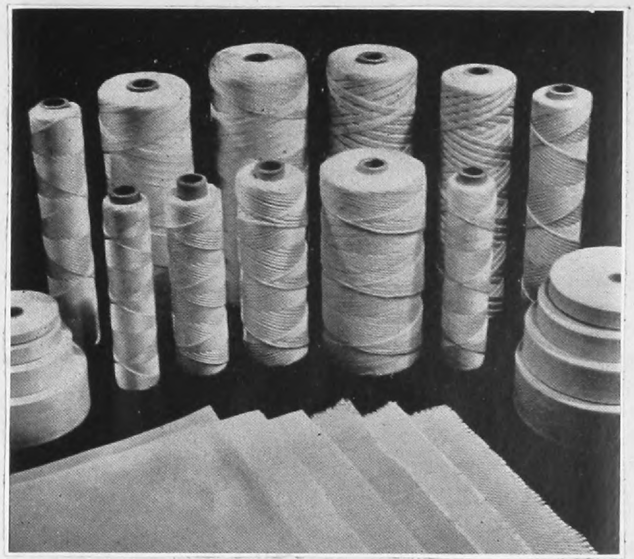


FIGURE V

In figure V are shown the unimpregnated glass fibers. Included are both the continuous filament and staple fiber types.

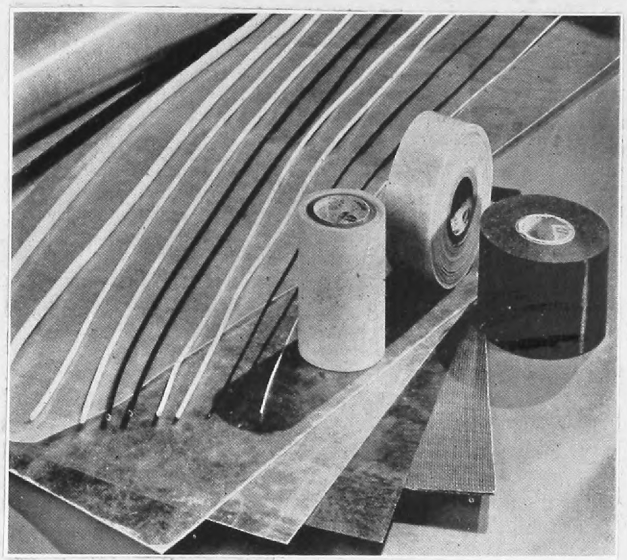


FIGURE VI

In figure VI are shown many of the impregnated types of glass fiber. Also shown in the foreground are the glass fiber laminated sheets.

FIGURE VII

In figure VII is shown how the web of fibers is being formed into an untwisted yarn.

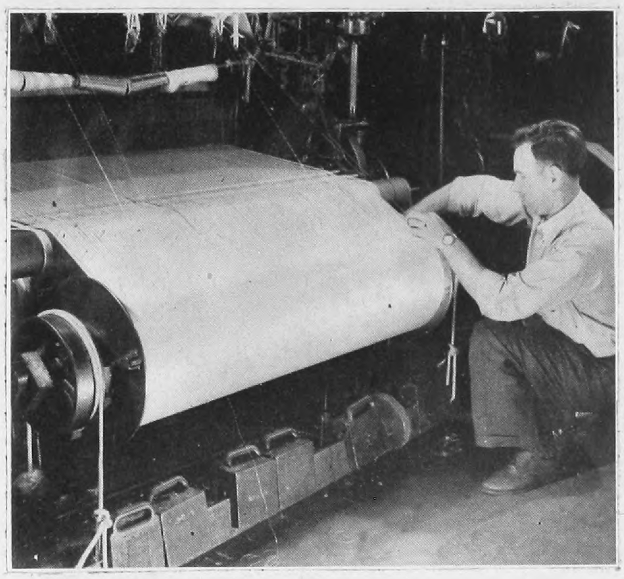


FIGURE VIII

In figure VIII is shown how glass fiber yarns are made ready for weaving into fabrics on regular textile machinery.

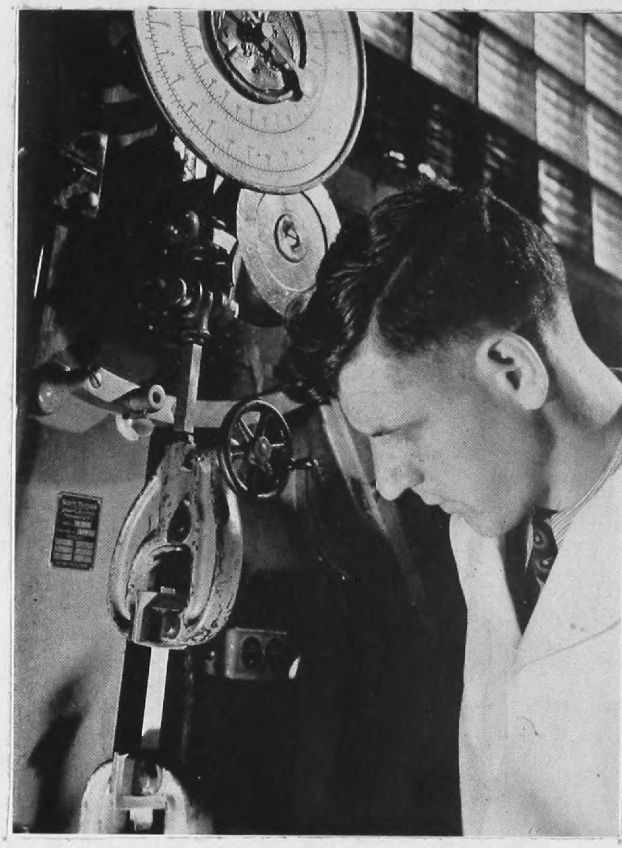


FIGURE IX

Shown here is a pendulum type tensile strength tester. It is also used to test 1/2" and 1" wide samples of impregnated cloths.

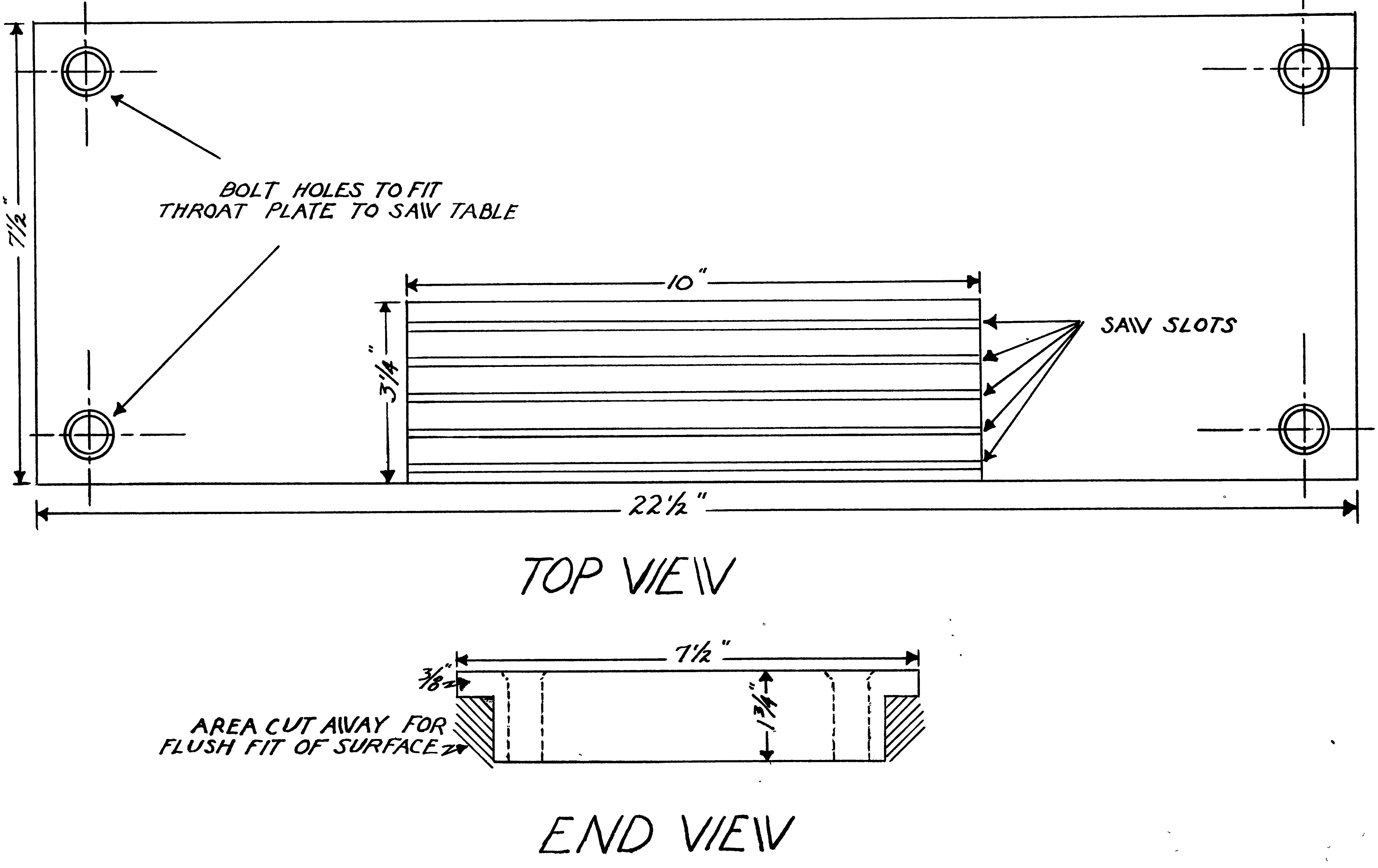
PART II

This second part also has a direct industrial application.

A plant cutting strips 8" x 1" x 1/4" on a rip saw, had in use a board made of hard southern pine as a throat plate for the saw. These strips were cut on a rip saw with four saws on a single arbor. This cutting operation necessitated a special throat plate to accomodate the saw blades.

The pine throat plate was inserted into the rip saw and screwed level with the table of the saw. A non-ferrous material must be used in an operation of this kind because slivers imbedding themselves between the saws and the edges of the slots in the throat plate can become very hazardous and expensive from a loss of production standpoint. The slivers can jam and heat the saws out of temper or cause them to touch the edges of the plate, thereby ruining the teeth of the saw. Needless to say, such occurrences are exceedingly costly both from the standpoint of interrupted production and unnecessary mutilation of equipment.

This particular plant was laid out in such a manner that all other operations such as moulding, planing, and the use of the cut-off saw depended on the gang rip saw for steady production. Any break-down to intall a new plate or new saws on the arbor caused a very valuable loss in production time. Also, any damage down to the saws themselves proved very expensive.



• ORIGINAL PLATE •

This board had to be changed after every 30 hours of production time. The narrow strips cut in the board were not tough enough to withstand the abrasive and cutting action of the slivers and the stresses caused by pieces wedging themselves between the edges and the saw and the edges and the arbor. Cracks would develop and then run on through to the bolt holes. The area near the bolt holes, on the underside of the slots, was entirely ripped away from the body of the throat plate.

Due to these various factors the problem was brought to the attention of the wood utilization laboratory of the University of Michigan.

Working Plan

The throat plate was made from a plank of Southern pine whose dimensions were 22 1/2" x 7 1/2" x 1 3/4". The growth characteristics of Southern pine are such that there is a ring of hard summer wood growth with a sharp line of demarcation where a wider band of soft spring wood occurs. From the analysis of the damage occurring in the original board, it was definitely shown that these facts were very undesirable and that a more homogeneous material would be more serviceable.

At first, a board of laminated hard maple veneers was made up. This panel was made up of 17 plies of 1/10" hard maple veneers under the following conditions:

Type of Glue: Urea-formaldehyde powder, mixed according to directions - 10 parts glue and 6 parts water.

Glue Spread - Single Spread

Pressure - 200 p.s.i.

After assembling, the built up panel was placed in the Riehle testing machine and put under pressure for approximately 24 hours.

The panel, after being taken from the press, was trimmed down to the proper size. Drilling and countersinking of bolt holes and the cutting of the slots was left to the plant personnel.

The panel was delivered and put into operation. After a few days of production time, the size of the strip cuttings were changed. Since the saw openings already had been cut to accommodate the first spacing of saws on the arbor, a changed setup meant a new spacing ratio. In turn, this meant cutting other saw openings. These cuts were very close to the first and therefore weakened the board considerably because the narrow strips of laminated maple were irregularly spaced.

Fully realizing the strength and toughness characteristics of Compreg, it seemed that this material would be excellent for a throat plate.

To make the entire board of Compreg would be unnecessary because the strength and toughness characteristics were needed in the areas where the saw openings occurred. To get the Compreg in the proper area, where the stresses were greatest, the Compreg was inserted in the recessed area of a hard maple laminated board similar to the one made in the previous experiment.

Materials and Procedure for Panel

For the panel, the following materials were used:

1. 17 plies of hard maple - 1/10" thickness.
2. Urea-formaldehyde powder glue mixed according to the specific directions - 10 parts of glue to 6 parts of water, by weight.

The glue was put on single spread and the panel was placed in the Riehle testing machine under a pressure of 200 p.s.i. for 24 hours.

After removing the maple board from the testing machine the area for the Compreg was routed out. (See page 45)

There were two ways of getting the Compreg into the recessed area, either by taking a piece of Compreg with the required dimensions and gluing it in or attempting to make the Compreg directly in the area cut away.

In a study made on the gluing of Compreg it was found nearly impossible to make a good glue joint on the hard and lustrous surface of the Compreg as it comes from the press. This may be due to a deposit of wax left from the cauls, or to a layer of highly polymerized resin on the surface. Even when the waxy surface finish was cut down with acetone the adhesive qualities were not improved very much.

Since the throat was to be subjected to severe vibrations in the saw, this method was impractical.

Materials and Procedure for the Compreg Insert

Since no Bakelite phenol-formaldehyde resin could be obtained, another type of phenol-formaldehyde resin in powder form was used. As a solvent, acetone was used. The acetone and the phenol-formaldehyde powder resin were mixed to form a 50% aqueous and a 30% solids content solution. The following is a list of the materials used:

1. 3.5 pounds - phenol-formaldehyde resin powder.
2. 4015 grams of acetone.
3. 17 plies of 1/16" yellow birch veneer.

The resin powder and the acetone were mixed to form a solution in a metal vat. The sheets of veneer were placed in the resinous solution to soak for a period of 48 hours. A few sample pieces of veneer were weighed prior to immersion to calculate the amount of solid resinous content absorbed.

The moisture content of the veneer sheets prior to immersion was about 6 - 8%.

After the soaking period, the veneer sheets were stacked between stickers and allowed to dry under room temperature conditions.

Since the amount of solids content absorbed during the immersion period was relatively low in comparison to the desirable 33% -- being only 20.9% -- sheets of Tego resin film were used in the assembly to reinforce the resin content after being cut to exact size.

The veneers were assembled with the grain in each ply going in the lengthwise direction. Each veneer ply was separated by a sheet of Tego film.

This entire assembly was placed in the recessed area of the maple board and placed in the hot press. Care was exercised to insure the forming of the Compreg in the recessed area. The corners were placed in position with the use of tape.

The maple board and the impregnated veneers were then subjected to the following conditions:

Pressure -- 1000 p.s.i.

Temperature --- 285°F.

Time --- 15 minutes.

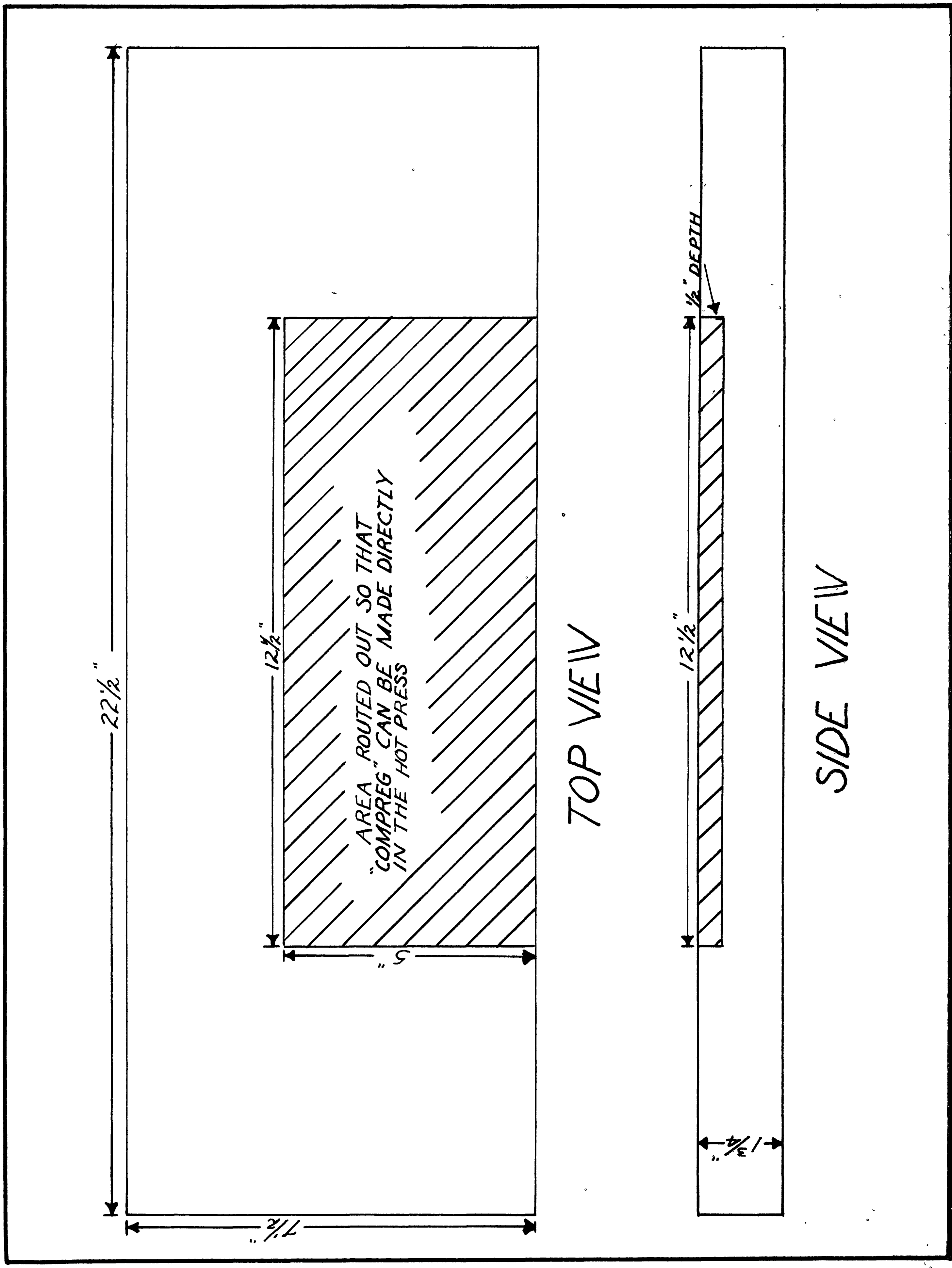
After pressing, the platens of the hot press were allowed to cool to 180°F to avoid any surface crazing or blistering (see page 10+11).

After removal from the press, the edge of Compreg that was overlapping the maple board was sawn and made flush.

Discussion of Results

The maple throat plate averaged about 20-35 hours of production time per week for a period of three months. When last seen, it was still in relatively good condition and capable of many more production hours.

Although the plant during this period was working on a 44 hour week, enough stripping could be run through the

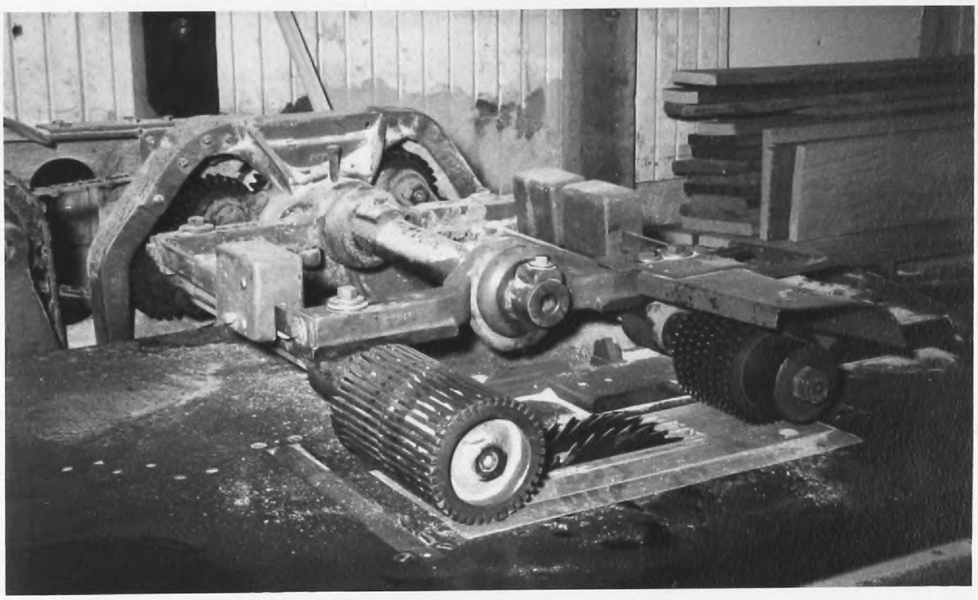

22½"
7½"
12½"
5"
AREA ROUTED OUT SO THAT "COMPREG" CAN BE MADE DIRECTLY IN THE HOT PRESS
TOP VIEW
½" DEPTH
12½"
1¾"
SIDE VIEW

gang rip saw in 30 hours to keep the plant going for the full 44 hours. Since two men operated the rip saw - one handled the lumber, they could be used elsewhere during the idle time of the rip saw. All this was possible because no time from production was lost in making throat plate changes.

Unfortunately, the compreg insert throat plate was never put into use. Curtailment of production prevented accurate production time data of the Compreg plate. Therefore, no definite information on running time could be obtained and no comparisons with the maple laminated board could be made. However, from the strength characteristics of Compreg as ascertained in Part I, it is very evident that the Compreg insert throat plate could endure all the forces of stress, vibration, and abrasive action to a much greater degree than the throat plate made entirely of laminated hard maple.

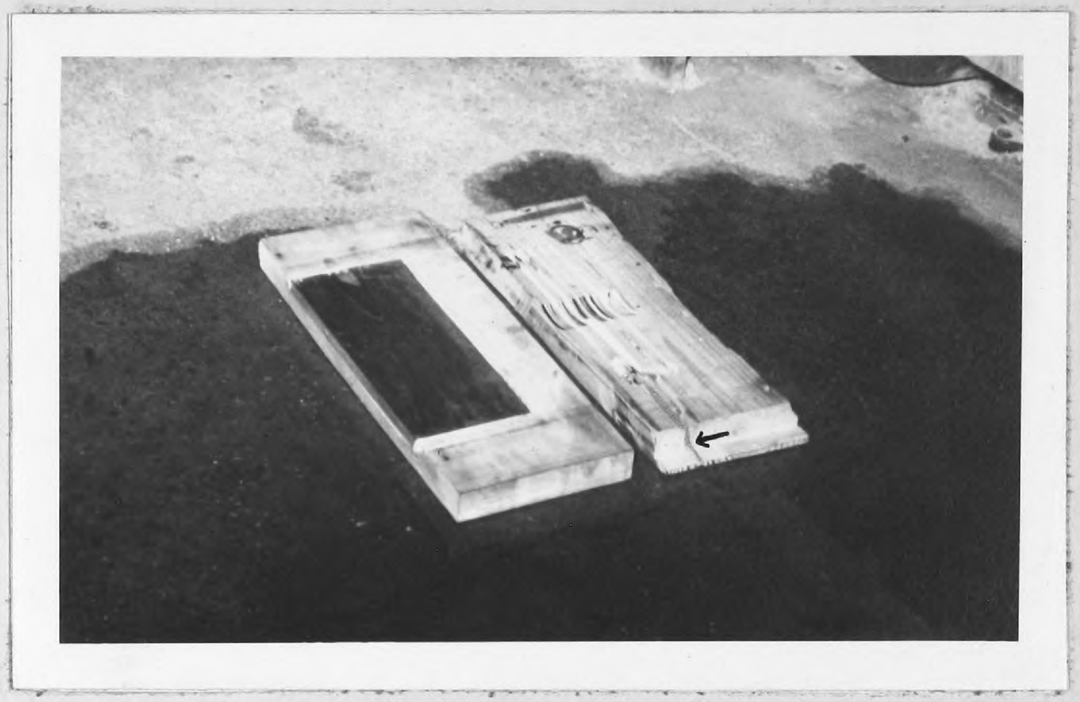
Summary

These two industrial problems are excellent examples of the type of problem that might enter into any phase of work in a wood fabricating plant. Means of solution could only be determined in some sort of laboratory regardless of size under trained and competent supervision. This sort of work would be of immeasurable value to industrial concerns from the three very important standpoints; namely, new products, saving of materials, and economy in the use of manpower.



PHOTOGRAPH I

The above photograph shows the gang-saw ripper with the laminated hard maple throat plate.



PHOTOGRAPH II

The above photograph shows the Compreg inserted throat plate on the left. On the right is seen the original Southern Yellow Pine throat plate with the arrow pointing to the split occurring in the soft spring wood.

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