1959

Use of wood residue in making reconstituted board products

Suthi Harnsongkram

*The University of Montana*

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THE USE OF WOOD RESIDUE
IN
MAKING RECONSTITUTED BOARD PRODUCTS

by
SUTHI HARNSONGKRAM
B.S.F., University of the Philippines, 1952

Presented in partial fulfillment of the requirements
for the degree of

Master of Forestry

MONTANA STATE UNIVERSITY

1959

Approved by:

[Signatures]

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CHAPTER I

INTRODUCTION

Demands on this country's natural resources are constantly increasing as the population grows and the economy expands. This trend focuses greater attention than ever before on the wise use of natural wealth.

In the Forest products field, ways are constantly being found for transforming the wood residue and low value timber into good quality construction materials for various uses, instead of burning such wood as fuel or disposing of it as residue.

The reconstituted board is one of the new products which has been developed in this field. It includes the manufacture of hardboard from wood fibers, particle board from wood particles, shaving board from specially cut wood shavings and softboard (insulation board) from wood fiber pulp.

A. ORIGIN

In 1914 (9) the first plant built to manufacture "softboard" (insulation board) was established by the Insulite Corp., now a division of Minnesota and Ontario Paper Company. The Wood Conversion Company, and the Celotex Company started production in 1920. Two of these firms also entered the hardboard field but are no longer producing hardboard. The Celotex Company at Marrero, Louisiana, discontinued production of hardboard after a successful patent infringement
suit by the Masonite Corporation in 1933. The Insulite Division, Minnesota and Ontario Paper Company, International Falls, Minnesota, continued manufacturing limited quantities of hardboard for export until 1940. However, this firm is now installing machinery to have a large hardboard plant in production.

Hardboard was a kind of reconstituted board product. It originated in 1924 when William H. Mason installed some apparatus in a work shed next to a lumber mill in Mississippi, and disintegrated the fibers in wood chips by "exploding" them with high pressure steam. These fibers were pressed into hard surfaced boards, known later on as "Masonite". A patent on the process and "hard grainless fiber" product was granted in 1928.

The second plant in manufacturing hardboard was the United States Gypsum Company. It began producing hardboard at Greenville, Mississippi in 1934. It and Masonite were the only two plants in the United States manufacturing hardboard up to the end of World War II.

Particle board was first produced as a commercial product by the Chapman Manufacturing Company, Corvallis, Oregon, in 1946. It was originally introduced to utilize wood waste. Germany, now a leader in the industry, started to produce particle board in 1948 (11).

B. GROWTH OF THE INDUSTRIES

The outbreak of hostilities in Korea stimulated the expansion of hardboard production capacity by the aid of the United States government in granting accelerated tax amortization on new plants in the amount of many millions of dollars for hardboard plant expansions and
In 1954, six new hardboard plants had been located in Oregon, two of them having been completed in 1954. A new plant was established in Washington and one in Minnesota. In addition, the Masonite Corporation built a new plant at Ukiah, California, in 1951.

At the end of 1956, there were about 16 hardboard and softboard plants, 34 particle board plants and 7 shaving board plants, or a total of about 57 reconstituted board plants.

It is estimated that, by the end of 1959, there will be many additional such plants in operation in the United States and also in Europe and Asia.

C. OUTLOOK FOR THE FUTURE

The country's bumper crop of babies is a key factor in determining future demand for reconstituted board products as well as for the many, many other things people use and need. Today's birth rate is one-half greater than 10 years ago. Then, too, people now live longer because of modern medical programs and higher living standards. Also the need for building and replacing dwellings offers another enormous market for wood reconstituted boards. The rapid growth in population will offer expanded markets for the many more items made of wood reconstituted boards such as furniture, cabinets, school desks, games, toys, and many others.

According to the Stanford Research Institute (19), the total reconstituted board consumption for all uses is estimated to grow three-fold in the next two decades.
All this indicates a bright future for this industry. The reconstituted board field is little different from others of its kind. Success still will depend in large degree on extensive product development work; in seeking out new uses, and new applications as a satisfactory substitute for another product; and from continually promoting and selling the advantages of the particular product.
CHAPTER II

CHARACTERISTICS OF WOOD RECONSTITUTED BOARD

The expression "wood reconstituted boards" is comparable to the term "synthetic lumber" in that it includes boards artificially made from wood materials of various kinds. It does not include boards consisting of mixtures of wood materials with other ingredients such as cement, gypsum or asphalt.

"Wood reconstituted boards" denote generally any boards made from residual wood, including "fiber board" (softboard and hardboard), "particle board", "shaving board", and also hard surfaced boards which are neither definitely wood fibers nor wood particles, but a combination of the two.

A. GENERAL CLASSIFICATION OF WOOD RECONSTITUTED BOARDS

The fiberboards differ from the shaving boards and particle boards in structure, physical properties and methods of production. Whereas fiberboards are constructed of wood fibers produced from chips by exploding, grinding, or chemical digestion, shaving boards and particle boards use discrete wood particles obtained from chipping, grinding or cutting.

Due to an overlapping between the different fiberboards as regards densities, end uses, thicknesses and other mechanical properties, it is difficult to classify them on any single basis. The disadvantage in a classification according to usage arises from the fact
that individual applications may successfully use fiberboards with a wide range of densities and strengths. Also, classification on the basis of thicknesses is not satisfactory since a fiberboard can be produced by several methods in thicknesses up to two inches. The same objection applies to a separation by manufacturing methods (10).

The most widely used means for classifying fiberboards, while not completely satisfactory either, can be used with better success than most. This means consists of classifying the boards with respect to density. A difficulty arises here from the fact that, due to process variables, the same type boards produced by different manufacturers will vary slightly in density. The method is, however, satisfactory for general purposes.

The U. S. Forest Products Laboratory classifies building fiberboards with regard to density as follows (8):

1. Softboard
   a. Semi-rigid insulation board 0.02 - 0.15
   b. Rigid insulation board 0.15 - 0.40

2. Intermediate density board 0.40 - 0.80

3. Hardboard
   a. Untreated 0.88 - 1.04
   b. Treated 0.95 - 1.15
   c. Special densified 1.35 - 1.45

The approximate strength and physical properties of the fiberboards as classified above are listed in Table 1 (24). The data shown will vary somewhat with boards from various manufacturers, due to differences in manufacturers, due to differences in manufacturing methods,
types of fibers used, etc.

**Softboard**

The term "softboard" (insulation board) is used to denote boards made from wood pulp, being held together entirely by the felting properties of the wood fibers. Its density is relatively low in comparison with other wood reconstituted boards (24). Figure 1 shows soft boards made from wood fiber pulp.

In producing softboard, the component fibers are merely mechanically felted like those of thick paper. The matted material is roll or screen pressed to consolidate it and squeeze out excess moisture before drying. Hot platens or rollers, or continuous tunnels, are used to dry the boards. The resulting product is porous throughout its thickness.

Semirigid insulation board is the term applied to fiberboard products manufactured primarily for use as insulation. These very low density fiberboards have about the same heat-flow characteristics as conventional blanket or batt insulation but have sufficient stiffness and strength to maintain their position and form without being attached to the structure proper (8).

Rigid insulation boards are generally classified as follows with respect to their use: Class A, general use boards; Class B, lath for plaster base; Class C, roof insulation board; Class D, interior boards, factory finished; Class E, sheathing; and, Class F, interior board, flame resistant, finish surface (8).

The classification of intermediate-density fiberboard includes boards weighing between about 25 and 50 pounds per cubic foot. They are sometimes called wallboards, but because rigid insulation board and
FIGURE 1

SOFTBOARD MADE FROM WOOD FIBER PULP
hardboard are also used as wall covering, the term "intermediate-density" is more restrictive. Included in the intermediate-density board are the laminated-paper wallboards and the partially densified hardboards (8).

**Hardboard**

The term "hardboard" was originally applied to denote boards produced only from wood fibers by either steam exploding or mechanically fiberizing wood, and then applying heat and pressure to reform the resultant fibers into a hard, homogeneous board having a density usually exceeding that of the original natural wood. The fibers are rebounded in the manufacturing process by the lignins (and any resins which are usually added) so that the fibers are held together as in the natural wood. Being grainless, "hardboard" does not crack, split nor splinter, and it is free of knots and other lumber defects (24). Figure 2 shows hardboard made from wood fibers.

The association of hardboard manufacturers has suggested the following definition of "hardboard": "Hardboard shall comprise inter-felted lignocellulosic wood fibers consolidated under heat and pressure into a board characterized by a natural ligneous bond (24)." This reference to the "natural ligneous bond" emphasizes the fact that the small amounts of additives cannot account for the high strength of the product.

The most common hardboard is smooth only on the top side. The bottom side bears the impression of a screen. Hence this type of product is sometimes referred to as "screenback" hardboard. A screen is necessary underneath the matted material being pressed whenever the
FIGURE 2

HARDBOARD MADE FROM WOOD FIBERS
mat has a high moisture content. The screen permits water to drain off and also enables the steam generated during the hot press cycle to escape. Boards having impressions left by screens are sometimes sanded or planed if it is necessary to have both sides smooth. If the mats are relatively dry when pressed, a screen is unnecessary, and two smooth sides result.

The "standard" or "untreated" grade of hardboard is the most commonly produced in the United States. Sometimes these boards are given specific treatment to impart certain additional properties. For example, both the strength and water resistance of hardboard may be improved through various methods of heat treatment. Boards so treated are generally called treated or "tempered" hardboard.

**Shaving Board**

The general character of "shaving board" was described by Armin Elmendorf of Elmendorf Research, Inc., in a paper presented before the American Society of Mechanical Engineers at Chicago, Illinois, November 14, 1955, entitled "Manufacture of Synthetic Lumber in Germany" (7).

"Wood shaving board consists essentially of flat, shaving-like flakes of wood bonded together with synthetic resins to produce thick panels that are subsequently generally faced with veneer when used in the furniture industry, but are simply varnished or lacquered when used for doors and for decorative purposes in display windows, and for interior paneling."

The terms "flakeboard", "shredboard" and "waferboard" are sometimes used to designate boards made from particular types of wood shavings, such as shreds, flakes or wafers. These reconstituted boards may
be classified generally as "shaving board", being made up of thin slices of wood specially produced by cutting whole wood with a knife hog or a special type of shaving, or flake, machine (2h). Figure 3 and Figure 4 show boards made from wood flakes and wafers respectively.

**Particle Board**

The term "particle board" is used more frequently now to denote boards made from wood particles by cutting, hammermilling or grinding wood to produce granules, slivers, or sawdust (2h). Figures 5, 6, and 7 show the boards made from planer shavings, screen fines, and hammer-milling respectively.

The Oregon Forest Products Laboratory has suggested that wood "particle board" be defined as (2h):

"A composition board consisting of distinct particles of wood bonded together with a synthetic resin or other added binder. This type of board is distinguished from fibrous-felted board in that the added resin or other binder provided the primary bond in the board."

The terms "chipboard" and "coreboard" are used at times to designate a certain type of particle board, usually granular in form. It is often used as core material to which a wood veneer is bonded.

The classification of particle boards was described by Dr. G. G. Marra (12). It is shown in Table 2 in condensed form.

In manufacturing hardboard, shaving board and particle board, heat is applied at the time of pressing to bond the material together and form a strong homogeneous mass. Also, the pressures are higher than in manufacturing softboard. These conditions produce hard surfaced boards.
FIGURE 3
FLAKE BOARD MADE FROM AMERICAN FLAKES
Figure 4

Wafer board made from Tenex wafers
FIGURE 5

PARTICLE BOARD MADE FROM PLANER SHAVINGS
FIGURE 6

PARTICLE BOARD MADE FROM SCREEN FINES
FIGURE 7

PARTICLE BOARD MADE FROM HAMMERMILLS
### TABLE II

CLASSIFICATION OF WOOD PARTICLEBOARDS ON THE BASIS OF CURRENT AND PROPOSED PRACTICE
IN EUROPE AND THE UNITED STATES (12)

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<td></td>
<td>ONE - LAYER</td>
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<td>PARTICLES</td>
<td></td>
</tr>
<tr>
<td>Produced by</td>
<td></td>
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<tr>
<td>Disc Grinders or</td>
<td></td>
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<tr>
<td>Hammermills from</td>
<td></td>
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<tr>
<td>Chips or Shavings</td>
<td>1. Flat-pressed particles.</td>
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<tr>
<td>(includes Fibrous</td>
<td>2. Extruded particles.</td>
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<tr>
<td>Fines)</td>
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<tr>
<td></td>
<td>3. Flat-pressed mixture of particles and disintegrated flakes.</td>
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<tr>
<td></td>
<td>4. Extruded mixture of particles and disintegrated flakes.</td>
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<td>FLAKES</td>
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<td>Produced by</td>
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<td>Special Cutters with</td>
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<td>Knives and Wood</td>
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<td>Grain oriented</td>
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<td>similar to Veneer</td>
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<td>Cutting.</td>
<td>5. Flat-pressed, intact flakes.</td>
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<tr>
<td></td>
<td>6. Flat-pressed, disintegrated flakes.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Specialty Board Variations

A new "diffusion board" has been announced that filters radioactive fallout, poison gasses and germ laden particles from the atmosphere. It is being tested for military and civilian shelters, as a protection from some of modern war's deadly effects. Secret chemicals are added to a fiber board during its manufacture to enable the screening out of the deadly gases and particles when used for human and animal shelters. It is claimed that life-sustaining oxygen passes through this board to prevent the suffocation of those staying inside the shelters. Also, carbon dioxide gas given off in breathing, along with respiratory vapors, can pass through this special board. It is believed that eventually this board will be made available to the general public for constructing shelters in homes and civilian buildings for protection during possible enemy attacks.

The term "Flapreg" is applied to denote a new kind of reconstituted board composed of resin impregnated wood flakes for it is a contraction of flakes and impregnation. It is of high density due to the large amounts of resin added (about 35%), has good dimensional stability, and possesses high tensile and flexural strength.

Figure 8 shows Flapreg made from Douglas fir flakes. The physical properties of Douglas fir Flapreg are mentioned in the following discussion of the properties of wood reconstituted board.

B. PROPERTIES OF WOOD RECONSTITUTED BOARDS

General properties of wood reconstituted boards are classified in Table 1, page 7. The data are based on 1953 information provided by
FIGURE 8

PIAPREG MADE FROM DOUGLAS FIR FLAKES
the Forest Products Laboratory of the United States Department of Agriculture at Madison, Wisconsin, and revised in 1955. One basis for classification is the board's density or "specific gravity". Specific gravity is the relation of the weight of an object to the weight of an equal volume of pure water, at 4°C. or 39.2°F.

From the standpoint of general physical characteristics, a board becomes stronger as its density increases; however, its insulation properties decrease. The density of a board, however, is not necessarily the controlling factor. For example, by making slight variations in manufacturing particle board, it is possible to modify these physical characteristics, by merely increasing or decreasing the amount of resin or other binders, including sizing.

The bonding of materials in a board may result from physical or chemical changes which take place in the composition of the wood fibers, or may come about through the addition of a binding substance such as resin.

Binding agents and other materials may be added to improve a board's physical characteristics by making it stronger or more resistant to moisture, fire, or decay. Some of the materials added are synthetic resins, alum, acid, waxes, drying oils, or chemicals to resist fire and decay.

Hardboard, shaving board, and particle board, like natural wood, are subject to swelling when exposed to moisture. However, the amount of moisture absorption (and subsequent dimensional change) by these boards can be controlled by special treatment, as mentioned in manufacturing processes.
The usual color range of wood reconstituted boards varies from a light straw shade to dark brown, unless coloring materials have been added in the manufacturing process.

The data in Table 1, page 7, shows that rigid softboard, with a low density of 9 to 25 pounds per cubic foot, has a coefficient of thermal conductivity of 0.27 to 0.40, meaning it has good insulation qualities against the transfer of heat or cold.

Low-density particle board varies from 25 to 50 pounds per cubic foot. High-density particle board falls in the same density grouping as hardboards varying from 50 to 70 pounds per cubic foot.

The thermal conductivity of standard hardboard ranges from 0.80 to 1.40, indicating poorer insulation properties than softboard.

On the other hand, the strength of untreated hardboard, expressed as "modulus of rupture", varies from 3000 to 7000 pounds per square inch, but for rigid softboard, only 200 to 800 pounds per square inch.

The average physical properties of Douglas fir Flapreg that was produced by Washington State Institute of Technology, were as follows (21):

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
<td>1.39</td>
</tr>
<tr>
<td>Modulus of rupture (psi)</td>
<td>13,170</td>
</tr>
<tr>
<td>Modulus of elasticity (psi)</td>
<td>1,910,000</td>
</tr>
<tr>
<td>Internal bond (psi)</td>
<td>1,097</td>
</tr>
<tr>
<td>Thickness swell % (24-hour water soak)</td>
<td>0.42</td>
</tr>
<tr>
<td>Water absorption % (24-hour water soak)</td>
<td>0.44</td>
</tr>
</tbody>
</table>
This Flapreg was produced under the following process conditions:

Average flake size: Thickness 0.008"
Width 1/4"
Length 1/2"

Resin content (dry wood basis): 35% solids

Moisture content at pressing (dry wood basis): 7%

Pressing conditions: Temperature 325°F.
Pressure 2500 psi
Curing time 25 minutes
Cooling 5 minutes

Flapreg can be readily worked with highspeed steel or carbide tools. It sands easily, takes a high polish, and needs no varnish or other finish for most applications (21).

The comparison between the properties of reconstituted boards and a common wood such as pine, are as follows:

1. According to specific gravity, the softboards (semi-rigid, and rigid) have a specific gravity between 0.02 - 0.40; intermediate-density 0.40 - 0.80; hardboards (untreated and treated), 0.88 - 1.15; special densified hardboard, 1.35 - 1.45; shaving board, 0.40 - 1.10; and particle board (low-density and high-density), 0.40 - 1.05; but pines have specific gravity between 0.34 - 0.61. This shows that the reconstituted boards, except semi-rigid insulation board, have a specific gravity nearly the same or more than pines. That means the stiffness, hardness, and weight of reconstituted boards is the same or more than pines.
2. According to thermal conductivity, pines have an average coefficient of thermal conductivity between 0.72 - 0.94, but softboards (semi-rigid and rigid) have coefficients of 0.24 - 0.40; intermediate-density, 0.40 - 0.80; hardboards, untreated 0.80 - 1.40, treated 1.50; special densified 1.85; and shaving boards and particle boards 0.40 - 0.80. Thus the softboards are the better insulators than pines. The thermal conductivity of other reconstituted boards is nearly the same or more than pines.

3. In reference to other physical properties, such as modulus of rupture, modulus of elasticity, tension and compression strength values, pines have such properties nearly the same as hardboard, shaving board and particle board.

C. USES OF WOOD RECONSTITUTED BOARD

The uses of hardboards, shaving boards and particle boards are similar in many respects to plywood. These boards also may be worked with ordinary wood working tools; they can generally be sawed, drilled, routed, nailed, scored, bent, shaped, laminated, and surface treated with stains, varnishes, paints and enamels.

1. Softboards having a low density are frequently used for thermal insulation purposes and also to deaden noises and undesirable sounds. Such boards are classified as being either semi-rigid or rigid.

a. Semi-rigid softboard, made from wood fibers, has the lowest density of all the wood reconstituted boards,
and weighs from 1.5 to 9 pounds per cubic foot. It is often used in bus and truck bodies, passenger automobiles, railroad cars, refrigerators, and other applications where vibrations make it undesirable to use loose-filled insulating material.

b. Rigid softboard, produced from wood fibers, weighs from 9 to 25 pounds per cubic foot. It is widely used in the housing field and in other building construction, but is not as resistant to scuffing or abrasions as intermediate density softboard. Its most common use is as facing material for interior walls, for ceilings, sheathing, roof insulation and structural roof decks. Its use as acoustical tile is also increasing.

2. Intermediate-density softboard, made from wood fibers, weighs from 25 to 50 pounds per cubic foot. It is extensively used in housing construction and in other buildings where a somewhat stronger quality board is desirable and excellent insulating properties are not as necessary. It ordinarily is used for interior facing and sheathing purposes.

3. Hardboard, made from wood fibers, weighs from 50 to 70 pounds per cubic foot. It is used wherever a material must have more of the characteristics essential for structural applications, or wherever hard-wearing surfaces are desired. Hardboard is being used more and more as a construction material because it is available in larger sizes, with high strength, with hard and smooth surfaces, and with uniform density,
thickness, and color. Then, too, hardboard often is bent into various shaped items. Hardboard has many of the same uses as thin plywood and sometimes it is even used as a substitute for metal.

4. Shaving board may be used as an alternate for solid lumber for numerous purposes in building construction. Many of its applications are similar to those found for plywood.

Such boards are being used successfully in furniture making and in building construction, especially for interior paneling and doors. The board is generally faced with veneer when used in furniture. It also is being used in the building of railroad freight cars.

Flakeboard, shredboard, and waferboard are used for interior walls, doors, and also furniture.

5. Particle board is being used in increasing quantities as core material to be faced with veneers for making furniture tops and panels and doors. It is being utilized in building construction as well. Plastic-surfaced countertops and cabinet sections frequently use wood particle board as a core material. A large amount of unveneered particle board is used for closet doors and a certain amount is used as a core material for household flush doors.

6. Flapreg in board or sheet form may be used as the excellent material for table, counter, and furniture tops, cutting boards, shelves, and floor tile. In machining to final form, it can be used in electric parts, gears, cams, metal spin-
ning chucks, patterns, punch and die sets for sheet metal forming, cutlery handles, saw handles, golf club heads, and brush handles. In molded form, Flapreg should be adaptable to trays, drain boards, chair seats and backs, toilet seats, and other simple shapes not requiring much flow (21).

New uses are being found almost daily for all reconstituted wood products.
CHAPTER III

WOOD RAW MATERIALS

Although some board manufacturers use cordwood, pulpwood, or other whole wood, most of the present plants use wood residues from other conversion operations and their primary sources of raw materials. The term "wood residue" denotes any wood material which does not lend itself to conversion into normal production items in logging, lumbering, milling, and wood-working operations, because of economic reasons or because of production reasons. Sometimes more specific terms are used such as "logging residue", "lumbering residue" or "milling residue", to denote the source of the "wood residue".

A. WOOD RESIDUE CLASSIFICATION

The variety of wood reconstituted boards being manufactured today is so extensive and the processes used vary so greatly, that many kinds of wood residue could be utilized, depending on the market demand for finished boards of the various types, and with the various properties within each type.

In classification of wood residue, sometimes the wood remnants produced at sawmills and veneer plants are known as "primary manufacturing residues". All residues beyond this point, i.e., those occurring in furniture, plywood and miscellaneous wood using industries, are termed "secondary manufacturing residues" (10).
According to Winters (25), residual wood may be classed as follows:

1. Logging waste
   a. Trees left in the forest because of excessive cull or low quality.
   b. Cut tree fragments left in the forest for the same reasons listed in (a).
   c. Trees which have been damaged in logging operations.

2. Manufacturing waste
   a. Wood material which is lost in secondary manufacturing operations (furniture, plywood).

A classification which mentions the specific forms of residues occurring at the various sources is listed below (26):

1. Species of timber not generally used for lumber production.

2. Logging residues, tree tops, broken sections, limbs, culls and thinnings.

3. Sawmill residues: bark, slabs, trimmings, edgings, sawdust, shavings, and broken pieces.


Wood residue may be classified broadly in two categories, "coarse" and "fine". Coarse residue consists of slabs, edgings, trimmings, mis-cuts, cull pieces, and veneer cores, and other such material suitable for re-manufacture or chipping. Sawdust, shavings, wood substance lost in debarking, chipper rejects, veneer clippings, and other
material generally too small for chipping is referred to as fine residue (25).

Sawdust, slabs, edgings, end trim, shavings and cull lumber are by-products of sawmill operations. Concentration yards accumulate an assortment of end trim, shavings and cull lumber. Veneer plant residues include sawdust, bolt trim-off, veneer scrap and cores. Furniture plant operations produce sawdust, and trim, edgings and shavings (17).

There are definite advantages to be gained by using some forms of residues in preference to others in reconstituted board manufacture depending on the kind of board and the process.

B. CHOICE OF RESIDUAL WOOD

The choice of the raw material, in any particular instance, is limited to that type of residue which is economically available in sufficient and permanent supply in the locality. The economic availability of the residue, will in part determine the type of board to be manufactured (6).

It is recognized that not all wood residue is suitable for hardboard production. In some processes the bark must be removed, but in some board making processes, all or part of the bark can be used. This is true for some fiber board processing and certain particle board production. The end use of the wood composition board is the determining factor as to whether bark may be admitted in the manufacturing process.

The factors to be considered in choosing the wood material sources can be broadly classified as follows (10):
1. Wood residue availability
   a. Quantity of residue available
   b. Permanence of ample residue supply
2. Types of residue
   a. Species
   b. Form
3. Residue costs
   a. Price of wood residues at their source
   b. Handling and transportation costs to point of use
   c. Processing required

Wood Residue Availability

The gross amount of wood materials required (per unit of board produced), in a reconstituted board manufacturing system is dependent on:

1. Quantity of undesirable matter present in the raw material.
2. Moisture content of the residue.
3. Loss of wood as "fines" (undersize particles produced during reproduction).
4. Resin and additive content.
5. Density of finished product.
6. Board loss, if any, in edge trim and surface finishing.

Undesirable Matter

The most prevalent of undesirable substances which accompany wood residue are tramp metal, dirt rotted wood, and bark. These must
be removed to maintain a high level of quality in reconstituted board, and to reduce "in-process" costs. In some fiber board processing and certain particle board production, all or part of the bark can be used depending on the end use of the wood reconstituted board. Slabs may possess up to 30 per cent bark by weight (4).

**Moisture Content of Wood Residue**

This is likewise an important consideration in estimating the amount of wood required for production at a certain level. The moisture content of kiln-dried residues such as furniture plant wastes approximates 6 to 10 per cent (15). Moisture content of this material is within the desired range for particle board production. If wet wood is used, it will require the consumption of a heavier amount of wood than kiln-dried residues, to produce an equivalent amount of board. The optimum moisture content of the felt or mat at the time of pressing in dry process boards is about 12%.

**Loss of Wood as "Fines"**

In grinding or chipping the residue to obtain the desired particles, a loss of wood material occurs which varies with size, species, moisture content, and type and amount of chipping and grinding. Besides producing particles which are suitable, reduction operations also produce particles that are too large or too small for use without further processing, it must also produce particles which are suitable. The oversize pieces are reprocessed, but the undersize particles, termed "fines", are usually dumped or sent to the boiler. Loss of fines that result when dry slabs and edgings are used, may amount to from 10
to 20 per cent, on an oven dry weight basis. The fines are sometimes used in three-layer boards as surface layer material.

Resin and Additive Content

The quantity of resin and additives used in the board also affect the amount of wood material included per square foot of end product. The wood in most instances constitutes roughly 80 to 90 per cent of the total weight of the board; the remaining 15 per cent of the composition is made up of resin, various additives, and moisture. Resin and additive content rarely will exceed 8-10% except in some specialty products; it is usually about 6% or less.

Board Loss

Trimming operations, where performed, may result in an additional loss of raw materials. Some captive operations find applications for the trim in their parent plant. Others route the trim to the raw material supply for reprocessing into particle board, and still others scrap it. If it is scrapped, the absolute loss will depend on the width of trim taken in relation to the size of the boards produced.

C. RESIDUE COSTS

Wood residue cost constituents, as previously mentioned, are, (a) cost of wood residue at point of occurrence, (b) handling and transportation costs, and (c) preparation costs.

The sale values of various forms of residue occurring at manufacturing operations in North Carolina, which were surveyed by the U. S. Forest Service, cooperating with the North Carolina Department of Con-
servation and Development, are listed in Table 3 (17). Estimates were also obtained covering the cost of this residue if delivered up to 30 miles away to a concentration yard.

Since cull lumber and veneer cores represent coarser forms of residue, and have higher current utility values, handling and transportation costs represent a smaller percentage of the total cost than is the case with fine residue.

As illustrated in Table 3, handling and transportation costs may amount to a considerable portion of the residue cost. Forest residue resulting from logging operations has definite drawbacks in this respect. Its cost may be high because of gathering and concentrating it at some central location for use. This is accentuated by the wide scattering of forest waste as compared with manufacturing waste (25).

Residue preparation procedure and equipment are dependent on the form in which the residue is obtained. Influenced are the cleaning, reduction, drying and screening operations.

Also an important consideration from an economic standpoint in material preparation is material containing bark. If this bark is to be included in the board, then, the problem of removal does not arise. Where the bark is not desired in the board, however, removal may be rather expensive. When bark removal is to be performed, it is usually less expensive to buy and process "barky" slabs than whole logs (16).

D. INTEGRATED OPERATION

Disposing of wood residue is a common problem of enterprises engaged in logging, sawmill and wood-fabrication operations. Therefore,
TABLE III
REPORTED SALE VALUE OF WOOD RESIDUE IN NORTH CAROLINA (17)

<table>
<thead>
<tr>
<th>Type of Residue</th>
<th>Unit of Measure</th>
<th>Small Sawmills</th>
<th>Large Sawmills</th>
<th>Veneer Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At Mill</td>
<td>At Conc. Yd.</td>
<td>At Mill</td>
<td>At Conc. Yd.</td>
</tr>
<tr>
<td>Sawdust</td>
<td>$ per Ton</td>
<td>$ 1.01</td>
<td>$ 5.06</td>
<td></td>
</tr>
<tr>
<td>Slabs</td>
<td>$ per Cord</td>
<td>1.58</td>
<td>6.20</td>
<td>$ 3.38</td>
</tr>
<tr>
<td>Edgings</td>
<td>$ per Cord</td>
<td>1.53</td>
<td>6.00</td>
<td>4.17</td>
</tr>
<tr>
<td>End Trim</td>
<td>$ per Cord</td>
<td>2.23</td>
<td>6.56</td>
<td>3.38</td>
</tr>
<tr>
<td>Shavings</td>
<td>$ per Ton</td>
<td>1.12</td>
<td>6.00</td>
<td></td>
</tr>
<tr>
<td>Cull Lumber</td>
<td>$ per M.Bd.Ft.</td>
<td>16.78</td>
<td>20.32</td>
<td>23.50</td>
</tr>
<tr>
<td>Cores</td>
<td>$ per Cord</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
a wood reconstituted board plant offers an ideal set-up for utilizing residual wood. The enterprises producing wood residue may either dispose of their "waste material" to independent wood reconstituted board plants or set up their own board plants.

In fact, a number of the reconstituted board plants are operated in conjunction with lumbering, sawmill or wood-fabrication operations. This condition is often ideal, since a supply of residual wood is readily available at low transportation cost. The economic advantage of adequate supplies of wood raw material at relatively low cost, and large-volume production of wood reconstituted boards, are strong factors favoring the continued growth of board manufacturing.

E. WOOD RESIDUE IN THE U.S.A.

A survey of wood residue on a national scale was made in 1944 and the results were released in 1948 under the title, "Wood Waste in the United States, Reappraisal Report No. I". The following material taken from this report was presented at the 1948 National Annual Meeting of F.P.R.S. (25).

Wood waste included the non-utilized portion of sound woods cut from trees at least 5 inches d.b.h. (diameter at breast height). Upper stems of conifers to a 1 inch top, and hardwood limbs to the same diameter (minimum), as well as sound parts of trees that were damaged but left in logging and slash disposal operations were also included. The report embraced manufacturing residues, such as sawdust, shavings, slabs, edgings, trimmings, etc. Total annual waste on this basis was estimated at 6.5 billion cubic feet. Of this, 2.5 billion cubic feet
was utilized as fuel. The balance, or 4 billion cubic feet, was available for utilization. Of the available waste reported, approximately 75 per cent, by volume, remained in the forest as logging residues.

Further information concerning this subject was published by the Pacific Power and Light Company (24). The reference source used here was the U. S. Forest Service publication, "Timber Resource Review", released October 17, 1955. The publication reported the results of a 1952 survey (10).

According to this source, wood residue in the United States and coastal Alaska in 1952 was comprised of approximately 3.4 billion cubic feet of plant residue and 1.4 billion cubic feet of logging residue, of which nearly 3 billion cubic feet were unused. Furthermore, one-third of the timber cut for lumber was not used either for fuel or any other purpose.

Sources and uses of plant residue in 1952 are shown in Figure 9 (24).

Statistics on plant residue by geographic regions are tabulated in Table 4 (24), giving a break-down between the volumes of "coarse residue" and "fine residue" produced in 1952 and unused.
SOURCES OF PLANT RESIDUE IN 1952

<table>
<thead>
<tr>
<th>Source</th>
<th>Million Cubic Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumber</td>
<td>2,950</td>
</tr>
<tr>
<td>Veneer</td>
<td>205</td>
</tr>
<tr>
<td>Pulp</td>
<td>170</td>
</tr>
<tr>
<td>Other</td>
<td>89</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3,414</strong></td>
</tr>
</tbody>
</table>

USES OF PLANT RESIDUE IN 1952

<table>
<thead>
<tr>
<th>Use</th>
<th>Million Cubic Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
<td>1,752</td>
</tr>
<tr>
<td>Fiber</td>
<td>110</td>
</tr>
<tr>
<td>Other</td>
<td>170</td>
</tr>
<tr>
<td>Unused</td>
<td>1,382</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3,414</strong></td>
</tr>
</tbody>
</table>

Coarse Residue: Slabs, Edgings, Trimmings, Veneer Cores, etc.
Fine Residue: Sawdust, Shavings, Veneer Clippings, etc.

FIGURE 9

SOURCES AND USES OF PLANT RESIDUE IN 1952, UNITED STATES AND COASTAL ALASKA (21)
## TABLE IV

### PLANT RESIDUE IN 1952 BY REGIONS, UNITED STATES AND COASTAL ALASKA (24)

IN MILLIONS OF CUBIC FEET

Determined from Survey by United States Forest Service
Timber Resource Review

<table>
<thead>
<tr>
<th>GEOGRAPHIC REGION</th>
<th>RESIDUE PRODUCED</th>
<th>UNUSED RESIDUE</th>
<th>RELATION TO PRODUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COARSE*</td>
<td>FINE</td>
<td>TOTAL</td>
</tr>
<tr>
<td>NORTH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New England</td>
<td>68</td>
<td>58</td>
<td>126</td>
</tr>
<tr>
<td>Middle Atlantic</td>
<td>79</td>
<td>64</td>
<td>143</td>
</tr>
<tr>
<td>Lake States</td>
<td>61</td>
<td>49</td>
<td>110</td>
</tr>
<tr>
<td>Central States</td>
<td>54</td>
<td>34</td>
<td>88</td>
</tr>
<tr>
<td>Plains States</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>TOTAL NORTH</td>
<td>264</td>
<td>207</td>
<td>471</td>
</tr>
<tr>
<td>SOUTH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Atlantic</td>
<td>241</td>
<td>263</td>
<td>504</td>
</tr>
<tr>
<td>Southeast</td>
<td>299</td>
<td>364</td>
<td>663</td>
</tr>
<tr>
<td>West Gulf</td>
<td>124</td>
<td>184</td>
<td>308</td>
</tr>
<tr>
<td>TOTAL SOUTH</td>
<td>664</td>
<td>811</td>
<td>1,475</td>
</tr>
<tr>
<td>WEST</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pacific Northwest</td>
<td>436</td>
<td>536</td>
<td>972</td>
</tr>
<tr>
<td>California</td>
<td>242</td>
<td>130</td>
<td>372</td>
</tr>
<tr>
<td>Northern Rocky Mtn</td>
<td>31</td>
<td>50</td>
<td>81</td>
</tr>
<tr>
<td>Southern Rocky Mtn</td>
<td>21</td>
<td>17</td>
<td>38</td>
</tr>
<tr>
<td>TOTAL WEST</td>
<td>730</td>
<td>733</td>
<td>1,463</td>
</tr>
<tr>
<td>Total United States</td>
<td>1,658</td>
<td>1,751</td>
<td>3,409</td>
</tr>
<tr>
<td>Coastal Alaska</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>UNITED STATES and COASTAL ALASKA</td>
<td>1,661</td>
<td>1,753</td>
<td>3,414</td>
</tr>
</tbody>
</table>

*Coarse residue consists of: slabs, edgings, trimmings, miscuts, cull pieces, veneer cores, and other cull material suitable for re-manufacture or chipping.

*Fine residue consists of: sawdust, shavings, wood substance lost in barking, chipper rejects, veneer clippings, and other material generally too small for chipping.
<table>
<thead>
<tr>
<th>Region</th>
<th>States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle Atlantic</td>
<td>New York, Pennsylvania, New Jersey, Delaware, Maryland, West Virginia.</td>
</tr>
<tr>
<td>Lake States</td>
<td>Michigan, Wisconsin, Minnesota.</td>
</tr>
<tr>
<td>Central States</td>
<td>Iowa, Missouri, Illinois, Indiana, Ohio, Kentucky.</td>
</tr>
<tr>
<td>Plains States</td>
<td>North Dakota, Central and Eastern South Dakota, Nebraska, Kansas, Western and Central Oklahoma, Western and Central Texas.</td>
</tr>
<tr>
<td>South Atlantic</td>
<td>Virginia, North Carolina, South Carolina.</td>
</tr>
<tr>
<td>Southeast</td>
<td>Tennessee, Mississippi, Alabama, Georgia, Florida.</td>
</tr>
<tr>
<td>Western Gulf</td>
<td>Arkansas, Louisiana, Eastern Texas, Eastern Oklahoma.</td>
</tr>
<tr>
<td>Northern Rocky Mountain</td>
<td>Montana, Idaho, Wyoming, Western South Dakota.</td>
</tr>
<tr>
<td>Southern Rocky Mountain</td>
<td>Nevada, Utah, Colorado, Arizona, New Mexico.</td>
</tr>
</tbody>
</table>
CHAPTER IV

MANUFACTURING PROCESSES

Wood reconstituted board manufacturing is frequently considered as being an adaptation of the paper-making process. This similarity prevails for the "wet process" method wherein the raw material is reduced to a pulp, formed into a mat under water suspension, and finally pressed. However, in the "dry process", air replaces water in forming the mats, and the process is usually a modified "batch" rather than a continuous one.

A. GENERAL MATERIALS PREPARATION

The methods used in preparing the wood component materials are dependent on the type of raw material to be processed as well as the type of board to be produced. A knife hog or a special type of shaving or flake machine is normally used for the production of coarse chips or shavings from large-size materials such as pulp-wood, or factory wastes such as slabs and edgings.

The bark is normally removed by a debarker before this primary reduction operation, but for some types of board it is allowed to remain. At the present, numerous log and slab debarkers have been developed. They may all be classified as either mechanical or hydraulic. Mechanical debarkers may be further classified as: 1. cutterhead-fixed or floating; 2. disk; 3. cambium; and, 4. friction.
In producing shaving or particle board, the coarse chips or shavings are next dried to a moisture content of approximately 5 percent in a special type of dryer. The drying of materials for shaving or particle board can be accomplished by a variety of means and many machines are being specifically designed for this purpose. The various types presently used might be listed as: 1. rotary drum dryer; 2. belt dryers; 3. circulation dryers; 4. plate or turbo dryers; 5. contact dryers; and, 6. suspension dryers (10).

If coarse chips are first produced, they are usually reduced further in size by means of a hammer-mill disk grinder or a similar type of disintegrator.

The materials are next passed into a series of vibrating or rotary screens, carefully classified according to size and then normally stored in separate bins before further processing.

The materials, in the correct particle size distribution, are then metered by weight to a mixer, or blender, where each chip is coated uniformly with the additives. The most common mixers in use today are of two types: 1. the batch type; and, 2. the continuous type. The batch type, or periodical type, mixer is probably more widely used.

Production of Wood Fibers

In manufacturing conventional fibrous hardboard the size of the residual wood used is generally large enough to permit chipping. Ordinarily, sawdust, shaving, and small wood scraps that cannot be chipped are not suitable to produce hardboard, although shavings have been successfully used. The wood is usually reduced to fiber for hardboard production by one of two methods: steam exploding, or mechanical defi-
brating and refining.

With the steam exploding method the wood residue is converted to chips by cutting wood diagonally across the grain. The chips average about 3/4 inch (L) by 1 inch (W) in size and 1/8 inch thick. The wood chips are cooked with high pressure steam in heavy steel vessels. This treatment softens the lignin cementing layer between the fibers. Near the end of the cooking cycle the pressure is raised to about 1,000 pounds per square inch, and then suddenly released. This causes the steam imprisoned in the wood chips to explode the wood into separate fibers and bundles of fibers (Masonite steam-gun method).

With the mechanical defibrating method, wood chips are also used. They may be softened by cooking with steam or water at high temperatures and pressures to weaken the fiber bonds. Then the wood pieces are rubbed apart by metal discs in attrition mills to produce a coarse fiber product (Asplund Defibrator).

Whether the fibers are steam exploded or mechanically defibrated they are generally processed further through mechanical disc-type refiners, (Bauer, Allis-Chalmers, Sprout-Waldron). Any coarse splinters and slivers are removed during the washing and screening operations. In some cases, the refiners alone are used in either dry or wet grinding operations.

No chemical digestion or bleaching is done in the defibrating and refining steps; they are simply mechanical actions.

With the stone grinding method, fibers are obtained from un-chipped bolts of pulp wood as a result of abrasive action of the stone revolving in water with the wood pressing against it. The basic pro-
procedure is similar to that in making groundwood pulp for paper.

The fiber for softboard may be made by mechanical processes such as those used for hardboard but more frequently a chemical or semi-chemical process is used.

The chemical process in producing a fibrous material suitable for the manufacture of softboard also requires the wood in chips (in the case of wood). The chips are screened to a uniform size and are cooked in digesters or special retorts with chemical solutions and steam pressure. The cook is generally not as complete as in the case of pulp for paper, and the cook is commonly followed by a further refining of the fibers by mechanical means. This being the case many processes could properly be termed "semi-chemical".

The fiberized material may be mixed in varying proportions with one or more of the following: repulped waste paper, hydrated pulp stock, and refined pulpmill screening. Moisture, fire, and vermin retardant materials and sometimes bonding agents are added.

Cutting Wood Shavings

In manufacturing shaving board, the bark-free wood is cut by special machines, as mentioned before, to produce thin flake-like shavings with the long axes of the botanic fibers being parallel to the surface of the flakes. Moisture may be added to the wood in order to obtain smoothly cut, whole shavings. This procedure lengthens the life of the cutting knives and also reduces the amount of "fines" generated.

In Europe the wood shavings vary greatly in width, but generally range in length from 1/2 to 1-1/2 inches, and have a thickness of about
There are two distinct types of shaving or flake machine—disk and cylindrical.

Making Wood Particles

In manufacturing particle board, the wood particles may range in size from pulverized material to granular chips of different sizes (24). The wood particles are produced mechanically by various kinds of cutters and mills. Wood residue may be hogged, chipped, hammermilled or ground to produce these small particles. In all cases, care is exercised to avoid serious damage to the fibers, since that reduces the strength of the finished product. A high moisture content in the wood residue being worked helps to reduce fiber damage and the percentage of "fines" produced.

The disintegrated wood is screened to obtain particles of uniform size and shape. Over-sized particles are either re-run to be reduced to proper size, or discarded. The "fines" (under-sized particles) are frequently discarded, although in a few plants layers of "fines" are concentrated at the surface of the particle board, resulting in a smoother finish.

The range of particle sizes that can be utilized in making any particular board is limited, since there is a tendency for different sized particles to segregate and stratify, thereby producing a board which will warp. This is caused by variations in density between the board’s top and bottom surfaces.
B. ADDING BINDING MATERIALS

The rapid advancements made in producing wood reconstituted boards are attributed to a large extent to the progress made by manufacturers of synthetic resins in formulating new resins to meet specific needs of individual board manufacturing processes.

One of the distinguishing characteristics of wood shaving board and particle board, in comparison to fiber-felted hardboard, is that the primary bonding of the wood shavings and wood particles results from the resins or other binders added.

In contrast, the primary bonding of the fibers in hardboard produced by the "wet process" results from the interfeling of fibers and the plasticizing and flow of natural lignin during the heat-press cycle. However, even in making hardboard with the "wet process" a small quantity of resin has proved beneficial.

With the "semi-dry process" and the "dry process" of hardboard production, more of the bonding is attributed to the resin additives, because with a lower moisture content in the mat being pressed there is less flow and plasticizing action of the natural lignin. It is recognized, though, that hardboard can be made by the "dry process" without using resin additives.

The amounts of resin used in making various types of wood reconstituted boards may be generally classified in the following ranges (24):
<table>
<thead>
<tr>
<th>Type of Board</th>
<th>Process</th>
<th>Per Cent Resin Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Softboard</td>
<td>Wet</td>
<td>0 - 1</td>
</tr>
<tr>
<td>Hardboard</td>
<td>Wet</td>
<td>3/4 - 1-1/2</td>
</tr>
<tr>
<td>Hardboard</td>
<td>Semi-dry</td>
<td>1 - 2-1/2</td>
</tr>
<tr>
<td>Hardboard</td>
<td>Dry</td>
<td>2 - 3</td>
</tr>
<tr>
<td>Shaving Board</td>
<td>Dry</td>
<td>3 - 6</td>
</tr>
<tr>
<td>Particle Board</td>
<td>Dry</td>
<td>3 - 6</td>
</tr>
</tbody>
</table>

For certain types of shaving board and particle board the resin content may be as much as 10 to 15 per cent. In making some kinds of three-ply boards the core material may contain from 6 to 8 per cent resin and the surface wood flakes bonded with 9 to 12 per cent of resin; less resin may be used, depending upon the physical properties desired of the finished product.

In making particle board, sufficient resin is necessary to coat the surface of a particle contacting other particles. The smaller the particles, the greater the area of surfaces in a board to be coated with resin, and hence the need for larger quantities of resin.

Since resins represent a costly ingredient in making particle board and shaving board, careful consideration must be given to selecting the proper sized wood particles and wood shavings in order to produce reconstituted boards at the lowest cost possible, and yet have boards with sufficient strength. There is a direct relationship between the size and shape of the wood materials and the percentage of resin needed to obtain certain physical characteristics in reconstituted boards.

The resin binders used in producing wood reconstituted boards are generally "made to order" for particular processes to suit the
process variables and the nature of the raw materials used.

In the "wet-felting" process of making hardboard, a liquid thermo-setting phenolic resin is generally added to the fiber slurry prior to the mat formation. Since this kind of resin is water soluble, it is necessary to precipitate it on the fibers. This is done by adding alum or acid to the fiber slurry so that the resin will adhere to the wood fibers and not be carried off in the water as it drains from the felted mat.

In the "air-felting" (dry or semi-dry) processes of hardboard manufacture, a liquid thermo-setting phenolic resin is also generally used. The resin is usually sprayed on the wood fibers as they are air blown continuously through a blender or mixer. No acids are necessary to precipitate the resin since the fibers are not in a water solution, but a catalyst may be used if the pH of the raw materials so dictates.

In manufacturing shaving board the method of applying resin is very important in order to achieve uniform coating of the wood shavings. Either urea or phenolic resin may be used, but most shaving boards are made with the urea type resin since high water resistance is not usually critical in its employment. Either a batch mixer or a continuous mixer is normally used in applying the resin, usually as a fine spray, to the wood shavings being agitated. The liquid resin's viscosity is controlled to permit fine spraying and yet avoid penetration into the wood shavings.

Waxes, in either a solid state or an emulsion, are generally added to wood reconstituted boards as "sizing" during their manufacture in order to reduce the water absorption by the finished product and to
secure a more even coating of the materials with resin without excessive penetration of the particles. In some instances especially formulated water repellants are added.

Wax emulsions or the solid petrolatums (hot sprayed) may be used for urea resin bonded reconstituted boards; however, under normal mill usage methods, the wax emulsions usually give better sizing properties than the solid petrolatums to phenolic bonded particle boards. The American-Marietta Co. (3) has developed methods by which the solid petrolatums may be used with good sizing efficiency.

These sizing materials are added in amounts of from 1/2 per cent to 1-1/2 per cent. The wax emulsions are usually added with, or just after, the resin. The petrolatums are sprayed on the particles as a hot melt.

No extenders or fillers are normally recommended with either the urea or the phenol formaldehyde resins. In a few instances, the use of an extender or filler may be beneficial because of a particular mill condition.

C. MAT FORMATION

Wet Mat Formation

In manufacturing hardboard with the "wet process", water is used as the felting medium in forming mats of wood fibers. Water conveys the fibers throughout each step, from their production to the formation of mats on screens. The water also facilitates the distribution of any resin or chemicals which may be added for better cohesion and water resistance of the finished board (24).
Principal advantages claimed for plants using the continuous, "wet-felting" or "wet process" method of making boards are: 1. uniformity of sheet formation; 2. volume production is high.

Wet-formed boards may either be produced continuously or one at a time (batch-wise). When formed continuously, the wet matted material passes over a Fourdrinier type wire screen or rotary screen to permit excess water to drain off. The name is derived from the Fourdrinier Brothers in England who perfected such a machine in the early days of paper-making. The fibers were poured out in a stream of water on a long wire screen looped over rollers, permitting the water to drain off as the screen moved along the rollers.

Ralph Chapman pioneered the "wet-felting" batch method in 1916 at his plant in Corvallis, Oregon. The type of raw material is similar to that used in other wet processes, and the finished product is essentially the same. The difference is that the wet mats are formed separately in a four-foot by eight-foot forming box. A vacuum is applied in the lower part of the box to suck water out of the stock, leaving a thick mat. The mat is prepressed (cold) to remove excess water and reduce its thickness before being placed in the hot-press.

According to the Forest Products Laboratory (18) this batch type is suitable for a daily production of from 25 to 50 tons of board.

**Dry and Semi-Dry Mat Formation**

The principal difference in producing hardboard with the "dry process" or the "semi-dry process" is that the wood fibers are fairly dry and are deposited in a forming box by air streams (air-felting) rather than by water. The fibers are then compacted (prepressed) into
mats by roller presses or belt presses before the final hot pressing.

As a general rule, mats having a moisture content of less than 15 per cent before pressing are said to be formed by the "dry process", and those having up to 50 per cent moisture are classified under the "semi-dry process". Naturally, mats having a very high moisture content are classified under the "wet process" category (24).

When the mats have a low moisture content they can be heat-pressed with presses having polished plates on both sides, resulting in boards having two smooth sides.

The Oregon Forest Products Laboratory studies show that water requirements in a plant using the "dry-felting" process might be as low as 300 to 400 gallons per ton of board produced. On the other hand, with the "wet-felting" process of manufacturing hardboard, the amount of water needed may be 20 to 30 times greater. On an average, 10,000 gallons of water are required to produce a ton of hardboard with the "wet-felting" process.

Advantages to be gained with the dry or semi-dry processes, as opposed to the wet processes, are: 1. less water required; 2. less pollution of streams; 3. lower investment costs due to the rather expensive pumping equipment and moving screen associated with the wet process; and, 4. shorter press cycles. Another advantage over the continuous wet process is the ability to produce a board with two smooth sides without the necessity of installing expensive dryer equipment, repressing or machining.

The dry or semi-dry hardboard processes also posses drawbacks by comparison with the wet processes. For example, resin requirements are
greater (24) and press-plating pressures must be higher (1500 psi maximum) (1). In addition, unit manufacturing costs are higher for these processes due to the difference in production volume.

Both shaving board and particle board are made by the "dry-process" in that neither the wood shavings nor the wood particles are conveyed in a water solution. Rather they are moved about by mechanical devices or air streams. The mats are usually "gravity-formed", that is, the wood material making up the mat falls down on the mat-forming machine through the force of gravity, rather than being blown out by air streams. The term "gravity-felting" would be incorrect when applied to particle board or shaving board manufacture since the wood materials in these boards is not subject to a felting action, as is the case with the wood fibers in making hardboard.

In making three-ply board, the bottom surface of wood face material is laid down first, then the wood material for the core, and finally the wood face material for the top surface.

The mats may be formed continuously or batchwise for either shaving board or particle board.

Flow diagrams of three typical board making processes are illustrated in Figure 10 (24), namely: "wet-felting" fiber process; "air-felting", semi-dry, or dry fiber process; and "gravity-formed" dry particle or shaving process.

D. PRE-PRESSING THE FORMED MAT

Usually the formed mats are pre-pressed (cold) after leaving the mat-forming machine to consolidate the wood mat before it is placed in
FIGURE 10

TYPICAL FLOW DIAGRAMS OF THREE MAT-FORMING PROCESSES (21)
the hot-press. This decreases the thickness of the mats, thereby permitting a reduction of the openings between the plates of the hot-press. Pre-pressing also gives firm compact edges to the formed mat so that it will not crumble upon hot pressing.

There are, in general, two ways in which mats are prepressed. One method utilizes a system of loaded rolls, between which the caul plate with its mat is passed. The other method is by the compression of the mat between the platens of a single-opening hydraulic cold press (10).

E. PRESSING, DRYING, CURING

In manufacturing softboard (insulation board) the matted material is generally roller-pressed without the application of heat, although in some instances a heated roll is used. Drying may be accomplished by passing the board through a continuous tunnel dryer, such as the Coe-type tunnel dryer, having a temperature as high as 300°F. Other methods of drying are to use either moving or stationary multiple-deck hot plates, or multiple-deck continuous roller dryers.

In manufacturing hardboard, the mats, whether wet-formed or dry-formed, are platen-pressed with external heat applied. In some plants the wet-formed mats are pressed while still wet; in others, they are prepressed or dried in tunnel type dryers to remove most of the moisture.

When wet-pressed, a screen is used on the under-side of the mat to permit moisture to escape during the hot-pressing. Thus, a screen impression results on the bottom surface of the finished hardboard.
However, the top side of the board comes out smooth since it is pressed against a smooth pressing plate. This top pressing plate may be made up with a specific surface pattern, such as leather graining, and thereby impart a corresponding finish to the board's top side.

A screen may be required even when the mats are produced by air-felting, if they are pressed at a high moisture content in order to improve the flow and plasticizing action of the natural lignin and to permit the moisture to escape as steam rather than to have it pocket within the board.

In manufacturing shaving board and particle board, it is not customary to dry the mats before hot-pressing, since the dry-formed mats usually have a low moisture content.

According to the pressing processes for manufacturing wood reconstituted board, they can be classified as follows (10):
1. Single or multi-platen hydraulic hot-plate press.
2. Extrusion between heated plates.
3. Continuous pressing process.

**Hydraulic Hot Plate Press**

This type of process is most commonly used in making hardboard, particle board and shaving board in this country and abroad. A weighed amount of adhesive-coated wood material is mechanically spread on a metal caul of the approximate size of the plates in the hot press. If a homogeneous-type board is to be pressed, the caul is filled in one operation. If a sandwich-type board is to be prepared, the materials are applied in separate layers in successive operations. The loose mat is compacted by passing the loaded caul through pressure rollers or by
means of a cold hydraulic pre-press which applies a uniform pressure to the entire mass. The mat of compacted material is then transferred to a hydraulic hot-plate press. This press may contain from one to thirty openings. The usual number of openings in each press is 20, although there are some presses in use with only 8 to 10 openings, and others with 30 openings. One plant uses a 7-opening press, another plant operates a 4-opening press. Several proposed small plants are considering 6-opening presses. The presses are usually of two surface sizes, to produce boards 4 feet by 8 feet, or 4 feet by 16 feet. All openings are filled simultaneously by means of a mechanical loader. Final form is given the mass by the application of heat and pressure transmitted through heated platens. The amount of pressure applied varies with the type of product desired. The pressures may range from 50 to 750, or even 1,000 pounds per square inch. For example, during a hot-press cycle in making hardboard with the wet process, the initial pressure might be 750 psi for about one minute then a reduction in pressure for a minute or more to allow the moisture in the mat to escape, then an increase in pressure to some intermediate point for several minutes for final curing. Press temperatures usually range from 315°F. to 400°F. in manufacturing hardboard; and, from 285°F. to 330°F. in manufacturing particle board. The press temperature in making shaving board is about 285°F. when manufacturing boards with urea resin. In producing 5/8 inch board the complete pressing cycle may be 12 minutes. The press is then automatically opened and unloaded. The pressed boards are removed from the cauls and stacked, except in making hardboards, in which case they are commonly passed through a
humidifying chamber after hot-pressing. Figures 11 and 12 (10) are schematic diagrams that illustrate these processes.

**Extrusion Pressing Process**

The extrusion press method of making particle board is used by a number of plants in the United States and abroad. It was developed to provide a continuous flow of product. This method of pressing is well suited to a continuous operation of producing wood reconstituted board.

This process is somewhat simpler from the mechanical standpoint than the hot-plate press process just described. As the name implies, the adhesive-coated particles are forced between two stationary heated plates by means of a reciprocating ram. After each forward stroke, as the ram withdraws from the extrusion chamber, another charge of coated particles is fed into position. Compactness of the charge is produced as a result of forces developed between the ram and the frictional resistance of the wood particle mass between the platens. The thickness of the product is determined by the distance between the platens, and the production rate is influenced by the length and temperature of the platens. The board is extruded as a continuous sheet which is cut to length by a traveling cross-cut saw. In Figures 13 and 14 (10) are shown the schematic diagrams of these processes. Extrusion may be horizontal or vertical in variations of this process, producing boards with correspondingly differing fiber alignment in relation to the axes of the board.

Advantages claimed are that the extruded product has a uniform density and a constant thickness, and changes can be made quickly and easily as required. Also, the extruded material may be formed into
FIGURE 11

SCHEMATIC DIAGRAM OF THE MILLER-HOFPT MULTIPLATEN CHIP
BOARD MANUFACTURING PROCESS (10)
FIGURE 12

SCHEMATIC DIAGRAM OF A MULTIPLATEK PROCESS FOR THREE-LAYER BOARD (10)
FIGURE 13

SCHEMATIC DIAGRAM OF THE KREIBAUM VERTICAL EXTRUSION PROCESS (10)
FIGURE 114

SCHEMATIC DIAGRAM OF THE HORIZONTAL EXTRUSION PROCESS (LANEWOOD) (10)
special shapes, such as fluted or irregular surfaces, and no edge trimming is necessary. Furthermore, the cost of such equipment, in terms of unit capacity, may be less than for multi-platen hot presses.

The expansion in thickness is said to be less for some extruded boards than for boards made by the conventional hot-press methods, but the dimensional change in the extruded direction is greater (24).

There is a mechanical disadvantage of the extruded material itself, in that the long axis of individual wood particles lie perpendicular to the extruded direction. Thus, the product is not as strong in the extruded direction as across it, and the board must be faced with a veneer or other facing material before it is used. Crossbanding with veneer strengthens the board and improves its dimensional stability in the extruded direction.

**Continuous Pressing Process**

A continuous type hot-press has been developed in England for manufacturing particle board (intermediate-density), and patents covering it are either pending or have been granted in at least 18 countries, including the United States (20). The system is unique in that it produces on a continuous basis, a board in which the particles lie generally in a plane parallel to the surface.

It is claimed by the owners that by having the pressing operations continuous, increased plant output results, along with a more uniform product. However, there appears to be a disadvantage of higher initial cost, and possibly higher maintenance cost (24).

In this process, the adhesive-coated particles are placed on an endless, stainless-steel belt which is somewhat wider than the board to
be produced. The particle charge is carried through an electronic field and preheated by radio-frequency waves. The particle charge is then carried under a second steel belt. Pressure is applied to the charge through both of the steel belts by means of steam-heated platens which are shaped in the form of "caterpillar" tracks. The board emerges from this unit in the form of a continuous sheet, and is cut to length as in the extrusion process. Figure 15 (10) shows a schematic diagram of the Continuous Pressing (Bartrev) Process.

F. TREATMENT AFTER PRESSING

**Humidifying**

Most varieties of hot-pressed boards have less moisture in them after pressing than they would normally have in their average end-use applications. In making hardboard, boards are generally passed through a humidifying chamber after manufacturing to increase their moisture content. Usually a relative humidity of at least 80 to 85 per cent and a temperature of approximately 120°F. is maintained in the board humidifying chamber (21).

Some of the stresses produced in the hardboard during the hot-pressing are relieved by humidification. If this were not done under controlled conditions, the board would warp as it picks up moisture from the air. After humidification the board is packaged for shipment.
FIGURE 15

SCHEMATIC DIAGRAM OF THE BARTREV PROCESS (10)
Heat Treating

Experience in Europe indicated that common practice in heat-treating hardboard should be done immediately after the hot-pressing to increase its strength and resistance to moisture. Some of the plants in the United States are reported to also heat-treat their product. It is claimed that the strength of hardboard may be improved 20 to 30 percent by baking it about four hours at 250°F. before final humidification.

Neither particle board nor shaving board is ordinarily passed through a humidifying chamber after hot-pressing.

Special Heat Treatment (Tempering)

When it is desired to produce hardboard for application requiring greater strength, more durable surface, high moisture resistance, or other special properties, it is given special treatment. The range of treatment may vary from simply dipping the board in moisture repellents or similar material, to "tempering" it with oil and heat.

The "tempering" process consists of passing the hardboard through a bath of drying oils or other chemicals and then baking it until the oils diffuse throughout the board and are stabilized chemically thereby improving the board's strength and resistance to water.

It is not customary to use such a process treatment in manufacturing particle board, shaving board, or softboard.
Special Finishes

There are various ways to finish the different kinds of hard surfaced boards made from wood residue. They may be sanded, stained, dyed, painted, grooved, perforated, tongued and grooved, corrugated, embossed with specific patterns, scored for tile effect, termite treated, or otherwise processed. The reconstituted board also may be veneered with grained wood, plastic material or metal sheeting.
CHAPTER V

PROCESS AND PRODUCT VARIABLES

The wood-using industry is one of the world's largest and most important industries. Research and development are very necessary for the new products. Research must continue to evaluate each variable while keeping in mind that production techniques are of necessity far removed from laboratory experiments. The following chapter discusses the results of existing research, and the complicated array of process variables encountered in the production of reconstituted board products.

A. WOOD SELECTION AND PREPARATION

Wood Species

The effect of wood species on reconstituted board is a question frequently raised upon preliminary selection of material for a process. There are certain variations among species which have some effect on reconstituted board. Differences in natural wood of density, compressibility, hardness, gluing ability, pH values, and fiber quality may exist.

The density differences among species aren't a controlling factor in chipboard production. Although the hardwoods may be much heavier than the softwoods, the factors of hardness and compressibility are the most significant. Softwoods, because they are more pliable and compressible than hardwoods, will usually form denser, more compact boards under a given pressure.
Certain species, especially some oaks, possess large amounts of tannic acid which may affect wood strength through acidic deterioration. Also, an acidic concentration may cause the adhesive to precure. However, elimination of the undesirable effects through process control of pH would seem to be a fairly simple procedure.

No data is presently available on species differences relative to gluing ability and fiber quality; however, any variation in wood quality arising from species may be minimized by process control. Mixing of species is feasible and is often done.

Condition of Raw Material

The principal factors in the determination of the raw wood material to be used are availability and acquired form. A balance must be reached between these two factors that will permit the most efficient production of the type of board desired with the process to be used. Ease of material preparation is dependent on: a. type material to be made; b. size; c. grade or quality; and, d. moisture content of the raw material.

Particle type. Throughout the wood particle board industry, the term "chip" is loosely used in speaking of almost all particles larger than sawdust size range. Hence, "chipboard" may, at times, refer to boards made from splinters, flakes, shavings, or various "crosses" or combinations of these forms, but more correctly it should refer to splinters only.

Splinter type particles are oblong, and may range from short, chunky shapes to needle-like shapes. They are produced by beating,
cutting, or grinding actions, or a combination of these; hence, they usually are produced with no rigidly controlled dimensions. Probably the widest range of raw material (from whole logs to small scraps) can be used in splinter production.

Flakes are thin, rectangular particles with closely controlled dimensions. These particles are produced with a cutting action, so that fiber damage is held to a minimum for optimum strength properties. In order that the fibers be as long as possible, the production usually is such that the wood grain is parallel to the longer direction.

Shavings, like flakes, are produced by a cutting action. However, planer shavings are rarely controlled as to dimension or fiber orientation. Load and speed variances of common planing operations make it impossible to produce shavings of the same size. However, special shaving machines are now devised so that specially cut shavings are made with the wood fibers parallel to the lengthwise direction.

The only real difference between flakes and specially cut shavings is relative size. In common usage, the terms "shavings", "wafers", and "flakes", are sometimes used interchangeably. However, the terms "flakes" and "wafers" most often refer to particles larger than planer shavings (10). Table 5 (10) lists average properties normally obtained from processes used by U. S. manufacture.

Size. Different types of raw material may be necessary for different type components. For instance, flake production is likely to require a larger sized raw material, such as slabs or whole logs, while splinter production may use small mill scraps. In general, a type of board and process is available for almost any given size or type of raw
<table>
<thead>
<tr>
<th>Property</th>
<th>Splinter</th>
<th>Planer Shaving</th>
<th>Flake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>0.50 - 0.80</td>
<td>0.50 - 0.80</td>
<td>0.50 - 0.80</td>
</tr>
<tr>
<td>Modulus of Rupture, psi</td>
<td>1500 - 5000</td>
<td>1500 - 4000</td>
<td>2000 - 6500</td>
</tr>
<tr>
<td>Modulus of Elasticity, psi</td>
<td>150,000/450,000</td>
<td>150,000/400,000</td>
<td>300,000/650,000</td>
</tr>
<tr>
<td>Hardness (ASTM), Lbs.</td>
<td>1000 - 3000</td>
<td>1000 - 3000</td>
<td>1000 - 3000</td>
</tr>
<tr>
<td>*Screw-Holding Power, Lbs.</td>
<td>250 - 500</td>
<td>250 - 450</td>
<td>250 - 450</td>
</tr>
</tbody>
</table>

*Pounds required to pull out a 3/4 inch No. 10 Screw inserted in a #30 pilot hole.
material.

**Grade or quality.** The presence of bark and tramp metal might seriously affect the blade of cutter-type machines, whereas more rugged equipment such as hammermill hogs would not be so affected. Bark, as discussed elsewhere, is generally an undesirable component but a low percentage is sometimes allowed. Thus, it is obvious that the quality (uniformity and cleanliness) may seriously limit the usefulness of a given raw material.

**Moisture content.** Moisture content is one of an important factor for considering raw material. Freshly-cut forest wood of common species may range from 30 to 100 per cent moisture content, whereas some kilndried mill waste may be as low as 2 to 3 per cent. Wood that is too dry tends to splinter easily to produce irregular shapes and an abnormal amount of wasteful fines. On the other hand, wood which is too wet has a tendency to tear, and open up the wood pores. Then an excessive amount of binder may be absorbed.

### B. ADHESIVE MIX MATERIALS

**Resin Type**

Among the binders that have been used or tried for reconstituting or reaggregating wood particles are inorganic materials such as magnesia cement, silicates, and Portland cement; and organic materials such as proteinic substances (animal glues, blood and casein), starchy materials, lignin, and synthetic resins. From the standpoint of ease of use, degree of flexibility, permanence, and strength, the synthetic
resins are generally superior to the aforementioned materials.

Of the synthetic resins for wood application, only those which are thermosetting, that is, those which irreversibly harden upon the addition of heat, are presently used in reconstituted board applications. The thermoplastic resins are those which soften and harden upon the application and removal of heat such as polyvinyl butyral and vinyl acetyl types. Within the thermosetting class lie urea-formaldehyde, phenol-formaldehyde, resorcinol formaldehyde, and melamine-formaldehyde which are frequently used. Melamine-formaldehyde is an excellent adhesive, but is too expensive to use alone; so the lower quality ureas are sometimes fortified with melamine to improve their qualities. Resorcinol is likewise an excellent adhesive, but the high price of it limits its use.

The comparative characteristics of urea and phenol formaldehyde are as follows (10):

Urea-formaldehyde.
1. Low cost (about one-half the cost of phenol-formaldehyde).
2. Lower curing or hardening temperature (therefore, a shorter production cycle).
3. Water-resistant, not water-proof.
4. Produces boards of lighter color (phenol darkens, when exposed to ultra-violet rays).
5. Will "craze" or embrittle with age.
6. Will not resist boiling in water.
7. Will not stand tropical use or heavy weathering (high temperature and humidity).
8. Will wear tools faster than phenol-formaldehyde when product is being machined.
It was found that although the urea resin bond weakened little upon weathering for four months, a twelve month exposure reduced the strength by one-half.

**Phenol-formaldehyde.**

1. Has high bonding strength and resists action of hot or cold water.
2. Withstands humidity cycles well (moistening-drying).
3. Withstands extremes of temperature and humidity.
4. Withstands temperatures close to the carbonization temperatures of wood. (Urea will weaken under heat treatments (140°C. - 180°C.) that may be applied to finished products to increase wood stability.)
5. Resists attacks of bacteria, molds, and termites.
6. Withstands chemical action of oils, alkalies, fire-resistant and pest-resistant wood preservatives.

Table 6 (10) illustrates the important properties of the resins themselves, and Table 7 (10) illustrates properties of chipboard made from the two resins for short term tests.

Urea resin has been found to be highly suitable for furniture and similar interior uses, but phenolic resins or urea-melamines are generally specified for exterior use.

**Catalysts**

The basic synthetic resin products presently used are condensation products of urea or phenol and formaldehyde. A solution of urea or phenol and formaldehyde thickens as long chains of complex molecules begin to form. In the production of the resin, this chain reaction is stopped at a certain point, and the user of the resin starts the reaction again by the application of heat and/or some catalytic chemical.
<table>
<thead>
<tr>
<th>Property</th>
<th>Urea Resin</th>
<th>Phenol Resin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weights</td>
<td>g/cm(^3)</td>
<td>1.3</td>
</tr>
<tr>
<td>Water Intake 24 hour, 20°C.</td>
<td>%</td>
<td>1.5</td>
</tr>
<tr>
<td>Water Intake 7 days, 20°C.</td>
<td>mg/100 cm(^3)</td>
<td>790</td>
</tr>
<tr>
<td>Heat Resistance</td>
<td>°Martens</td>
<td>110</td>
</tr>
<tr>
<td>Tear Resistance</td>
<td>kg/cm(^2)</td>
<td>600 - 700</td>
</tr>
<tr>
<td>Bending Resistance</td>
<td>kg/cm(^2)</td>
<td>800 - 1100</td>
</tr>
<tr>
<td>Impact Resistance</td>
<td>cm/kg/cm(^2)</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 - 10</td>
</tr>
</tbody>
</table>
### TABLE VII

**PROPERTIES OF CHIPBOARDS FROM PINE CHIPS WITH BINDING OF UREA AND PHENOL RESIN (10)**

<table>
<thead>
<tr>
<th>BINDERS</th>
<th>UREA</th>
<th>PHENOL RESIN</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BOARDS FROM PINE CHIPS, 0.1 mm THICK</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bending Resistance, Dry kg/cm²</td>
<td>300</td>
<td>265</td>
</tr>
<tr>
<td>Swelling in Thickness % (Test Size 10 x 10 cm²)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- In Water 24 hours</td>
<td>11.5</td>
<td>12.4</td>
</tr>
<tr>
<td>- In Humidity Chamber: 5 days</td>
<td>8.0</td>
<td>6.6</td>
</tr>
<tr>
<td>10 days</td>
<td>10.6</td>
<td>8.4</td>
</tr>
<tr>
<td>Water Uptake % in Humidity Chamber: 5 days</td>
<td>11.2</td>
<td>8.8</td>
</tr>
<tr>
<td>10 days</td>
<td>13.4</td>
<td>11.3</td>
</tr>
</tbody>
</table>

| **BOARDS FROM PINE CHIPS, 0.3 mm THICK** |      |              |
| Bending Resistance, Dry kg/cm² | 295  | 226          |
| Bending Resistance, Wet kg/cm² |      |              |
| - After 24 hours in Water | 120  | 96           |
| - After 96 hours in Water | 106  | 83           |
| Swelling in Thickness % |      |              |
| - In Water 24 hours | 12.2 | 14.2         |
| - In Humidity Chamber: 5 days | 9.0  | 8.2          |
|    10 days        | 11.6 | 10.5         |
| Water Uptake % in Humidity Chamber: 5 days | 10.0 | 10.1         |
|    10 days        | 12.2 | 12.9         |
One-stage urea resins actually require only heat, but a catalyst is often used to speed the process. Actually, the polycondensation of liquid resin may never completely stop. For this reason, storage may not be of too long duration in this stage. Common limits recommended for this storage are from 3 to 6 months, depending on surrounding conditions, temperature being most important.

Catalysts used to renew the chain reaction are most important, because the control of curing time and temperature is dependent upon the selection of the proper agent. Other technical aspects of production also depend on this choice.

Usually, a compromise between speed of catalyzation and pot life (time between mixing of resin and catalyst and curing) must be reached, since pot life has a tendency to shorten with the quick-acting, direct-action hardeners. Besides the direct-action catalyst, one other type is widely used in wood industries. This type is the retarded-action catalyst, which lengthens pot life, but retards the actual curing.

Because resins tend to cure with acid additions, pH values are important in the choice of catalysts. Harmful effects will be noted in wood materials themselves upon excessive acidity; therefore, a balance may be necessary between the type of catalysts and wood species used. Usually, no catalysts are necessary with highly acidic type wood species such as Douglas fir (3). This latter is, of course, highly desirable since the application of heat without catalyst completes the polymerization and the question of pot life is avoided.
Extenders

Materials which aid in controlling resin flow and penetration are used in wood bonding industries, and are known as extenders. These extenders, which usually are flours that are added to the resin mix, may be used under certain conditions to reduce resin costs, since their function is the "holding" of the adhesive on the wood particle surface, and to aid in the distribution of the resin film. Besides affecting the efficiency of the adhesive in the board, wheat flour itself contributes some bonding power, but there is a limit to the amount of foreign material that can be introduced without seriously reducing the quality of the bond of the resin itself. Also, since flours impart a degree of plasticity to binders, they aid in reducing the inherent brittleness of urea resin (2).

The use of extenders also influences other stages of the process. Some processes rely on accurate and free flow of the wood particles subsequent to their mixing process. It has been found that under certain conditions, the extender greatly enhances the free flow of the chip mass, since the moisture tends to remain on the surfaces and serve as a lubricant.

Flour compositions usually vary with grade, locale, and season of growth, but many flour mills' grading systems are not of sufficient accuracy to insure the close chemical tolerance required for trouble-free production of chipboard. The extenders should be ordered by analysis rather than by grade, and a constant check is a good policy.

Flour should mix readily with water to produce a smooth, spreadable mix. Usually, the soft grades which flow freely while dry are
suitable. Hard or sandy flours are generally poor in this respect (13). Treated flours such as bromated, phosphated, or self-rising are likely to cause difficulty if foaming is undesirable. High ash or protein are undesirable, for large amounts of water are usually necessary to produce a mixture that is thin enough for proper application. Variations in the acidity of flour will necessitate changes in adhesive formulations. Variations in particle size from lot to lot may affect application, especially in a process using a spray type apparatus. In fact, clogging of spraying unit nozzles caused by the use of extenders is largely responsible for the decreasing popularity of these agents.

Additives

Reconstituted boards are subject to many of the same effects as natural wood. It is necessary that some reconstituted boards be rendered impervious or resistant to such things as insects (especially termites), fungi, water, and fire. The treatments which can be incorporated into the production process to provide these special qualities are as follows:

Pest repellents. The addition of penta-chlorophenol has been used to provide fungus and termite protection for reconstituted boards.

The method of applying the repellent that is most easily performed in the process is the one preferred, since no differences in efficiency of repelling were noted, relative to application. The penta-chlorophenol will be absorbed by the particles if added prior to the resin mix; while if added to the mix for simultaneous application, the penta-chlorophenol will be bound within the resin itself. This
might bear rechecking, since "penta" salts do not vaporize — just the solvent, which is not the effective component.

Water repellents. The use of water repellents in the product is to reduce moisture absorption and control dimensional stability. The most common materials used for this purpose are wax sizes or petrolatum. These are usually added to the adhesive mix prior to application on the particles. The water resistance of boards increases with the amount of repellent added, but strength properties are lowered when added beyond optimum amounts. Most processes, therefore, use less than 2 per cent based on the dry wood weight.

Other additives. It is known that phosphates are suitable for the processing of fire-retardant reconstituted boards, but these chemicals lessen the strength of urea-bound boards, so it would seem that phenolic boards are most suitable for phosphate addition. In addition, the phenolic resins are more resistant to high temperatures than are the ureas. Unfortunately, most good fire retardants interfere with the setting of the resin formulations involved.

Another additive to the chip mass which may be used when a free-flowing mass is required for production control is zinc or calcium stearate. Tints or dyes may be added under special conditions for decorative effects.

Mixing

A homogeneous mixture of resin, extenders, lubricants, and other additives is imperative in the production of quality-controlled reconstituted board. The most careful selection of materials may be rendered
ineffective if they are improperly mixed prior to blending with the wood material.

The factors which must be given serious consideration are (10):

1. The type of mixer.
2. Ratio of total liquids to solids.
3. Temperature at which the mixing is performed.

Mixers. The mixers are usually rather simple in construction, and incorporate paddles or scraping knives which assist in breaking up lumps and accumulations of solids.

Ratio. The most common method of mixing consists of mixing part of the total amount of water with the resin; adding the extender, if any; the balance of the water; and finally the other additives such as water-repellents, fire retardants, and pest-repellents. Each of these stages is carried out to a smooth, homogeneous end before the subsequent stage is begun. In this way, a thoroughly mixed end product is assured. The catalyst is added during one of the final stages, so that the resin cure will be as little advanced as possible when the mix is completed for use.

Temperature. The temperature of mixing, if too low, increases the resistance to proper mixing by raising the viscosity of the material; whereas, too high a temperature decreases the pot life of the mix considerably, and may even result in a partial pre-cure.
Viscosity. Viscosity of the adhesive mix must not be so high as to clog up the equipment, and to hinder good distribution over the mass. These stages may be varied to meet an individual process, and probably little difference will be made by changing the order of mix of the various materials, as long as the desired end result is reached.

Application of Adhesive Mix

Many types of special machines have been developed for the purpose of distributing the adhesive. These machines may range from complicated, sensitive spraying equipment to "cement mixers" in which the adhesive is "dumped" by hand. The criteria of the method hinges on the ability to consistently and evenly coat the particles, not on the cost or complexity of the machines. The method used will vary with the size and shape of the particles, the viscosity of the mix to be applied, the penetration of the mix desired in the wood, and the volume to be processed. Roller-type operations are best suited for larger, flat flakes, and a higher mix viscosity is usually used. Spray-types, on the other hand, require a fairly thin mix in order that the spray nozzles will not clog up, and high extensions are not feasible. Spray application is conducive to outstanding evenness of coating. The tremendous total surface area of the chip mass must be exposed to the mix entering in any application. This requires a large churning action in a mixing or spraying process.

Some processes are more suitable for the application of binders which are in powdered or dry form, rather than in solution or suspension. This may be true when the wood mass consists of very small
particles such as sawdust, which possess a very large total surface area. A given volume of liquid, when introduced into such an absorbent mass, may quickly become assimilated before all surfaces are uniformly coated. On the other hand, a powder which is uniformly deposited on the surfaces will melt to produce an even film which does not penetrate deeply into the wood. In the case of the larger particles, some dry resins are being used for the regularly shaped particles such as flat flakes. There is a possibility that in the case of larger irregular particles, the powder or granules may sift downward or collect in voids and pockets and result in an uneven distribution.

Since there are so many variables which influence resin efficiency, board quality, and product end uses, the ranges of resin solids in different brands of boards may vary from as much as 12 percent resin solids, based on the dry weight of the wood, down to none in some specialty use products which depend solely upon the natural lignin for bonding.

C. CURING CONDITIONS

The actual forming of reconstituted boards takes place under conditions of heat and pressure after the wood and binder mass has been processed to a specified state. These conditions have much effect on the final characteristics of the board, and are also important in the production cycle of a plant. Temperature, pressure, time, moisture content and thickness of the mat are all related to the production cycle (10); hence the manufacturer strives to maintain optimum conditions for efficient plant operation, consistent with the quality board
that is to be produced.

Moisture Content

A certain amount of moisture within the wood mass is necessary, but an excess is detrimental. Vaporization of the mixture detracts from the amount of energy that is available for hardening of the resin and increases curing time. This vapor, if in excess, may be trapped within the board, especially the denser, less porous ones. If the vapor pressure exceeds the strength of the resin bonds being formed "blows" or "blisters" will occur in the board, and be evident on the surface. Excessive moisture may also produce a "washing" effect on the resin, and carry it out of the center toward the surfaces. As a result, the resin concentration will be low in the board middle and high on the outside. This effect is most noticeable when the slow curing binders are used, and is not generally of too great a consequence, except where the lowered internal bond strength limits use. A moisture deficiency, on the other hand, reduces the plasticity or compressibility of the chips. As the moisture content of the wood increases the plasticization, compression of the wood, and flow of resin increases (13). Therefore, it is necessary to press the particles at a moisture content which will not allow excessive flow of the resin but will still permit good plasticization of the wood. Macdonald (14) stated that a 25 per cent moisture content prior to pressing is required for optimum strength and a drop to 12 per cent or less decreases the bending strength about 20 per cent. The particle size used in his investigation ranged from 0.05 - 0.25 inch.
Since mat moisture content affects ease of compressibility, one company, CoreBoard Products, Inc., uses a rule of thumb method to correlate this factor with mat thickness and final product thickness. They use a standard mat thickness three times that of the desired end product, with a reference mat moisture content of 12 per cent. Then, to determine proper mat thickness for different moisture contents and a given product thickness, the thickness of the mat must be increased or decreased by 1/16 inch for each decrease or increase of one per cent in moisture content.

Usually the final wood-resin mix should not have more than 12 per cent moisture content (13). The wood particles should not be over-dried. Overdrying gives a harsh brash particle with a subsequent decrease in strength of the particle board. Data on effects of the pressing moisture content on the physical properties of particle board are given in Figures 16 through 19 (3).

Since moisture is a good conductor of heat, this optimum of 12% for particle boards, contributes toward the shortening of the press cycle. Current trade practices frequently call for a fine water spray applied to increase the surface moisture content. This increases the quality of the surface by increasing plasticity and flow in this area, without the previously discussed "blowing" of internal steam pockets or the weakening of the internal bond by resin migration.

Pressure

The pressure exerted on the chip mass both forms the board and holds the particles in place while the binder hardens. The force that is exerted determines the compactness, or density, of the board, if the
FIGURE 16

EFFECT OF MAT MOISTURE ON MODULUS OF RUPTURE (3)
FIGURE 17

EFFECT OF MAT MOISTURE ON EDGE SCREW HOLDING (3)
FIGURE 18

EFFECT OF MAT MOISTURE ON THICKNESS SWELLING (3)
FIGURE 19

EFFECT OF MAT MOISTURE ON WATER ABSORPTION (3)
other factors such as particle size, moisture content, etc., are considered equal. Any factor that helps to make the wood mass more compressible will also help to make a stronger board at a given pressure.

Many processes use a pre-press operation to partially form the board before curing. Heat is not used in the pre-pressing operation, but enough pressure is applied so that the mat may be easily handled.

The main press cycle frequently consists of three parts: 1. High initial pressure; 2. Release to a lower intermediate pressure (breather step); and, 3. Final pressure.

In the initial pressure stage, while the moisture content was still high, and the plasticity of the chips at a maximum, the larger pressures were found to have more influence on the final board properties. The strength properties were greater because of the better bonds, the thickness of the panels was less, and the specific gravity greater; and the water absorption was decreased because the denser material resisted moisture pickup. The final pressure stage may not be necessary, depending on the duration and magnitude of the intermediate "breather" or "steam extraction" pressure (10).

Some processes press to mechanical stops to obtain the final dimension. In any event, the pressure should be applied quickly in order to compress the mat before the binder cures. Resin bonds which harden before the final form is reached may break under the continuing compressive forces. This effect would be more outstanding nearer the board surfaces.
Curing Cycles

Heat is necessary in the production of resin-bonded wood reconstituted boards to cure or set the binder and to cause lignin flow. The adhesives used thus far have been thermosetting; that is, they are irreversibly set by the action of heat. The economics of production require that the heating cycle be as short as possible, but an incomplete cure cannot be tolerated in quality boards. The center of the board is the most difficult section to heat, while the surface is easily heated.

Because the curing cycle is usually the limiting factor in volume of production, much effort is being directed toward speeding up this cycle. A reduction of the mat moisture content from between 14 and 18 per cent to 11 per cent, and an increase of press temperature from 140°C. to 170°C. was found to reduce the production cycle by one-half. For a board 20mm. (approximately 0.8 inches) thick, having a specific gravity of 0.6, the starting moisture content of only 11 per cent enables the following cycles to be used: ten minutes at 140°C., seven minutes at 160°C., and only five minutes at 180°C. (10).

Excessive temperatures may produce premature drying of the surfaces, excessive resin cure (resulting in brittle and flaky resin and a fragile surface), and scorching or burning of the surfaces. These effects may be reduced by the spraying of excess water on the mat surfaces prior to curing.

Recommended press temperatures for phenolic and urea resins are 330°F. and 285°F., respectively, with 10 to 20 minutes press time for a 3/4" board (3). The times required will depend on press conditions and
heat transfer rates of particular presses.

The curing cycle will vary depending on the particular mill process and product (3).

D. PRODUCT PROPERTIES

Properties of reconstituted boards, like their production processes, are so complicated by the interplay of factors of unknown magnitude, that empirical methods must be utilized for the determination of the quality of reconstituted boards.

Density

Board density, or specific gravity, is a measure of the compactness of the individual particles and other materials within a board. It depends on the factors of pressure, mat moisture content, specific gravity of binder and additives, density of the wood raw material, and curing cycle. Since the total strength is related to the sum of the strength values of the individual particles, and since these particles are able to transmit more of their strength through a tight, close contact with other particles, it follows that strength values closely parallel the density.

Not only does overall board density play a major role in final characteristics, but one of the most perplexing aspects of reconstituted board production stems from control of homogeneity of density throughout a panel. It is most difficult to insure an evenly distributed weight of chips over a caul prior to pressing, and, unless each unit area of mat contains the same weight of material, the finished board will contain areas of unequal density. These areas will respond in different degrees
to outside conditions, most notably moisture variances, to produce warpage from the unevenness of shrinking and swelling. In regard to strength, the lower density areas are the critical areas. The development of a mat felter, or chip spreader, which will allow an even distribution, by weight rather than volume, since the bulk density of a chip mass often varies. In the case of lighter, more uniform fibers, a volumetric control of mat thickness is quite effective.

**Dimensional Stability**

One of the major selling points of reconstituted board is its dimensional stability, which is accomplished (a) through the production of a homogeneous board without "grain" direction, and (b) by the use of various processing methods which are easily applied. The swelling and shrinkage of normal solid lumber is difficult to predict because of the possible presence of different natural defects such as tension wood, compression wood, etc. Many present applications of reconstituted board require reasonable control of dimensional stability, and every effort is being made to continually improve this property.

Any wood or wood-based material exhibits a certain amount of dimensional change due to changing surrounding moisture or humidity conditions. Two ways to combat this instability are the elimination or reduction of entering moisture, and the control of the effects produced after the moisture has entered. Moisture absorbing ability of wood particle boards is a complex function of (22):

1. The volume of the voids (which will hold water) in and between the particles.
2. The capillary passages to the voids.
3. The surface area of the particles.

4. The densification of each particle by the molding pressure.

5. The amount of particle surface area uncovered by resin.

6. The permeability of the resin binder.

7. The depth of impregnation of each wood particle by resin.

8. The original moisture content of the wood particles.

9. The nature of the moisture (viscosity, surface tension, etc.).

Any production variable that affects these factors also affects dimensional stability. Increase of resin amount and curing pressures, or addition of water repellent are the three most common methods of reducing absorption.

Tremendous gains in water-resistance can be made by additions of less than three per cent wax size. Since petrolatum and wax decrease board strengths, if in too large quantities, most manufacturers probably use less than 2 per cent (10).

There are two types of dimensional change which affect reconstituted boards extensively, once moisture has entered or departed. One is the normal moisture swelling or shrinkage in wood, a common and familiar movement. The other type of change is labeled "springback", and is a release of the compressive forces instilled in the board during manufacture.

It was reported (10) that higher density woods produce boards with less springback than do lighter woods, if the boards are of the same density; since the heavier woods need not be compressed as much as the lighter woods for a given density board, their tendency to return
is less. High density boards will tend to springback more than lighter ones formed from the same species.

Turner (25) found that higher resin contents decrease springback, but it was felt that a rate retardation rather than an elimination may have been effected. Boards cured at low temperatures and for short periods of time were more prone to springback than those cured with high temperatures and long times.

Wood has very little swelling and shrinkage along the fibers, but perpendicularly the change is quite noticeable. For this reason, fiber damage and particle orientation play an important part in dimensional stability. It was found (10) that boards of thinner particles swell less; that higher density boards swell more; and that higher density woods produce boards more prone to swell (for equal board densities).

It has been also found (10) that veneered board panels will expand less in thickness than unveneered boards, possibly because the veneering process releases some of the compressive forces incurred during board forming.

In summary, dimensional stability is important in wood particle board and is affected by (10):

1. Particle shape
2. Particle size
3. Fiber structure
4. Density of product
5. Moisture content
6. Amount and kind of additives
Particle Orientation

Two general classifications of particle orientation can be made relative to wood particle board. These are (10): (a) when the long axes of the particles lie for the most part parallel to the board surfaces, and (b) when the long axes of the particles are perpendicular to the board surfaces.

In any process, the chips tend to set in a position parallel to the pressing surface, or ram. In a platen (flat-plate) process, the pressing surface corresponds to the board surface; whereas, in an extrusion process the ram which packs the particles into a solid mass is the pressing surface, and corresponds to the board edge. So, the fibrous strength of a flat-pressed board is generally parallel to the board surfaces; while in an extrusion process board, the fibrous strength is generally perpendicular. In the extrusion-type board, the particles overlap to a large degree within the plane parallel to the ram surface, and the bending stress across the extruded width of the board is roughly five times as great as that along the extruded length of the board. Also, the sliding friction produced by the chip mass as it is forced along next to the hot plate turns the surface particles parallel to the plates. The most visible characteristics distinguishing the two types of boards is the uniform vertical orientation of the chips as seen in a cross-section of the board which parallels the direction of extrusion; while throughout a platen-type board the particles are horizontal.
The dimensional stability characteristics of flat-pressed boards differ from those of extrusion-type boards. The thickness swelling (and shrinkage) of the former type is much greater than the length and width swelling. Conversely, an extrusion board is very stable in thickness but swells considerably more in length and width. These inherent characteristics may greatly influence the choice of a board for a specific use. Springback is problematic in extruded boards, as in the platen type, though the largest effect is along the direction of extrusion. Therefore, it is apparent that extruded board would be desirable, dimensionally, where thickness stability is required; and flat-pressed board where length and width stability is required.

**Surface Quality**

Board surfaces may be made of various types and sizes of wood materials, ranging from wood flour to long, wide flakes. The finer particles are generally used when an outstandingly smooth surface is desired; and the larger flakes are often used for decorative purposes.

"Telegraphing" or "show-through" is the effect caused by individual particles appearing through applied veneers. A tendency exists for some surface particles to swell unevenly producing a roughened surface effect. Thick splinter-type particles are most prone to give trouble in this respect; while fines (sawdust, wood flour) probably give the least. Denser boards tend to telegraph more than lighter ones (13), since thickness swelling occurs to a greater degree in more highly compressed chips. As mentioned previously, some processes incorporate surface layers of fines to cover the coarse inner particles. This type of construction is known as a "sandwich" type, and very high
quality surfaces are obtained in this manner. Other processes use a "filling" operation on the finished board to produce smoothness. This is accomplished by adding thin coats of a filler material to close up the pores, or spaces between the particles, and sanding between the applications. The use of a resinous compound with wood flour as a filler can produce a clear, smooth, shiny surface. When a surface smoothness is desired in a splinter-type process in which a sandwich construction is impractical, or "filling" is not economically feasible, a certain amount of fines may be incorporated into the chip mass, which fairly effectively fills the surface voids. Care must be taken here that an excessive amount of fines does not weaken the board unduly by inherent resin absorption.

Ease of veneering is also an important characteristic. The board surface must be generally without ridges and depressions so that the veneer will wholly contact the surface, and an even resin bond overall can be obtained.

Stiffness and Creep

Stiffness is important when the load to be applied is continuous. It is measured by initial deflection upon exertion of a force. The increase in deflection under a constant load is termed "creep" or "sag". These two characteristics are important where the board is used as a table or desk top, shelf, or other application wherein a load may be applied perpendicular to the face of the piece.

It was reported (10) that single-layer, unveneered chipboards were not suitable for shelving unless more support was used than was necessary for solid wood. There is a possibility of veneered chipboard
being used satisfactorily for medium-duty shelving.

**Screw-Holding Ability**

Particle board screw-holding ability, particularly for boards in the density range 0.55 - 0.80, is usually less than that of lumber such as poplar (10). Screw-holding ability perpendicular to the surface is, for the most part, controlled by overall board density; but, the closeness of contact of the individual particles is a major factor in screw-holding parallel to the surface.

It has been found that screw-holding ability may be greatly enhanced by the application of resin to the pilot hole prior to insertion of the screw. A reduction in pilot-hole size will also aid screw-holding ability. The optimum pilot-hole size should be approximately 75 per cent of the diameter of the threaded section of the screw (10).

Where greater strength is required than is obtainable otherwise, especially when screwing into the edge of the board, it has been suggested that larger and longer screws may increase the withdrawal force required. Another possible solution may be effected by gluing and inserting a wood plug in the board edge to receive the screw (10). Edge screw-holding ability may be increased in extruded boards by crossbands and veneers.

**Machinability**

Particle boards can be worked with machine-tools and hand-tools in much the same way as normal lumber. There are certain considerations which must be made regarding ease of machinability. These are (10): (a) resin content; (b) tendency to chip; (c) density variances;
and, (d) lower strength characteristics.

**Resin.** The resin content of a chipboard has a dulling effect on tools. (Urea resin is more brittle and abrasive than phenolic resin.)

**Chipping.** Unless care is taken, individual chips may break or tear out of the remainder of the board. In the case of planing operations, it is sometimes advantageous to allow a newly produced board to "set" for at least a day before planing. In this period, the resin hardens further, lessening the chance of chip pull-out. In sawing operations, chips tend to tear out of the board with the saw blade. Close support of the board, therefore, is desirable. Drilling operations may sometimes be best performed with saw-toothed augers, rather than twisted augers, in order to lessen chipping.

**Density variances.** Drilling operations, unless the board and machine are well fixed, may be hampered by the presence of areas of high or low density. A drifting of the drill may occur upon contact with these areas. (Also, a sizeable center punch may initially be necessary to prevent slippage of the drill point off a prominent surface chip.)

**Strength.** Since chipboards are usually weaker than solid lumber, joints must not be too delicate or thin. Mortise and tenon, or dovetail joints should be avoided, if possible.

**E. STANDARDS**

There are presently no accepted standards available for guidance of those who are concerned with reconstituted board production and use.
Various organizations have undertaken to compile standards satisfactory to the industry. The most complete set of standards thus far drafted in the United States was prepared by representatives of the particle board industry who are members of the National Woodwork Manufacturers Association. These as yet have not been released or accepted. Also, the American Society for Testing Materials has reportedly appointed a committee to propose standard tests for dry-process hardboards. In the absence of other standards, however, most manufacturers attempt to prepare their own as a method of quality control, if customer specifications are not sufficient.

In the testing, three major considerations are evident. These are: 1. selection and preparation of specimen; 2. apparatus; and, 3. reporting methods.

Selection and Preparation of Specimen

The choice of sample must be made so that a representative specimen is obtained; then the sample must be cut to size and conditioned properly as to temperature and moisture content. Depending on the type of test, additional sample preparation, such as gluing, cross-banding or shaping may be required.

Apparatus

The machines to be used must be capable of performing the various tests under the specified conditions. That is, the correct force applications depend on such things as headspeeds of the machines and the size, shape, and spacing of supports and clamps. The materials to be used in tests, such as nails, screws, abrasives, etc., must be of
specified type or compositions.

Reporting

All the profits of standardization will be lost if the reports of the values obtained are not presented clearly and accurately. The methods and equipment used must lend themselves to proper measurements, and the merest discrepancies or abnormalities noted in any procedure should be included in the final report.

Reconstituted board properties and the laboratory methods used by various organizations for evaluating these properties are:

**Physical properties.**

1. Density
2. Per cent of water absorption
3. Moisture content ex-factory
4. Dimensional stability
5. Fire resistance
6. Sound insulation
7. Sound absorption

**Strength properties.**

8. Tensile strength perpendicular to plane of board (or cleavage strength in plane of board or internal bond)
9. Bending strength perpendicular to plane of board
10. Deflection under sustained load
11. Shear strength in plane of board
12. Compression perpendicular to plane of board
13. Impact bending (or puncture test)
14. Nail holding in two/three planes
15. Screw holding in two/three planes

Working properties.

16. Accuracy to size and tolerances
17. Surface roughness
18. Surface stability
19. Bending capacity
20. Machining properties

Specific details concerning testing of these boards may be most readily found in the A.S.T.M. publication (23) dealing with this subject area.
A wood reconstituted board plant usually operates "around the clock" on a 24 hour basis. The number of operating days per week may vary from five to seven. Throughout the year there may be occasional shutdown periods for a variety of reasons, so that the annual hours of actual plant operation may vary from 5,750 up to 8,760. (24 hours x 365 days equals 8,760 hours, the maximum possible.)

In determining the plant capacity, a major variable having a bearing on the output of a plant is the thickness and density of the board produced. For example, a plant producing board 1/8 inch thick can manufacture more square feet of product per day than if the board were 1/4 inch thick. For this reason, it is customary to express the production capacity of a plant in square feet for a definite thickness of finished product, the most common one for hardboard plants being 1/8 inch, and for softboard (insulation board) plants 1/2 inch.

In the case of particle board manufacture, since the limiting production factor in a particle board manufacturing plant, regardless of process type, is the operation involving the application of heat and pressure to the chip-glue mix, all other operations are geared to meet the output of this unit. To step up production in a plant beyond the capacity of the press requires either a physical modification or replacement of this unit, or a reduction in the curing cycle.
In the extrusion processes, more than one extruder can be installed to increase production. For additional capacity in a multi-platen press operation, extra platens may be added to the existing press if the press can accommodate this addition, or an extra press may be installed to operate in parallel with the present installation.

Shortening of the press cycle may be accomplished by the incorporation of a radio frequency heating unit into the system, by adjusting moisture content, by use of a hot stack, or by manipulating other pressing variables.

These alternatives will require adjustments in capacities of the other machinery throughout the system. The necessity for operating at maximum press capacity arises from the fact that it represents the most expensive single unit in the system.

In the design of a particle board process, the usual procedure is to build greater capacity into the particle preparation units than into the pressing unit. This serves to allow a buffer supply of chips to be prepared in advance of the need for them. The same may be said for shaving board.

The cost advantage in providing excess capacity in the reduction equipment is realized in a more efficient utilization of manpower. Standard operating procedure in many plants calls for the operation of the reduction machinery for one shift only, to supply sufficient particles to operate the balance of the system for two or three shifts. The need for retaining yard men or hog operators on all shifts is thereby eliminated.
Actual board production at a plant depends basically on market demands for the product and availability of raw materials, although technical problems or other reasons may tend to keep the total output somewhat below capacity.

The solution of technical problems may be easier than creating new markets and selling the finished product. The point being made is that it usually requires several months of "shake-down" operation in a new plant to overcome unforeseen problems that always seem to arise in getting new equipment or new processes running smoothly.

The problems encountered in operating a wood reconstituted board plant are considered basically similar to those occurring in a plywood plant. Sound engineering, proper technical supervision and good management are important in assuring high level production.
CHAPTER VII

CAPITAL INVESTMENT

At the present time the cost of building a reconstituted board plant is probably higher than before because of the continuing trend toward higher prices for materials, equipment, and labor. The figures that are given in the paragraphs following, were reported in 1956.

A. PLANT SIZE ECONOMICS

In contemplating the establishment of a wood reconstituted board plant, consideration should be given to constructing a plant having a large enough output capacity to enjoy a low unit manufacturing cost.

It is also important to be sure that a sufficient quantity of suitable raw material is available, at the right price, to enable large scale production. Otherwise it may be difficult to compete with existing plants having ample raw material supplies, especially plants which obtain all or a large part of their wood residue from a parent mill.

Experience in the United States indicates that the smallest hardboard plant (wet process, batch method) that can be operated economically is one with a minimum daily capacity of 35 to 40 tons of board production (24).

A hardboard plant producing 1/8 inch board, a 20-opening hot-press for 4 foot by 8 foot boards operating on a 7-1/2 minute cycle will require the equivalent of about 50 tons of dry wood residue during 24 hours of operation and can produce about 120 thousand square feet or
45 tons of product. This estimate is based on the assumption that 1/8 inch hardboard weighs 750 pounds per 1,000 square feet (24).

Particle board, especially "coreboard" to be integrated in other products may be manufactured in smaller plants than those using wood fibers for making hardboard. Experience in the United States also indicates that such particle board plants may be operated economically with a daily capacity of about 10 tons of product. Capital investment generally is lower in plants designed to manufacture particle board. The principal reason is that the wood refining and mat forming equipment usually costs less. In manufacturing shaving board, the plant size economics are somewhat similar to that of particle board plants.

B. CAPITAL INVESTMENT

Complete physical plant costs, excluding land, for a wood reconstituted board plant are generally comprised of the following components. In addition to the costs listed, funds must be available for initial operation and the "shake down" period.

1. Process machinery and installation cost
2. Incidental equipment cost
3. Freight charges (on equipment)
4. Building and facilities costs

Process Machinery and Installation Cost

The following factors influence the costs of machinery directly used in connection with the production of wood reconstituted board (10):

a. Type of process
b. Type of board produced
c. Raw material form

d. Extent of mechanization

e. Plant capacity

Type of process. The Oregon Forest Products Laboratory studies show that investment costs for existing hardboard plants using the wet process vary from $20,000 to $30,000 per ton daily capacity, and for existing plants utilizing the dry process from $10,000 to $20,000 per ton of daily capacity. The lower figure for the dry process is attributed mainly to the substitution of different equipment for the water handling equipment used with the wet process (2h).

It was reported that capital investment for hardboard plants using the wet process, continuous method, varied from $1 million to $1.5 million for a production capacity of 50 tons of board per day. A plant using the wet process, batch method, was priced around $600,000 to $800,000, producing 35 tons of board per day (2h).

A particular plant utilizing the dry process or semi-dry process could possibly cost as much as a particular wet process plant, especially if a large-size press is installed. For example, it is reported that a 20-opening hot-press, to produce hard surfaced boards 4 feet by 16 feet and providing pressures up to 1,000 pounds per square inch, may cost as much as a half-million dollars. An entire dry process hardboard plant using 20-opening, 4 foot by 8 foot, hot-press generally costs about $800,000 for 40 tons of finished product daily (2h).

Generally, capital investment for plants manufacturing hardboard is considered substantially lower than for plants producing wood pulp, but higher than for most wood-industry plants of equivalent capacity.
The estimated costs of the capital investment required for the three general processes of particle board production is as follows (10):

- Extrusion (2 extruders) . . . . . $661,600
- Multi-platen (16 openings) . . . $705,000
- Continuous pressing . . . . . $1,203,900

These costs cover relatively large operations. Included in the estimates are building, equipment, installation, and engineering costs as well as an allowance of 10 per cent of the total to cover contingencies. Production rates of each process is estimated at 2,000 square feet of 3/4 inch thick board per hour. The board density is 40 lbs. per cu. ft., and panel size is 4 by 8 feet.

Type of board produced. The type of board to be produced also effects the cost of the machinery. It is reported that the production of a three-layer board may result in an expenditure of $65,000 in excess of that required for the production of a single-layer board (10).

Raw material form. The reconstituted board plants are usually required to invest in some extra equipment for reducing and preparing wood raw material for board production. The equipment required depends upon the wood raw material form. For a particle board plant, extra equipment is required when wood raw material is in the form of cordwood, veneer cores, or slabs and edgings. Primary and secondary reduction is necessary to reduce the wood to usable particles, whereas in the case of secondary manufacturing residue which is kiln-dried and in relatively small sizes, only secondary reduction is required. A
dryer must also be installed or the material receiving primary reduction, while the kiln-dried waste requires no drying operation. The added costs involved in the primary reduction and drying operations, plus the necessary conveying equipment, may add $20,000 to the overall equipment cost (10).

Extent of mechanization. Mechanization of a process, by its very nature, requires a high or initial equipment cost. Mechanized processes, however, allow a lower labor cost per unit of production. They also result in a more uniform product.

Plant capacity. As the mentioned plant costs indicate, there is a difference in the initial investment required for the purchase and installation of different process types of comparable production capacity.

Incidental Equipment Cost

Aside from the machinery required for directly producing the reconstituted board, several items of incidental equipment must be available to assist in the production and handling, such as heating and ventilation fans, fork-lift trucks, tanks for glue storage and board finishing equipment (when incorporated). For the most part, this equipment is standard and the costs are easily obtainable. The total cost may conceivably run as high as $90,000 (10).

Freight Charges

Transportation of the equipment to the installation site amounts to a considerable sum. At $2.00 per cwt, for example, a 400,000 pound
plant will cost $8,000 to ship (5).

Building and Facilities Cost

Space is required for the establishment of the reconstituted board plant including building space and storage space. The area required for the reconstituted board plant will vary depending upon the kinds, capacities, and processes of board production. In general, floor space cost is estimated at an average of $5 to $7 per square foot (10).

For example, it was reported that the multi-platen press for particle board produced 1,000 square feet of 3/4 inch thick board per hour, required 11,900 square feet. A horizontal extrusion press, specifically the Lanewood Press, which produced 960 square feet of board per hour, required approximately 200 square feet of floor space for the press and its output (exclusive of preparation equipment) (10).

From the foregoing discussion it may be concluded that the choice of manufacturing process can have a direct bearing on the amount of money needed to establish a wood reconstituted board plant.
CHAPTER VIII

MANUFACTURING COSTS

Manufacturing costs of plants producing wood reconstituted boards reported in this chapter were current in 1955 and 1956. The manufacturing costs today must be higher than before because the raw material costs, conversion costs, and fixed charged have generally become higher.

Total manufacturing costs of fiberboard, particle board and shaving board are comprised of (10): 1. raw material costs; 2. conversion costs; and, 3. indirect costs.

A. RAW MATERIAL COSTS

The raw materials which enter the processes to ultimately become wood reconstituted board consist of:

1. Wood materials
2. Resins
3. Other additives

Wood Materials

Wood material cost, although a relatively minor item, is an important cost factor included in manufacturing costs. The economic aspects of the wood materials used are discussed in Chapter III, and the costs of wood materials are shown in Table 3, page 36.
Resins

The largest, single cost item per unit of board produced is the synthetic resin that is used to bond the wood materials together. Urea-formaldehyde and phenol-formaldehyde adhesives are the most widely used and, where the application of the board is as furniture corestock, urea-formaldehyde is almost exclusively the choice. The cost of the urea resins, in relation to the phenolics, is approximately 50 per cent, based on comparable solids content. A portion of the cost advantage in favor of the ureas is reportedly offset by the lower percentage of phenolic resins which can be used. Whereas 5 to 10 per cent urea solids, based on the dry weight of the wood-glue mix, is generally used in particle board manufacture, phenolic resin solids are used in quantities approximately 3 to 6 per cent of dry weight of the wood-glue mix (10).

The purchase price of urea-formaldehyde resins varies with the size of purchase and the type of container. Shipments are made of quantities ranging from 30 gallon units to tank cars containing 6000 to 8000 gallons. Manufacturers' catalogs list purchase prices, based on 60 to 66 per cent resins solid content, from $0.14 to $0.15 per pound for individual 30 gallon drums to about $0.095 per pound as purchased in tank car lots. Various particle board manufacturers report their resin costs at between $0.085 and $0.090 per pound, on the basis of 60 to 66 per cent resin solids (10).

Reconstituted board producers, in some instances, employ chemical engineers to manufacture their own resins, and service the demands of the company in this respect.
Resin manufacturers, through their representatives, work with individual concerns in formulating the most suitable resin and catalyst combinations for a particular application. As resin prices are fairly uniform across the industry, and as the resins furnished by any of the established suppliers are satisfactory, service represents one of the major selling points.

In manufacturing particle board or shaving board, more resin is required than in making hardboard, and the cost of the resin per ton of particle board and shaving board can be expected to be higher than the resin cost for making a ton of hardboard.

Other Additives

Catalysts suitable for application in particle board and shaving board production usually sell for approximately $0.10 per pound. Usage approximates 2 to 6 per cent based on the weight of the urea-formaldehyde resin (60 to 66 per cent resin solids) (10).

The resin, suitably catalyzed and incorporated into the particle board, represents approximately 35 to 60 per cent of the total manufacturing cost of the board. This is equivalent to between $0.025 and $0.040 per square foot of medium-density 3/4 inch thick board if the total manufacturing cost is $0.07 per square foot (10).

Resin extenders, such as wheat flour, are used by some producers. The extension, in cases where the method of application to the wood particles is by spraying, has been used in quantities up to about 25 per cent based on the resin weight (60 to 66 per cent resin solids). The cost of the wheat flour ranges from $0.045 to $0.055 per pound (10).
Size materials, when used, are applied in quantities approxi-
mating 2 to 3 per cent of the weight of the resin-wood mix. The cost is
roughly $0.045 to $0.055 per pound (10).

B. CONVERSION COSTS

Direct costs incurred in converting the raw material into wood
reconstituted board are:

1. Steam
2. Electric
3. Oil
4. Labor

Steam

Steam is a relatively small cost item. The cost of this item is
usually placed at around $0.050 to $0.70 per 1000 pounds (10). The
Miller-Hofft Process, as indicated in their economic study, utilizes
1200 pounds per hour in its eight-opening press (5).

Electricity

Electricity rates vary with the location. For example, in North
Carolina, it is available at $0.010 to $0.015 per KWH; Chicago, Illinois
at $0.006; Corvallis, Oregon at $0.023. Electricity costs will also
vary with the processes (10, 24).

Oil

Oil constitutes a cost factor when the wood material to be used
must be dried, and oil-fired dryers are used to accomplish the job. It
is also used in some cases to heat the steam boiler. This cost item is
not a function of the process type, but depends on the level of production and the moisture content of the wood. Cost of oil is approximately $0.15 per gallon (10).

Labor

Labor rates vary with the location of operation. The hourly pay for Pacific Northwest workers averaged $2.29, compared to $1.68 for Mississippi (24), and $1.25 to $1.50 for North Carolina (10). The number of man-hours required for board production depends on the types of board product and the processes.

C. INDIRECT COSTS

Cost items indirectly connected with the production of reconstituted board are, in most instances, fixed charges that continue at the same rate irrespective of the production level. They may represent 20 to 25 per cent of the total manufacturing cost (10). Composing these charges are depreciation on buildings and machinery, property taxes, insurance, maintenance, and supervision. In addition to the indirect manufacturing costs are such charges as general administration, selling expenses, office supplies and expenses, etc.

Estimates of manufacturing costs for making 1/8 inch and 1/4 inch hardboard, and 1/4 inch particle board, are summarized in Table 8 (10), from data of Elmendorf Research, Inc., of Palo Alto, California. In studying such tabular data, attention is directed to the fact that some variations in production cost should be expected depending upon the cost accounting method used, the size of operation, and the wide range of values placed on the wood residue utilized.
TABLE VIII
APPROXIMATE MANUFACTURING COSTS OF HARDBOARD AND PARTICLE BOARD (2)
PER 1,000 SQUARE FEET AND PER TON

Estimated by Elmendorf Research Incorporated, Chicago, Illinois

<table>
<thead>
<tr>
<th>ITEM</th>
<th>1/8 IN. HARDBOARD</th>
<th>1/4 IN. HARDBOARD</th>
<th>1/4 IN. PARTICLE BOARD</th>
</tr>
</thead>
<tbody>
<tr>
<td>MANUFACTURING PROCESS</td>
<td>WOOD FIBERS</td>
<td>WOOD FIBERS</td>
<td>WOOD GRANULES</td>
</tr>
<tr>
<td></td>
<td>WET FORMING</td>
<td>WET FORMING</td>
<td>DRY FORMING</td>
</tr>
<tr>
<td></td>
<td>CONTINUOUS METHOD</td>
<td>BATCH METHOD</td>
<td>BATCH METHOD</td>
</tr>
<tr>
<td>RAW MATERIAL</td>
<td>SLABS, EDGINGS, TRIM</td>
<td>SLABS, EDGINGS, TRIM</td>
<td>SAWDUST, SHAVINGS</td>
</tr>
</tbody>
</table>

Pressing Cycle:
Minutes: 12 15 5

Weight of Board:
Lbs. per 1,000 Sq. Ft.: 700 1,300 1,300

Production Volume:
Sq. Ft. per 24 Hr. Day: 160,000 50,000 50,000
Tons per 24 Hr. Day: 56 32 32

Man Hours of Labor:
per Ton of Board: About 7 About 7 About 10

Capital Investment:
$1,900,000 $800,000 $350,000

Amortization:
10 years, $136 per year $136 per year $136 per year
Interest 6% per $1,000 per $1,000 per $1,000

UNIT COSTS - DOLLARS PER 1,000 SQUARE FEET

RAW MATERIAL COSTS

Slabs, Edgings, Trim:
$7.00 per ton Dry Basis $2.45 $4.55

Sawdust, Shavings:
$4.00 per ton Dry Basis $2.60

Chemicals, Resin, Alum $1.95

Phenolic Resin:
3% at 30¢ per lb. $11.70
8% at 30¢ per lb. $31.20

Total Raw Material Costs: $4.40 $16.25 $33.80
### TABLE VIII (continued)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>1/8 IN. HARDBOARD</th>
<th>1/4 IN. HARDBOARD</th>
<th>1/4 IN. PARTICLE BOARD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MANUFACTURING PROCESS</strong></td>
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<td><strong>WOOD FIBERS</strong></td>
<td><strong>WOOD GRANULES</strong></td>
</tr>
<tr>
<td></td>
<td><strong>WET FORMING</strong></td>
<td><strong>WET FORMING</strong></td>
<td><strong>DRY FORMING</strong></td>
</tr>
<tr>
<td></td>
<td><strong>CONTINUOUS METHOD</strong></td>
<td><strong>BATCH METHOD</strong></td>
<td><strong>BATCH METHOD</strong></td>
</tr>
<tr>
<td><strong>RAW MATERIAL</strong></td>
<td>SLABS, EDGINGS, TRIM</td>
<td>SLABS, EDGINGS, TRIM</td>
<td>SAWDUST, SHAVINGS</td>
</tr>
</tbody>
</table>

### UNIT COSTS - DOLLARS PER 1,000 SQUARE FEET (continued)

**CONVERSION COSTS**

<table>
<thead>
<tr>
<th>Supplies:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire Cloth, Oil, Repair Parts</td>
<td>$2.50</td>
<td></td>
</tr>
<tr>
<td>Cauls, Screens, Oil, Repair Parts</td>
<td>$2.00</td>
<td></td>
</tr>
<tr>
<td>Cauls, Oil, Repair Parts</td>
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<td>$2.00</td>
</tr>
<tr>
<td>Steam at 80¢ per Ton</td>
<td>$1.70</td>
<td>$1.50</td>
</tr>
<tr>
<td>Electricity at 0.6¢ per K.W.H.</td>
<td>$1.25</td>
<td>$2.35</td>
</tr>
<tr>
<td>Labor at $2.00 per Hr.</td>
<td>$4.80</td>
<td>$8.00</td>
</tr>
<tr>
<td><strong>Total Conversion Costs:</strong></td>
<td><strong>$10.25</strong></td>
<td><strong>$13.85</strong></td>
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</table>

**FIXED CHARGES**

<table>
<thead>
<tr>
<th>Administration Estimated at:</th>
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</thead>
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<tr>
<td>$300 per day</td>
<td>$1.90</td>
<td></td>
</tr>
<tr>
<td>$150 per day</td>
<td>$3.00</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Insurance: Fire, Workmen's Compensation Estimated at:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$25,000 annually</td>
<td>$0.70</td>
<td></td>
</tr>
<tr>
<td>$18,000 annually</td>
<td>$1.20</td>
<td></td>
</tr>
<tr>
<td>$7,500 annually</td>
<td></td>
<td>$1.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Taxes: 2% on Investment</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.80</td>
<td>$1.00</td>
<td>$0.50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Amortization of Investment</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$5.25</td>
<td>$7.00</td>
<td>$3.20</td>
</tr>
</tbody>
</table>

<p>| <strong>Total Fixed Charges:</strong> | <strong>$8.65</strong> | <strong>$12.20</strong> | <strong>$7.70</strong> |</p>
<table>
<thead>
<tr>
<th>ITEM</th>
<th>1/8 IN. HARDBOARD</th>
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<td>RAW MATERIAL</td>
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<td>SLABS, EDGINGS, TRIM</td>
<td>SAWDUST, SHAVINGS</td>
</tr>
</tbody>
</table>

| TOTAL MANUFACTURING COST PER 1,000 SQUARE FEET | $23.30 | $42.30* | $56.80* |

| TOTAL MANUFACTURING COST PER TON | $66.60 | $65.00* | $87.40* |

*1/4 Inch Board

Based on these conditions:
- Slab Wood at $7.00 per ton, Dry Basis
- Sawdust at $4.00 per ton, Dry Basis
- Phenolic Resin at 30¢ per pound
- Labor at $2.00 per hour
CHAPTER IX
MARKETING

In today's business world the marketing of some products may be more of a problem than manufacturing them or getting the raw materials, even if the products fill a utilitarian need satisfactorily and are desired by many people. Limited consumption of such products may be attributed either to lack of consumer acceptance or to failure in overcoming intensified competition for the limited dollars which consumers have available to spend. In other words, the solution for such situations lies in conducting proper advertising, sales promotion, and direct selling activities.

A. PRODUCTION FOR THE MARKET

At the end of 1956, there were about 16 hardboard plants (24) and 31 particle board plants (10) which were producing board for sale on the open market. The total annual capacity of these 16 hardboard plants and 31 particle board plants was about 1250 million square feet, on a 1/8 inch thick board basis (24), and 225 million square feet, on a 3/4 inch thick board basis (10), respectively. The larger part of this particle board volume was applied as corestock, but included sliding doors, decorative panels, sheathing, and under layment for floors.

Future demands for wood reconstituted board can be determined by population growth. It was estimated that the excess of births over
deaths results in an equivalent of adding a city of 40,000 people in the United States every week \((24)\). Today's population of 173 million is expected to grow to 175 million by 1960, and to exceed 200 million by 1975, based on the present growth rate \((24)\). So the rapid growth in population will offer expanded markets for the many items of wood reconstituted boards -- residential construction, furniture, cabinets, and many others.

With increased popularity of hardboard, plus higher demands through population gains, it is entirely possible that some 860 million square feet of hardboard, 1/8 inch basis, will be used in 1975 for residential construction and 3,050 million square feet in all fields, as predicted by the Stanford Research Institute \((19)\) estimates for selected years, 1960-1975, are summarized in Tables 9 and 10 \((24)\), giving a break-down by uses.

Considerable growth also is expected for the insulating board and shaving board market for the same reasons.

B. PRICING FACTORS

Basic pricing factors consist of:

1. Factory price
2. Freight costs

**Factory Price**

The market price of wood reconstituted board will vary with its type and quality. The price depends partly on manufacturing costs, and partly on the selling price of other materials used for the same purposes. For example, cut-to-size yellow poplar lumber corestock, 5/8 to
TABLE IX
MARKET FOR HARDBOARD IN NEW RESIDENTIAL CONSTRUCTION (24)
MILLIONS OF SQUARE FEET OF BOARD
1953 ACTUAL; 1960 - 1975 ESTIMATED

Compiled by Stanford Research Institute

QUANTITIES FOR VARIOUS USES IN DWELLINGS

<table>
<thead>
<tr>
<th>YEAR</th>
<th>FLOORS</th>
<th>WALLS</th>
<th>CEILINGS</th>
<th>ROOFS</th>
<th>OTHER</th>
<th>TOTAL</th>
<th>1/8 Inch BASIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1953</td>
<td>15</td>
<td>41</td>
<td>23</td>
<td>17</td>
<td>14</td>
<td>110</td>
<td>126</td>
</tr>
<tr>
<td>1960</td>
<td>45</td>
<td>95</td>
<td>50</td>
<td>40</td>
<td>30</td>
<td>260</td>
<td>300</td>
</tr>
<tr>
<td>1965</td>
<td>60</td>
<td>155</td>
<td>85</td>
<td>65</td>
<td>55</td>
<td>420</td>
<td>475</td>
</tr>
<tr>
<td>1970</td>
<td>60</td>
<td>230</td>
<td>115</td>
<td>95</td>
<td>70</td>
<td>570</td>
<td>645</td>
</tr>
<tr>
<td>1975</td>
<td>70</td>
<td>320</td>
<td>145</td>
<td>130</td>
<td>95</td>
<td>760</td>
<td>860</td>
</tr>
</tbody>
</table>
TABLE X
MARKET FOR HARDBOARD IN ALL FIELDS (2a)
SQUARE FEET OF BOARD, 1/8 INCH BASIS
1952 ACTUAL: 1960 - 1975 ESTIMATED
Compiled by Stanford Research Institute

<table>
<thead>
<tr>
<th>YEAR</th>
<th>MANUFACTURING</th>
<th>FURNITURE</th>
<th>HOUSEHOLD</th>
<th>CONSTRUCTION</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1952</td>
<td>280,000,000</td>
<td>325,000,000</td>
<td>175,000,000</td>
<td>220,000,000</td>
<td>1,000,000,000</td>
</tr>
<tr>
<td>1960</td>
<td>400,000,000</td>
<td>430,000,000</td>
<td>240,000,000</td>
<td>530,000,000</td>
<td>1,600,000,000</td>
</tr>
<tr>
<td>1965</td>
<td>460,000,000</td>
<td>530,000,000</td>
<td>270,000,000</td>
<td>770,000,000</td>
<td>2,030,000,000</td>
</tr>
<tr>
<td>1970</td>
<td>570,000,000</td>
<td>650,000,000</td>
<td>330,000,000</td>
<td>1,000,000,000</td>
<td>2,550,000,000</td>
</tr>
<tr>
<td>1975</td>
<td>630,000,000</td>
<td>780,000,000</td>
<td>360,000,000</td>
<td>1,280,000,000</td>
<td>3,050,000,000</td>
</tr>
</tbody>
</table>
11/16 inch thick, ready to glue into plywood, sells for $0.25 per square foot. Particle board, on the other hand, in thicknesses of 3/4 to 7/8 inch, sells for $0.14 per square foot. The manufacturing cost for yellow poplar lumber cores varies from $0.15 to $0.22 per square foot; while the same cost for wood particle board ranges from $0.05 to $0.10 per square foot (10).

**Freight Costs**

The distance over which the wood reconstituted board must be transported to a market, and consequently the freight charges incurred, are an important consideration from the standpoint of price. The manufacturing location is practically limited to the source of raw material which is, in the main, bulky residual wood. The ideal situation would be to have raw material supply and the market in proximity to one another.

Freight rates vary by the type of board and the distance shipments travel from the plant to their destination.

**C. MARKET POTENTIAL**

**Expansion in Applications**

One of the most obvious means of expanding the use of the products is to capture a greater portion of the market in which the product already has a share. Wood reconstituted board appears likely to follow this procedure. The expanded application of reconstituted board also depends to some extent on technical improvement of its properties. In addition to the possibility of direct substitution of reconstituted board for other materials, additional markets may be
found through product development. It is conceivable that the price, and in some cases the physical, advantages of reconstituted board can be exploited through changes in structural design of the product.

Export and Import

The export and/or import of wood reconstituted board apparently will not greatly influence the potential sales of the product in this country. Since reconstituted board has a low value per unit of weight, long distance shipments have a tremendous effect on the relative cost of the delivered product. A small import duty, along with high freight costs, should prevent reconstituted boards from foreign countries from flooding the United States market. In this country, the product has a total labor cost which is lower than distance freight charges, and this should prevent low-wage countries from overcoming the high freight costs and duty by paying low wages. Exports from the U.S. will be limited by the same economic considerations.

D. RECONSTITUTED BOARD PURCHASES BY TYPE OF DOMESTIC CUSTOMER

Purchasers of reconstituted board may be classified into five general groups (24):

1. Industrial consumers and fabricators that convert reconstituted board into finished products, or that utilize reconstituted board as a component part of their product.

2. Wholesale distributors of building materials which carry substantial stocks of various kinds of reconstituted board for resale to retail establishments.
3. "Brand-name" firms in the building materials field which distribute reconstituted board (to round out their line) along with other products of their own manufacture, selling under private labels on a nationwide basis.

4. Retail dealers of lumber and building materials, who sell to building contractors, to the small industries, and to the public generally.

5. The United States Government, which uses reconstituted board for various military, industrial, and civilian applications.

E. TRADE PROMOTION

Industry Cooperation

The industry-wide trade promotion should be used to inform the public concerning the characteristics of the product. This would not only include advertising to the general public, but would also include the publication of technical bulletins for architects and designers.

Advertising

Advertising is now being conducted on a wide scale by the larger producers of wood reconstituted board. Consumer advertising is bringing reconstituted board to the attention of the public. Information is being distributed both through trade outlets and directly to architects and designers.

F. MARKET ANALYSIS

Advertising and trade promotion can develop sales for a new product only when the potential market actually exists. Comprehensive market analyses are very helpful in determining where a potential market lies and what sales volume can reasonably be expected. With the
facts determined from a scientific market analysis, advertising and trade promotion can be realistically pointed toward a definite goal.

G. COORDINATION OF PRODUCTION WITH ADVERTISING

Advertising cannot be properly directed to the market until it is coordinated with the actual manufacturer of the product. The characteristics of the product to be made are determined by the demands of the consumers, as indicated from the market analysis. This is dependent on the ability of the factory to produce the board which is specified, at the price the consumers will pay. When all this information is available, an advertising program can be developed which will obtain customers for the product as it is produced. Consumers must be advised of the characteristics of the board being produced, the range of sizes in which it can be obtained and where it is available. For the advertising to be effective, the product must have the characteristics and availability as advertised. This means that current records must be kept of distributors’ sales so that production can be coordinated with sales and advertising.
BIBLIOGRAPHY
BIBLIOGRAPHY


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