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PREFACE

This book on particleboard and dry-process fiberboard was made possible only by the many professionals who so generously contributed their time in preparing presentations for the ten symposia on particleboard held at Washington State University from 1967 through 1976. They are the true authors of this book and it is dedicated to them. The selected references at the end of each chapter contain the key references used in assembling the book.

One of the original objectives of the symposia was the consolidation of the information presented in the series into one general book on the subject. To help meet this objective, an outline was prepared for each symposium. The earlier outlines, in particular, were prepared in great detail in order to develop comprehensive information on the basics of board manufacture. Another of the reasons for holding the symposia on particleboard was to "research" the experiences of many people in the field. Competent people with appropriate practical experiences were searched out and persuaded to talk and write about these experiences to implement the research and development papers presented. Such factual information is extremely difficult to obtain, and these contributions have been most important to the success of the symposium series.

For detailed study, therefore, the several volumes of proceedings of the Washington State University symposia on particleboard are recommended. Information from other publications is also included in an attempt to tell the full story. My apologies to the many authors if I have misconstrued any of their papers in preparing the text.

There is so much information available that it is difficult to include all of it in a single book. This effort attempts to highlight the important facets of the industry. Some may disagree with the author's selection of equipment and processes to be discussed in detail and those to be mentioned briefly or omitted entirely. However, for those wanting to enter the industry, this volume should provide basic information and the background for asking detailed, intelligent questions before embarking on such a new venture.

The emphasis is on U.S. practices; however, information from other parts of the world has been included to try to provide different viewpoints on how to produce and handle composition board. The U.S. board industry has generally been based on waste material from sawmills, such as planer shavings and sawdust, combined with some fiber generated from chips. Other parts of the world produce

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1. INTRODUCTION

The composition board industry, including hardboard, insulation board, particleboard (extruded and platen-pressed), medium-density fiberboard, cement-bonded board, and molded products, is of very recent origin. No one has been able to coin a good, descriptive term acceptable to everyone for this relatively new branch of the forest products industry. These products were conceived in the laboratory and brought to fruition through laboratory research endeavors as well as pilot plant development programs. Thus, these industries are tied very closely to science and technology.

Products made from comminuted woody materials in the shape of fiber, shavings, and the many other possible types of particles have special appeal, as they can be and mostly are made from woodworking waste, noncommercial or low-value tree species, and agricultural wastes. Future considerations indicate that bark, forest slash, industrial and municipal refuse, and other agriculture wastes will go into similar building products. This development is also ecologically sound, as previously wasted material is now and will be going into useful products, thereby conserving our natural resources. Relatively small amounts of energy and petrochemical derivatives are needed for this industry, further demonstrating its value to society in this day when people are becoming aware of the limitations of Earth's natural resources. Full use of nature's renewable resources such as wood places the forest products industry in a powerful position for maintaining and improving mankind's standard of living. No other building products industry has a resource base which can be maintained indefinitely.

Composition board products do, at present, require small amounts of other raw materials such as synthetic resin adhesives, but these are conserved because minor amounts are needed in a board or product consisting primarily of wood. Development of adhesive systems from paper-industry wastes or other plant sources now seems likely. It does not make ecological sense to produce buildings entirely of nonrenewable resources such as plastic or metal when wood is available. Our nonrenewable resources must be allotted carefully to provide the most for the common good; we must not use them if the renewable resource can provide the proper function.

Present commercial products of comminuted wood have some very desirable characteristics: availability in large sheets, smooth surfaces, uniformity in properties from sheet to sheet, and freedom from localized defects. However, such



products have been largely excluded from primary structural uses because they have been unable to approach the longitudinal stiffness, dimensional stability, and long-term load-carrying ability of sawn lumber or plywood. Changes in construction design can accommodate many of the present products but this has not occurred to any extent yet.

The future situation seems likely to be dramatically changed. Combinations of recently developed methods of particle alignment, with the use of particles deliberately manufactured with optimum particle geometry, can yield materials equaling or surpassing the structural capability and reliability of sawn lumber and plywood. Another contributing factor is the ease with which properties of comminuted-wood products can be modified by treatment of the particles with fire retardants, preservatives, and stabilizing impregnations. Coupled with composition board's much higher efficiency of resource utilization, these factors must bring about extensive rethinking, reorganization, and realignment in the entire wood products industry.

Thus, while the quality of lumber and plywood trends downward as we enter the era of small-log, short-rotation forestry, the opportunity is opened for particle-based products of greatly improved structural utility to serve in much broader markets. This is in line with the continuing trend from labor-intensive processes to mechanized, automated, capital-intensive processes involving greater technological sophistication.

A particular advantage that platen-pressed, dry-process boards can have over other types of boards is unlimited size within practical consideration. Most plywood is 4x8 ft (1.22x2.44 m) in size. However, most particleboard and medium-density fiberboard is made in larger sheets for reasons which will be brought out later. The largest board made in the United States at present is 8x48 ft (2.44x14.63 m); however, a medium-density fiberboard plant will soon be producing board 8x65 ft (2.44x19.81 m). This size of press is already in use in Europe. Thus, board size can usually be determined by the end use rather than by the limitations of the board-producing equipment or the raw material, as with plywood.

This book will be about products made with comminuted wood. It will concentrate on the dry-process segment of the industry, as will be explained later. The dry-process board or products industry started its worldwide rapid expansion about 1949, as far as commercial production is concerned. The development of this industry will be traced later. The emphasis in this book will be on dry-process methods and technology for producing platen-pressed boards. Some discussion will cover extruded particleboard and molded products, but the main focus will be on those production processes used and products made in greatest volume in the United States and Canada.

Before discussing the various products made with comminuted wood, let us consider the wood elements that can be combined into a multitude of products. Dr. George G. Marra (1969) has eloquently spoken and written about these. His table of nonperiodic wood elements is presented in Figure 1.1. He shows 14 basic wood elements, of which 10 can be produced from residue wood or wood unsuitable for plywood and lumber. Seven or eight of these are of direct concern to the manufacture of composition board. The following discussion, which is of major importance to the forest products industry, is quoted from his treatise.

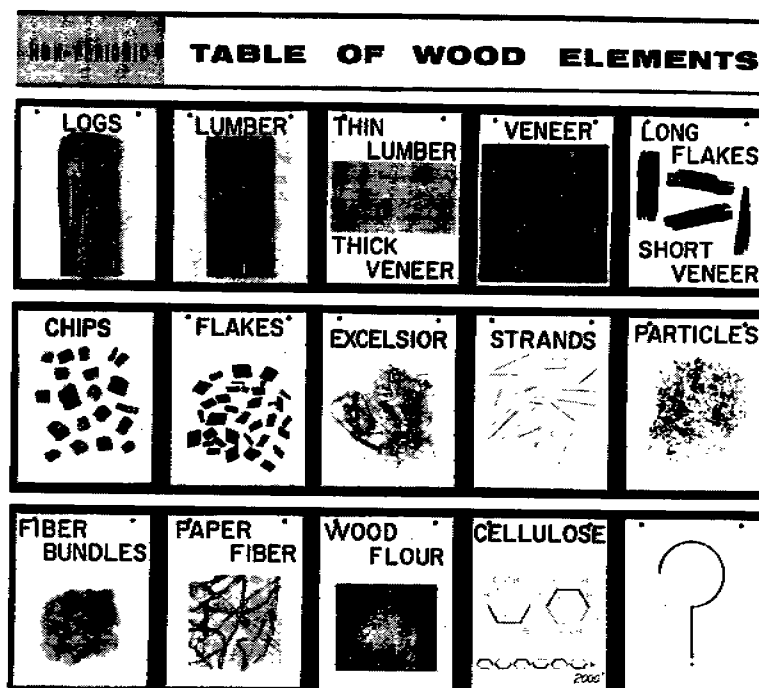


Figure 1.1. Basic wood elements arranged from largest to smallest. Of the 14 elements shown, 10 can be produced from residue wood, or material unsuitable for lumber and plywood, and all can contribute to the development of new product concepts (Marra 1969).

Hundreds of useful products can be produced from these elements individually in homogeneous fashion, and thousands can be produced from combinations of elements. Such factors as density, size of element, and wood species contribute greatly to the proliferation of products.

While a group of products may display differences in varying degrees, often the basic concept is the same. Therefore, these concepts, from which many products may spring for marketing purposes, bear a special aura of importance and their genesis marks a significant innovative event. In order to analyze the output of past innovative effort and future potential, it is useful to consider each combination of elements as a distinct product concept. On the basis of this definition and the element shown in Figure 1 [see Figure 1.1], the number of possible concepts is seen to be mathematically limited. Taken in combinations of twos, for example, these elements would provide a maximum of 196 possible concepts, including homogeneous and seemingly redundant combinations. These redundant combinations are somewhat indeterminate in regard to concept status because of the wide difference in product properties resulting from varying proportions of each element, and because of the varying degree of deliberate orientation of which many elements are capable. Nevertheless, some real redundancy exists in this analytical scheme, but the main point I wish to make is not thereby invalidated.

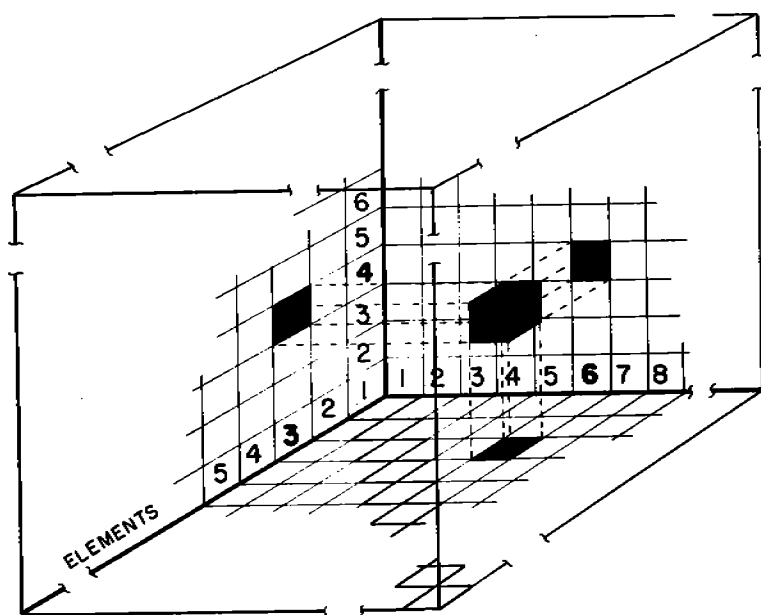


Figure 1.2. Schematic representation of a three-element product concept. The 14 wood elements and 3 non-wood elements arranged in a three-dimensional array in this fashion generate a total of 4913 such product concepts, of which perhaps 3000 may have technical validity. The product concept shown, for example, contains element numbers 3, 4, and 6 (Marra 1969).

A significant expansion in the number of possible product concepts occurs when three logical non-wood elements are included, namely, plastics, metals, and minerals. A very large increase in concepts occurs when both wood and non-wood elements are considered in combinations of threes. This is shown schematically in Figure 2 [see Figure 1.2]. On this basis, there is a theoretical maximum of 4913 concepts. However, with some discounting for redundancy and foolhardy combinations (i.e., logs and homogeneous non-wood), the theoretical maximum is probably nearer to 3000. Since each of these basic concepts can spawn a veritable galaxy of products, as some already have, it becomes clear that each such development is indeed an important event. Of course, other wood elements are likely to be discovered in the future, as indicated by the question mark in Figure 1, and these will further increase the concept possibilities. Bark, when it comes into its own, may develop another array of elements in similar fashion, and another array of products.

Analysis of current wood products reveals that most of them emerge from the application of relatively few basic concepts. For example, according to statistical summaries of the Department of Commerce, only three concepts account for practically the entire forest output of the State of Washington, and one of these, lumber, falls short of the status of a concept as I have defined it. . . This suggests, then, that if my premises are true, the State of Washington [for example] is operating on only 0.1% of the total possibilities. Actually, some other concepts such as laminated lumber, fiberboard, particleboard, and overlaid plywood are being utilized, which indicates a higher perfor-

mance level, technically speaking. On a world basis, the operating level is probably about 20 times greater than this over-simplified example. According to my analysis, about 64 of the total of 3000 concepts are presently being used or being developed, or roughly 2%. The rest are waiting to be discovered and exploited by enterprising individuals.

Perhaps I have made a 100% error in tabulating existing concepts in use. If so, the percentage is about 4% instead of 2%, and one might well wonder why it isn't higher considering the pace of technological advances in other fields. Therefore at this moment, approximately 2872 concepts remain tantalizingly at large.

Without depreciating the value of single-element products, nor inflating the value of three-element products, it seems obvious that much progress lies beyond the horizon. In addition, we need to consider the tremendous potential inherent in particle products by virtue of the concept of molding to simple and complex shapes, and the concept of orientation of elements for directional strength. Furthermore, the unique susceptibility of all particle-type elements to special treatments for resistance to fire, insects, fungi, and moisture, adds a further dimension to product possibilities.

. . . people in the composition board industry are potentially in command of half of the basic wood elements known to man. It is unthinkable that [there has ever been] cause to complain about lack of opportunity for technical progress. . .

It is rather tempting to cogitate on the 2872 product concepts awaiting discovery and to try artfully to select one for possible development. However, I believe that this would not be the most effective approach. Leading market analysts have long advocated that a thorough knowledge of the performance requirements of a proposed new product is necessary first in order to optimize the development effort and assure future market acceptance of the product. The sequence of action presumes that performance requirements can be translated into measurable properties, and these then scientifically designed into the product.

Wood, in general, has been slow to adjust to this principle, and understandably so because it is essentially a product of nature, and the initial processors have in the past been able to pass it on still largely in the form of a raw material with no essential change in its basic properties. However, in the hands of the particleboard technologist, wood can be made to absorb considerable amounts of science during processing—all in the interest of improved properties and better performance during ultimate use.

Here, then, lies one of the important keys to future industrial progress with wood. Given the service requirements of a product, add a knowledge of what elements contribute what properties, together with accessory knowledge of processing parameters, and it should be possible to zero in on an ideal product for the intended use.

The new fighting stance this kind of capability gives to wood may well be taken in stride and may be little noticed by our busy technologists and engineers. However, I believe that it is more than a pleasing academic platitude: It will be a whole new way of life for wood and it will embrace management attitudes as well as technical skill.

We are, of course, nowhere near [having] an adequate knowledge of wood elements to be able to make such optimistic advance guarantees of success. However, I believe that the trend of research effort is in that direction, or should be, and it is only a matter of time that such occurrences will be commonplace. The development of fine surfaces for certain types of particleboard in recent years is an excellent example of the operation of this principle.

DEFINITIONS

Composition boards have many different names and definitions, and they vary somewhat throughout the world. To start, let us define some of the products based on definitions set forth in the American Society for Testing and Materials (ASTM) Standard D 1554, "Standard Definitions of Terms Relating to Wood-Base Fiber and Particle Panel Materials," which covers U.S. practice. Terminology for worldwide use will then be reviewed.

General Definitions

Wood-base fiber and particle panel materials: A generic term applied to a group of board materials manufactured from wood or other lignocellulosic fibers or particles to which binding agents and other materials may be added during manufacture to obtain or improve certain properties. Composed of two broad types, fibrous-felted and particleboards.

Fibrous-felted board: A felted wood-base panel material manufactured of refined or partly refined lignocellulosic fibers characterized by an integral bond produced by an interfelting of fibers and, in the case of certain densities and control of conditions of manufacture, by ligneous bond, and to which other materials may have been added during manufacture to improve certain of its properties.

Particleboard: A generic term for a panel manufactured from lignocellulosic materials (usually wood), primarily in the form of discrete pieces or particles, as distinguished from fibers, combined with a synthetic resin or other suitable binder and bonded together under heat and pressure in a hot press by a process in which the entire interparticle bond is created by the added binder, and to which other materials may have been added during manufacture to improve certain properties. Particleboards are further defined by the method of pressing. When the pressure is applied in the direction perpendicular to the faces, as in a conventional multi-platen hot press, they are defined as flat-platen-pressed; and when the applied pressure is parallel to the faces, they are defined as extruded.

Wood-cement board: A panel material in which wood, usually in the form of excelsior, is bonded with inorganic cement.

Classification of Fibrous-Felted Boards

Structural insulating board: A generic term for a homogeneous panel made from lignocellulosic fibers (usually wood or cane) characterized by an integral bond produced by interfelting of the fibers, to which other materials may have been added during manufacture to improve certain properties, but which has not been consolidated under heat and pressure as a separate stage in manufacture, said board having a density of less than 31 lbs/ft³ (specific gravity [sp gr] 0.50) but having a density of more than 10 lbs/ft³ (sp gr 0.16).

Hardboard: A generic term for a panel manufactured primarily from interfelted lignocellulosic fibers (usually wood), consolidated under heat and pressure in a hot press to a density of 31 lbs/ft³ (sp gr 0.50) or greater and to which other materials may have been added during manufacture to improve certain board properties.

Medium-density hardboard: A hardboard, as previously defined, in a density between 31 and 50 lbs/ft³ (sp gr between 0.50 and 0.80).

High-density hardboard: A hardboard, as previously defined, with a density greater than 50 lbs/ft³ (sp gr 0.80).

Classification of Particleboards

Low-density particleboard: A particleboard, as previously defined, with a density of less than 37 lbs/ft³ (sp gr 0.59).

Medium-density particleboard: A particleboard, as previously defined, with a density between 37 and 50 lbs/ft³ (sp gr between 0.59 and 0.80).

High-density particleboard: A particleboard, as previously defined, with a density greater than 50 lbs/ft³ (sp gr 0.80).

By carefully studying these definitions, it can be seen that the terms are clearly defined. However, one of the most significant trends in the board industry is the elimination of the previously distinct differences between particleboard and hardboard, making it difficult to employ such clear definitions.

As noted above, hardboard is characterized as a product made of fibers. Most hardboards initially were of high density. In wet-process hardboard the lignocellulosic bonds hold the boards together, and it was not until the late 1940s or early 1950s that synthetic resins were used extensively in bonding fibers in the new dry-process hardboard industry. Particleboard, a dry-process product using a number of different types of particles, was at first usually made at low and medium densities. However, as both of these industries evolved, a wide overlapping has developed in their respective density ranges and particle types. Much fiber is now going into particleboard. Some very coarse fiber, which approaches a particle rather than a fiber, is employed in certain hardboards. In the previously mentioned ASTM D 1554, fibers are one type of element included in both the wood-base fiber and particle panel materials.

Certain hardboards such as the thick, medium-density board, are made primarily for the furniture market and are used interchangeably with particleboard. While usually classified as a hardboard, this medium-density board is marketed on the basis of the previous particleboard specifications for physical properties. In 1973 this board was referenced for the first time in PS58-73, which is a voluntary products standard for the Acoustical and Board Products Association (a recent merger of the American Hardboard Association and the Acoustical and Insulating Materials Association), covering the basic hardboards classed as tempered, standard, service-tempered, service, and industrialite. Industrialite is the new classification covering medium-density hardboard.

Also in 1973, the National Particleboard Association brought out the "Standard for Medium Density Fiberboard," NPA 4-73. The following definition is based on this standard:

Medium-density fiberboard: A dry formed panel product manufactured from lignocellulosic fibers combined with a synthetic resin or other suitable binder. The panels are compressed to a density of 31 to 50 lbs/ft³ in a hot press by a process in which substantially the entire interfiber bond is created by the addition of binder. Other materials may have been added during manufacture to improve certain properties.

Introduction

Maloney (1977)

Maloney 1977

Maloney 1977

Presently, thin particleboard is marketed along with hardboard in the pre-finished paneling market. Causing further confusion in definitions of board type is the product Cladwood, which is produced with a dry-process core and wet-process faces which are formulated as a fibrous slurry made from old newsprint. To complete the confusion, there is a Canadian process for making wet-felted particleboard by which the board can be composed of 85% particles and 15% fiber.

Consequently, the early distinct differences between these hardboards and particleboards are becoming more and more blurred, although both are still represented by separate and distinct associations.

It is not unreasonable to assume that the two groups of products at some time in the future may be jointly included under some new descriptive term such as *particle and fiber products*, *reconstituted products*, *composition products*, *engineered board*, or *wood-based panels*. Perhaps this latter classification is the most fruitful approach, as a family of related products will result which will be differentiated on the basis of properties rather than on the type of fiber or particle used.

Another recent development is the previously mentioned invention of a method for orienting fibers or other particles parallel to each other so that a board can be produced having far greater strength in one direction, compared with its other direction. Such a board can be comparable to lumber or plywood in properties. As such, it will be possible to use this board of oriented fibers for the face sheets on structural panels, in combination with a core of other types of particles, for a high-quality structural composition board. The distinction between types of boards therefore will be blurred further as composition board material moves more into the structural area.

Turning now to the world situation, the United Nations Economic Commission for Europe (ECE) and the Food and Agriculture Organization of the United Nations (FAO), in their "Classification and Definitions of Forest Products," present a number of definitions relative to wood-based panels which show the difficulty in pinpointing product descriptions. Wood-based panels (including similar panels from other lignocellulosic materials) cover plywood, particleboard, and fiberboard as a family. It is pointed out that fiberboard refers to fiber building board.

The product may be manufactured from wood in the form of solid wood, veneer, strands, particles, or fibers. Bonding agents and other materials may be added during manufacture to improve certain properties. The bonding agent can be an organic binder as in plywood and particleboard or may be inherent as in some fiberboards. The document goes on to state that the term *wood-based panel* is also applied to composite structures of the panel type such as cellular board (plywood of cellular construction) and those in which materials other than wood, such as foam plastic cores and plastic or metal faces or cores, constitute a small part of the whole material content, as well as to panels with an inorganic binder but in which wood or other lignocellulosic material constitutes the most important part of the product by volume, e.g., panel, mineral bonded, wood particle base. The interesting point with the panels made with inorganic binder is that volume is used in determining that the product is to be called wood-based. On a weight basis, the inorganic binder, which is usually cement, weighs more than the wood.

This definition goes on to state that non-wood lignocellulosic materials, including agricultural residues such as bagasse, flax shives, jute sticks, straw and hemp, the form of stalks, particles, and fibers, are also used to manufacture particleboard and fiberboard. In these the bond may be inherent or provided by synthetic resin. Additives may be applied during manufacture to improve certain properties. Veneer sheets are included in this product grouping.

The breakdown of wood-based panels shows veneer sheets, plywood, veneer plywood, core plywood other plywood, particleboard of wood (flat press), particleboard of other lignocellulosic materials (flat press), particleboard (extruded), fiberboard (fiber building board), insulating board, medium hardboard, medium hardboard (regular), hardboard, hardboard (regular), mineral-bonded panel (wood particle base), straw panel board, and other panels, which at the present time include combinations of two or more wood-based panels.

Blockboard, which is made of narrow widths of board overlaid with veneer, is a very popular product in Europe and elsewhere in the world. This is classified as core plywood. It also appears that the composite panel of particles and veneer apparently will be called plywood for statistical purposes.

OBJECTIVE

It was decided to include in this book all those composition products manufactured by dry processing. Particleboard is made by dry processes while, as will be discussed, fiberboard can be made by wet or dry processes. The difference between dry processing and wet processing is basically in how the particles or fibers are laid up into the mat before it is consolidated into a board. Wet-process board can be considered an offshoot of the paper industry and involves some different technology from the dry-process board industry. The basic techniques for producing both dry-process hardboard, medium-density fiberboard, and particleboard (U.S. terminology) are quite similar and, as mentioned, will tend to overlap in the two industries as now represented by trade associations. As a case in point, the largest plant in the United States, if not in the world, is at the present time using a combination of planer shavings, other particles, and fiber for producing its particleboard product.

The objective of this book is to consider the dry-process board industry according to the rationale already described. The intended audience consists of those involved in the production of these types of boards and those who are interested in becoming acquainted with this industry. The presentation is meant to be practically oriented. Arguments as to whether a certain product should be called *hardboard*, *medium-density fiberboard*, or *particleboard* will be left to those involved in the trade associations.

Extruded board, molded products, and mineral-bonded products are minor parts of this industry and will be dealt with briefly. The book is organized to present historical, production, and market data first. This will be followed by an examination of the processes and product properties. For those unfamiliar with property terminology, it might be best to read Chapter 4 first in order to be familiar with these terms. Next, the scientific and technological parameters governing processing will be discussed, and the various process steps will be examined.

Both English and metric measurements will be used, as the United States is slowly moving toward the metric system. The metric or SI units will be those specified in ISO 1000 (International Organization for Standardization). The basic unit for pressure and stress is Pascal (Pa) or Newtons per square meter (N/m^2). The multiples include megapascal (MPa) and kilopascal (kPa). The choice of the appropriate multiple (decimal multiple or sub-multiple) of an SI unit is governed by convenience, the multiple chosen for a particular application being the one which will lead to numerical values within a practical range. The multiple usually chosen is between the numerical values 0.1 and 1000. A table of conversion values is in the Appendix.

HISTORY

Boards and building products of small particles or fiber are of very recent historical origin, although timber is man's oldest building material with the possible exception of stone. The earliest recorded history notes the use of timber and wood products for building.

Outside of building material, paper is the other major product of wood. The early Egyptians initiated its development when they used papyrus for the raw material. In A.D. 105 the Chinese developed the first paper out of wood by pounding the inner bark of the mulberry tree into pulp, adding water, and then drying the mixture in flat, fibrous sheets. It was not until 1799, however, that a Frenchman patented the first machine for making paper in a continuous sheet. In 1844 the Germans patented the first practical method of producing wood fiber by inventing a wood grinding machine, and in 1851 the English developed a system for breaking down the wood into fibers by chemical action. The manufacture of low-cost paper was then achieved by producing paper from wood, which was both cheap and plentiful, but the original concept was centuries old.

Plywood, a term that did not come into common usage until the late 1920s, was known in early times under the term *veneers*. The oldest portrayal of the art of veneering apparently was the mural, *Sculpture of Thebes*, which has been dated around 1450 B.C. The first commercial veneer firm in North America was established in New York City in 1824. In 1905, in Portland, Oregon, the idea of using veneer for a structural building panel was used to create the first structural plywood as we now know it. About 1934 waterproof adhesives were perfected for plywood manufacture, a development which enabled the use of plywood in exterior applications.

Timber, as mentioned previously, has always been known as a building material. The concept of plywood is centuries old, with the commercial exploitation taking place over the last fifty years. The concept of producing paper is also centuries old, with relatively recent commercial exploitation. The point of this brief discussion is that most of the useful materials made from wood have been known or the concepts have been established for centuries, and recent developments have been refinements of old concepts.

This brings us to boards or products of comminuted wood—the newest members of the forest products family. As is well known, a tremendous amount of residual material results from the production of lumber and plywood. Perhaps the

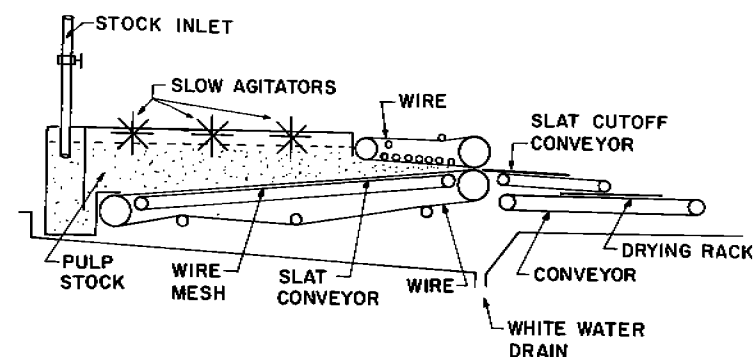


Figure 1.3. Side view of the first machine for producing insulation board, taken from a drawing by Carl Muench. Wood fibers carried in water flowed past rollers and onto a screen mesh where water was removed from the mat. Continuous mat was cut off at the end of the machine, then sheets went into a dryer. (Courtesy American Board Products Assn.)

most widespread use of this material over the centuries has been for fuel. No doubt, innumerable people over the centuries have visualized taking the waste material and producing some type of man-made board. However, records show that such developments are of very recent origin.

Wet-Process Fiberboard

Lyman obtained a United States patent in 1858 on fiberboard. Fleury obtained a United States patent in 1866 on an artificial nonflammable wood, which was a wet-formed fibrous product which was to be compressed in a press or by heated rolls. Other early experiments are reported in the 1880s for producing a wet-process hardboard or insulation board type of product.

In 1914 Carl G. Muench had an idea for producing an insulating board out of wood fibers. He was hired by a paper company to develop this new product, and he was able to build a machine and make the world's first insulation board on it within ten weeks. This was a partial adaptation of the process used in making paper and consisted of a huge "head box" for holding wood fibers in water from which the fiber slurry was metered out onto a continuously moving screen. The water was drained away through the screen, leaving a damp mat of interlaced fibers as shown in Figure 1.3. This material was then oven dried, yielding the sheets of board. Later this process was adapted for making insulation board from bagasse, which is the residual sugar cane stalk after the sugar has been extracted. This process has been refined over the years, but the key point is that it is a wet-process system based on papermaking technology.

This type of board ranges in density from 10 to 25 lbs/ft^3 (0.16–0.40 sp gr), which is lower than the wood and other raw materials from which it is usually made. It is widely used for sheathing, interior paneling, rigid roof insulation, and



Figure 1.4. Examples of typical insulation board products. (Courtesy Washington State Univ.)

as siding. It is a relatively low-cost material which requires little, if any, binding agent. However, it should be mentioned that for higher-quality boards, materials such as asphalt or vinsol (a thermoplastic binder) are added to improve board properties, particularly those associated with the pickup of water or moisture from the atmosphere. Figure 1.4 is a photograph of typical boards.

It is possible also to densify the insulation board after drying by consolidation in a heated press. This results in a high-density hardboard product.

Wet-process hardboard, another refinement on paper-producing technology, was the next type of composition board material to appear on the scene. William H. Mason discovered the process in 1924, and his discovery established the Masonite process for producing hardboard. To prepare the fiber, chips are subjected to high-temperature steam in a pressure vessel called a *gun*. The chips are subjected to approximately 600-psi (4.1 MPa) steam pressure for one minute, and then the pressure is quickly raised to more than 1000 psi (6.9 MPa) for five seconds. The pressure is suddenly released and the chips are exhausted from the gun. The pressure built up within the chips literally explodes them into a coarse mass of fibers. This mass can be further reduced into individual fibers or fiber bundles by means of an attrition mill. Lignin, in general terms, is nature's glue for binding the wood fibers together. In the steaming operation the lignin bonds between the cellulose fibers are softened, which permits a more improved disintegration of the chips into the fiber bundles as compared to unsteamed chips ground to fiber in an attrition mill.

After the fluffy masses of fiber are refined, the fiber is washed and the fines and hemicellulose solubles are removed. The hemicelluloses in the wood are hydrolyzed in the gun so they can be removed by washing. Removal of this material improves the dimensional stability, as sites for combining with water

molecules in the finished hardboard are eliminated. The remaining stock then goes to a former, somewhat similar to the one for producing insulation board, and is felted into a mat for the production of the hardboard. The mat is dewatered by draining most of the water through a fourdrinier-type screen which carries the formed mat. This type of mat is pressed into its final density in a hot press. A screen is used on the bottom of the mat to allow the moisture to escape during the pressing operation. If a smooth-two-sides (S2S) board is desired, the damp mat must first be oven dried before it is put into the hot press. Otherwise, the high moisture content of the mat will cause an excessive amount of steam to be generated, which will blow the board apart during or immediately after pressing. Board strength is obtained from the interlacing of the fibers developed during felting and by the rebonding of the lignin to the fibers, which occurs during the hot pressing of damp mats. Additives can be used to improve properties. The main point here is that this is again a wet-process method of producing a composition board.

It is interesting to note how Mason discovered the final steps of producing hardboard. Like many scientific breakthroughs, it occurred by accident. He had formed a wood fiber mat similar to the ones used in the insulation board industry. Just before his lunch hour he had placed this wet mat inside a crude hot press. He was using this method for drying the mat. As a precaution before he left for lunch, he turned off the steam so that excessive drying would not occur. However, the steam valve was faulty and steam kept on heating the press during his absence. When he returned he found the fiber mat had been pressed into a high-density hardboard. So from this initial discovery he proceeded to develop the modern wet-process hardboard industry.

This building material is well known throughout the world, as many plants have been constructed to produce this relatively new product. In comparison to insulation board, hardboard must have a density of at least 31 lbs/ft³ (0.50 sp gr). For most production, the specific gravity is approximately 1.00. Figure 1.5 is a photograph of typical products.

Platen-Pressed Particleboard

For the platen-pressed particleboard industry as it is now known, an early reference for producing this type of board occurred when Ernst Hubbard in 1887, in a publication, "Die Derwertung Der Holzfalle" ("Utilization of Wood Waste"), proposed to manufacture artificial wood from sawdust and blood albumin under application of pressure and heat, which illustrates the early conceptualization of the particleboard process.

Krammer in 1889 obtained a German patent for a method for gluing planer shavings onto linen cloth and then laying up the cloth layers in a cross-lap construction much like that for plywood.

Watson, an American, in 1905 referenced making thin wood particles for pressing into boards. This patent shows clearly a flakeboard very similar to some types of board made today. Watson could be called the inventor of the flake type of particleboard, but it is very difficult to state this as an absolute truth without a complete search of the world's scientific literature.



Figure 1.5. Examples of typical hardboard products. (Courtesy Washington State Univ.)

Beckman, a German, in 1918 suggested making a board with chips or wood dust in the center and surface veneers on the outside. This particular formulation is now coming onto the market as a "new" type of structural building panel. Another German, Freudenberg, in 1926 talked about utilizing planer shavings with the adhesives available at that time for making a board. He noted that the adhesive level should be between three and ten percent, which, interestingly enough, is about the range for the present-day particleboard.

Nevin, an American, in 1933 recommended the mixing of coarse sawdust and waste wood shavings with an adhesive and then forming and compressing them under the application of heat. A Frenchman, Antoni, in 1933 discussed boards of a mixture of wood fibers and particles and large elements such as excelsior or even metal netting in a board that was to be bonded with phenolic or urea glues. This, of course, was about the time of the development of these two new synthetic resins.

Samsonow, another Frenchman, in 1935 recommended using lengthy strips made from veneers in a board. These were to be arranged in a cross-lap manner, again much in the same fashion as a conventional plywood. This is a forerunner of the development of oriented flakeboard, which is going into production in the United States at this time. A Japanese, Satow, in 1935 obtained an American patent for making board with 75-mm-long (3 in.) chips arranged randomly within the board to prevent warpage. The German, Roher, in 1935 discussed pressing particles onto the surface of a plywood core in a single operation.

Carson, an American, was awarded a patent in 1936, which he applied for initially in 1932, for establishing a regular production line for producing particleboard. He proposed using a splintery type of sawdust with a moisture content of about 12%, which was to be first sized, impregnated against fungi growth, and applied with a fire retardant. A binding agent, which was to be a urea-

formaldehyde-condensation product dilutable in water, was to be sprayed on the wood particles in a rotary-drum blender. Before hot pressing, a prepress operation was to take place, and he proposed covering the final board with thermoplastic coating of synthetic resin. Much of what he discussed here will be found in many particleboard plants.

Another American, E. C. Loetscher, in a 1936 patent, provided interesting details on how to produce a particleboard in an automated system. In 1937 he discussed the production of a board made of sawdust with unconnected individual flakes on the surfaces to provide a decorative effect. These patents were the result of research initiated in 1933. Of great interest is the Farley & Loetscher Manufacturing Co., a millwork firm, which started pilot plant production in 1935 in Dubuque, Iowa, based on this research. Hammermilled particles were blended with liquid phenolic resin in an adapted concrete mixer. Four ¼-in.-thick (3.2 mm) mats were formed for each press opening, prepressed, and then assembled into a package using metal caul plates between the mats. An 11-opening press was used; thus 11 boards were pressed at a time. Board specific gravity ranged from 1.2 to 1.7. Finished boards, trade named Loetex, were trimmed, sanded, and then used for core material to which a high-pressure thermosetting plastic was applied. The trade name Farloex was used for the board surfaced with a decorative laminate. This pilot plant ran until 1942, when it was discontinued because of difficulties in producing plastic sheet material near a dusty particleboard plant and because the company did not have enough raw material for developing a full-scale plant. Perhaps this could be called the first operational particleboard plant. The firm performed research on boards ranging from 0.70 to 1.8 in specific gravity with wood particles varying in size from coarse "hog chips" to fine wood flour. Many different species were investigated. Research also covered a variety of water resistant additives and extenders. Figure 1.6 shows the Baldwin-Southwark press used in this plant.

In a Swiss patent, Chappuis in 1937 described producing board with dry particles with dry binder in the form of a powder, which, in this case, was to be Bakelite.

F. Pfhof obtained a Swiss patent in 1936 and described the use of long strips between 50 and 200 mm (2-7.9 in.) long, 4 to 8 mm (0.16-0.31 in.) wide, and 0.5 to 1 mm (0.020-0.079 in.) thick, which were to be arranged in a criss-cross fashion resulting in a board with high stability characteristics. He recommended covering the surfaces with finer strips 25 mm (1 in.) long, 3 mm (0.12 in.) wide, and 0.2 mm (0.008 in.) thick. This is the best-known European patent in the particleboard industry. Pfhof, however, also obtained a patent in Czechoslovakia in 1936 on "Boards for Cabinetmakers and Carpenters." The description of his process follows:

The boards consist generally of wooden particles in the form of flakes cut from veneers, chips, etc., which for the coarser core layer are for instance about 50-100 mm (2-4 in.) long, about 4-8 mm (0.16-0.31 in.) wide and about 0.5-1 mm (0.020-0.039 in.) thick. For the finer outer layers on both sides, these wooden particles are about 25-50 mm (1-2 in.) long, about 2-4 mm (0.079-0.16 in.) wide, and 0.1-0.5 mm (0.004-0.020 in.) thick. These coarser and finer particles are separately soaked in a bonding agent or glue and the surplus of glue is thereafter removed by centrifugal force. Then it is required to

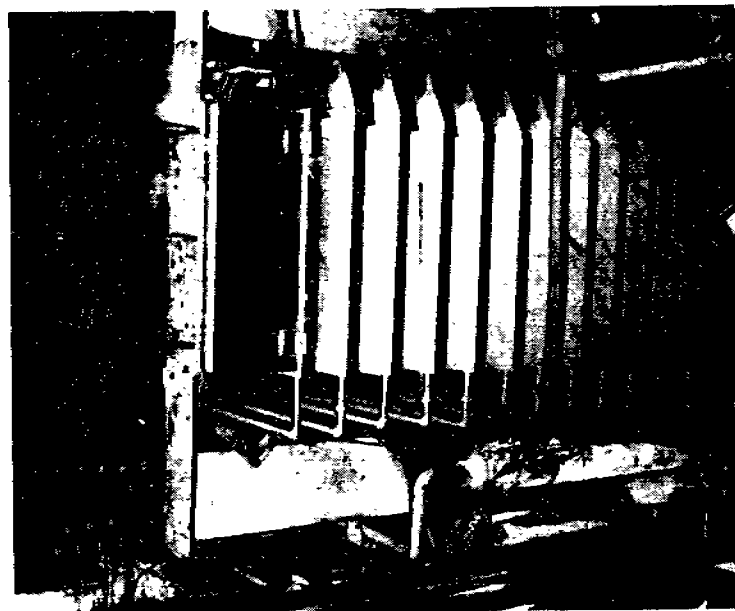
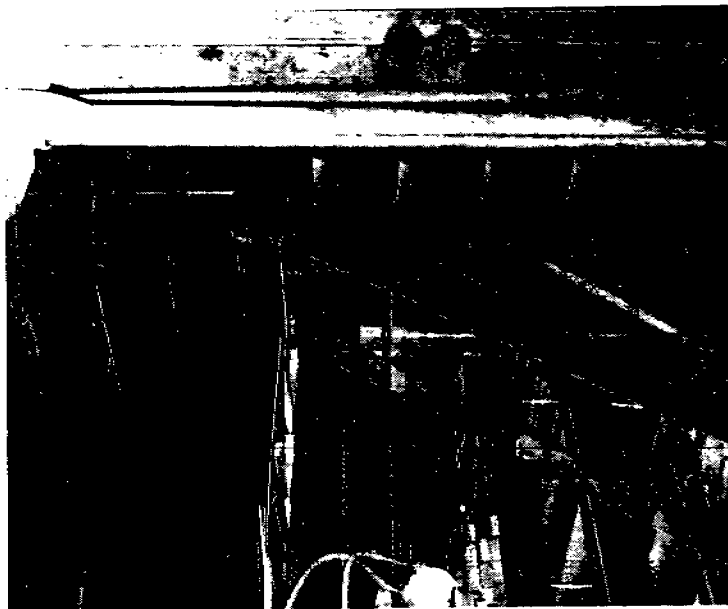


Figure 1.6. Views of Baldwin-Southwark press used for producing particleboard in the 1930s (Ter Louw 1976).

dry the particles so far as to reach the optimal gluing properties of the glue sticking them. Thereafter a layer of fine particles is poured into a special press frame, followed by a layer of coarser particles and then again a layer of fine particles, all this in proper proportion to achieve the required board thickness.

This pouring has to be done in such a way so that the particles will lay in horizontal layers, i.e., in the plane of the board, but criss-cross over each other, which gives board proper strength. The total height of the poured mat is governed by the required board thickness, and is about six times the final board thickness.

This mat is then pressed into a board in a heated press and after removal from the press can be used for overlaying with expensive veneers without any further preparation.

The board size depends only on the press size.

The Dyas Wood Products Industry, Ltd., bought the rights to this patent after one and a half years of experimental work, designed and built a commercial production line and went into commercial production. World War II started the production was shifted to aircraft plywood. After the war, production did resume as other more refined processes were then available.

In 1938 and 1940, Torfitwerke G. A. Haseke obtained patents on methods for producing particleboard. The first one covered the use of liquid adhesives with a post-drying step, after application of the adhesive, to reduce the moisture content. The second patent covered gluing in the press before removing the board to prevent the blows in a high-density board.

This company in 1941 erected a commercial wood particleboard plant in Bremen, Germany, and this has been noted as the first operational plant. It can be argued, however, that the American plant of Farley & Loetscher Mfg. Co., established in 1937, was the first. It thus appears that universal agreement on who was the first manufacturer may not be possible. There probably are some other early producers not noted here. The Bremen plant produced ten tons of board a day from spruce chips using phenolic resin as the binder. In the years 1941-1942 two plywood plants in Germany began to produce similar boards with waste wood from their plywood operations, using urea resin as the binder.

In 1943 Fred Fahrni obtained a French patent covering the most favorable moisture content for pressing. Fahrni continued on to become one of the first pioneers of this industry, developing the worldwide system of Novopan particleboard plants.

The first commercial particleboard in the United States after World War II was supposedly produced by the Southern Box and Lumber Company in Wilmington, North Carolina, although the Hu-Wood plant in North Sacramento, California, supposedly started operations about 1944. In 1947 the Plaswood Corporation in Wilton, New Hampshire, began to make itself known with a product called Plaswood. Other early plants in the Midwest were Swain Industries, Co., Company, and Rock Island Millwork Company. In 1951 the Long-Bell Lumber Company commenced production with a small plant in Longview, Washington. At the same time, U.S. Plywood Corporation in Anderson, California, started producing Novoply under franchise from the Fahrni Institute in Switzerland. Shortly thereafter, the Pack River Lumber Company started to develop its plant in Dover, Idaho, which was designed to produce board with large flat surfaces now commonly called *wafers*, that yielded a board suitable for both structural applications and decorative effects.

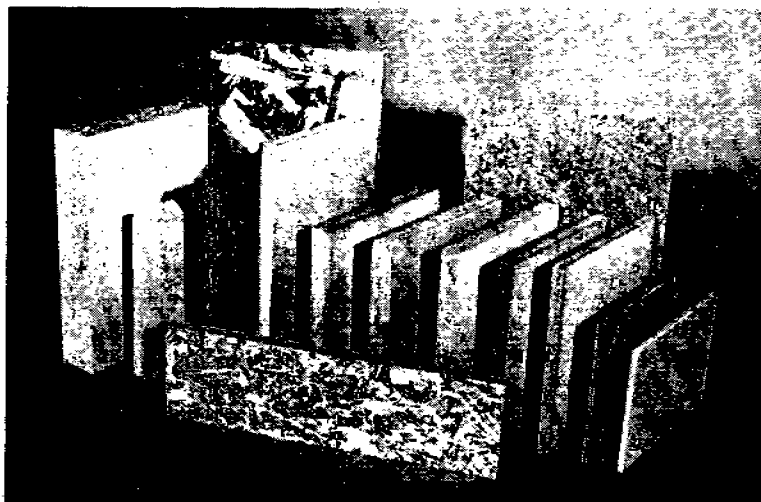


Figure 1.7. Examples of typical platen-pressed boards. (Courtesy Washington State Univ.)

About 1960 the massive expansion of the United States industry commenced. Techniques were developed to produce boards with smooth surfaces, and resins were refined to speed curing times in the press. Breakthroughs into the furniture core and floor underlayment markets opened up huge markets that were exploited successfully. Plant sizes increased from about 100 tons (91 metric tons [mt]) per day to the massive Roseburg Lumber Company plant in Oregon, which can produce 2000 tons (1814 mt) of board per day. Some of the pioneer plants would probably fit into the largest forming line of this monstrous plant. Figure 1.7 shows examples of typical products.

Significant efforts are being made to bring particleboard and fiberboard further into the structural building panel market in direct competition with plywood. Some large breakthroughs have already occurred, most notably in the mobile home decking market, where urea-bonded particleboard has supplanted plywood for the floor membranes. These boards, 4 ft (1.22 m) wide or wider by 12 or 14 ft (3.66 or 4.27 m) long, are lower in cost, smooth-surfaced, and produced in lengths suitable for full-width spanning of the mobile home floors. Structural flakeboard is approved for use in Canada. Other particleboards are used structurally throughout the world.

The development of this particular segment of the board industry has been phenomenal since World War II. Many different types of board plants have been built around the world, based not only on wood waste and roundwood cut especially for particleboard but also from other lignocellulosic materials such as bagasse and flax. The ability to use the heretofore wasted raw materials has been a boon to all of society.

Extruded Particleboard

The extrusion method of producing particleboard was initially developed in Germany by Otto Kreibbaum in the years 1947–1949. This production process has been expanded over the years in Europe to the extent that at least one manufacturer is producing both boards and factory-built houses in a single manufacturing complex. In the United States, several plants were built in the 1950s based upon the original concept from Europe as well as on developments by United States firms. The plants producing this type of board in the United States are relatively small and are captive in the sense that they produce board for use by other parts of their firms' operations, notably in furniture factories. No new plants of this type have been built in the United States for many years, probably because of their low production rates and because of inherent problems with the board, which will be mentioned later. Several plant expansions, however, have been made. Figure 1.8 illustrates typical products. A newer system for making a ribbed product has recently been developed in Texas and reportedly will be in use soon.

Dry-Process Hardboard

The next development in the composition board area was that of manufacturing hardboard by means of a dry process. In 1945 the Plywood Research Foundation began experimenting on and developing this process. The Plywood Research

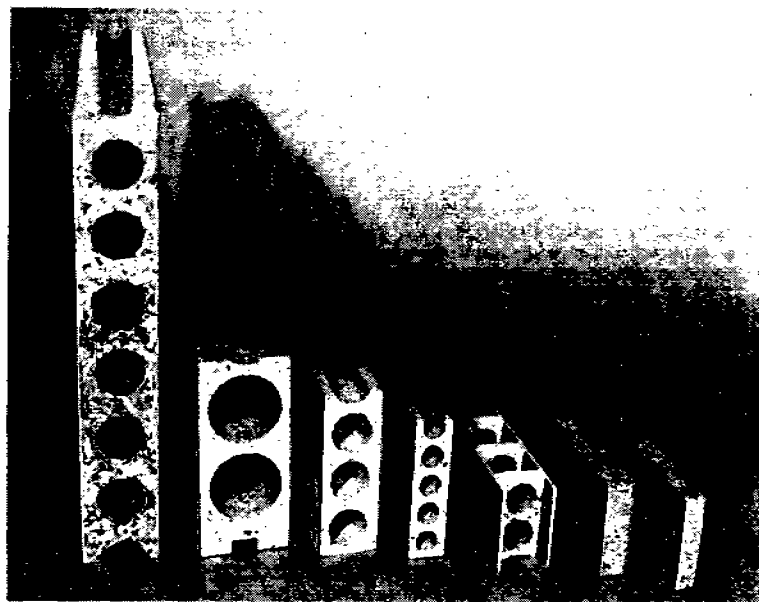


Figure 1.8. Typical extruded board. (Courtesy Washington State Univ.)

Foundation is the research arm of the American Plywood Association, which was known as the Douglas Fir Plywood Association in 1945. The thrust of this development was to eliminate the waterforming of the mat found in the wet-process industry.

Normally the chips or other residual materials are conveyed mechanically through cooking and grinding units where the fiber is prepared. It is also now normal to apply the resin and wax to the raw material prior to grinding so that the attrition mill simultaneously prepares fiber and blends the additives with the fiber. In initial experiments and in the early plants, the resin was added after the fiber was prepared. The mats were then formed using air and mechanical means in a continuous system. This mat, however, did not have the fiber interlocking that is possible when forming mats by the wet process. Because of this lack of interlocking and the very low, if any, adhesion that can be obtained by lignin flow and hydrogen bonding in the hot press, the dry-process hardboard is dependent upon the binder for the development of physical properties. If the mat has a moisture content below 10%, it normally is pressed into a smooth-two-sides board which has a very light color in contrast to boards prepared by the wet-process system. At moisture contents over 10%, it is necessary to use a screen on one side of a mat in order to press the board, much in the same way as pressing a wet-process mat.

The boards manufactured by this method enter the same market as the wet-process board. Some people hold that the wet-process board is somewhat superior in properties because of the self-bonding of the fibers, the intermeshing of the fibers as developed in the wet-forming operation, and the removal of the hemicellulose. The elimination of the massive amounts of water necessary for forming the mat is an advantage of making this type of board, particularly now that tough constraints have been implemented governing the release of effluents from any industrial operation. However, synthetic resins, which are becoming more expensive, must be used for binders in the dry-process board.

Medium-Density Fiberboard

In the mid-1960s the most recent development in the board industry occurred. This breakthrough has been called medium-density fiberboard (MDF). Most of the plants producing this board use the pressurized refiner for generating finer fibers, which have far greater bulk than those usually produced by atmospheric refiners. These details will be developed later in this book. This particular board is usually much thicker than the traditional hardboards, which range from about 1/10 in. (2.5 mm) to about 3/8 in. (9.5 mm) in thickness. Most of the board produced in the MDF process is over 3/8 in. in thickness and goes to the furniture industry for use as core stock. Much of the recent interest in building plants has centered on the MDF process. Figure 1.9 shows typical products. This is a further refinement in the development of dry-process boards produced essentially with fiber.

Mineral-Bonded Products

Another type of panel building product that merits mention is mineral-bonded building products usually made of excelsior (wood wool, as it is known in Europe)

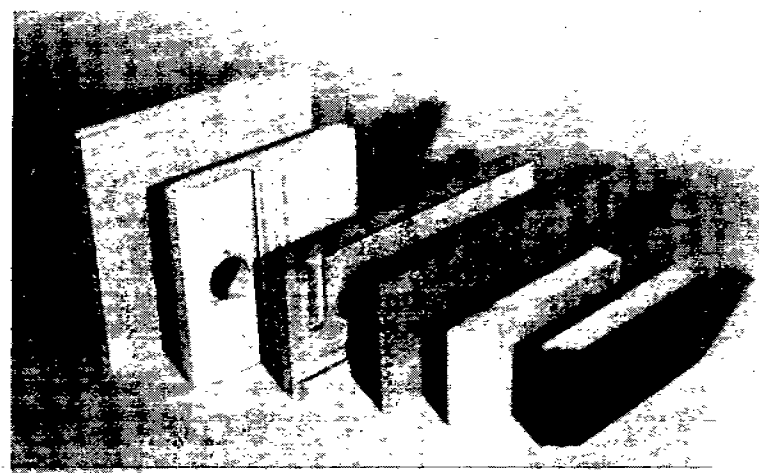


Figure 1.9. Examples of medium-density fiberboard. (Courtesy Washington State Univ.)

and cement. The first boards of this type had magnesite as a binder and were developed in 1914 in Radenthein, Austria. Over 600 million square meters of this material were manufactured by the Heraklith method in Austria through 1963. At that time the company was reporting that over 50% of the world's consumption was with the use of its product. Portland cement was used in this type of product in 1928, and later gypsum was used as a binder. The plants now manufacturing this product in the United States started operation in the late 1940s, although the product was manufactured much earlier.

Recently, greater interest has been shown in this product, as evidenced by the building of plants in both the underdeveloped and developed nations. It has particular appeal in the underdeveloped countries since it can be produced with crude methods using available cement for the binder. Many developing countries do not have the synthetic adhesives that are available for producing the fiberboard and particleboard as known in much of the world. However, good acoustic, thermal, fungi-resistant, and fire-resistant properties of this product are also appealing to the industrialized countries.

The use of the excelsior provides panels with a bending strength suitable for use as spanning members in construction. Other structural panels have been developed using wood flakes in the mix. These particular panels also have bending strengths that allow their use in standard building construction. Figure 1.10 is a photograph of typical panel products.

In another application, relatively lightweight building blocks approximately 8 in. square by 16 in. long (203x406 mm) or larger can be produced by using planer shavings or wood particles and the mineral binder. Walls are fabricated using the same techniques as for cinder block construction. Also, this wood aggregate

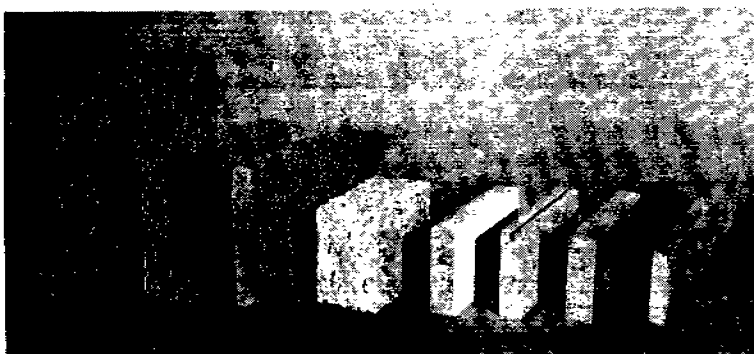


Figure 1.10. Typical wood-based panel products using cement as the binder. (Courtesy Washington State Univ.)

concrete can either be made into tilt-up walls or poured in place for wall sections. It is also used as lightweight concrete in apartment construction, particularly for its value in sound deadening.

Some feel that the further development of this part of the board industry will be accelerated because of the shortage of synthetic resins. This shortage is associated with the worldwide energy problems, as the conventional synthetic resins are petroleum-based derivatives. However, the fact that the production of cement is also closely associated with energy should not be overlooked, as a great amount of energy is necessary for cement manufacture.

Molded Products

Another type of comminuted particle product that is different from the conventional flat panel familiar to most people is molded particleboard (examples shown in Figure 3.9). This group of products has not received extensive attention in the United States because production of molded parts out of plastics has been more economical. With the advent of the energy and petroleum shortage, it is quite possible that the economics of producing this type of product out of wood particles in comparison to plastics will change dramatically. As a consequence, there is the likely possibility that this industry, which is fairly well developed in Europe, will find expanded applications in the United States. Details of this system will be covered later.

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2. PRODUCTION AND MARKETS

DEVELOPMENT

High-density hardboard, as mentioned previously, can be made by either the wet or dry process. The boards produced by both processes compete in the same markets. The boards usually are relatively thin (about $\frac{1}{8}$ in. or 3.2 mm) unless they are specifically laminated into much thicker products for specialty markets. A significant increase in the dry-process production over the last few years has been in siding, usually in thickness about 9/32 to 7/16 in. (7.1–11.1 mm). Several plants are now concentrating on this product.

At first, both the wet- and dry-process segments of the industry preferred using pulp chips for the raw material because a superior fiber could be generated from this source. However, as the demand for the prices of pulp chips increased, the hardboard industry moved into lower grades of residual materials such as sawdust and shavings for its raw material supply. Technological improvements in the processing had to be made to utilize this lower-grade raw material properly so that quality of the resultant board did not diminish, although chips are usually the preferred raw material. This trend of moving from a higher-grade residual material to a lower-grade residual material has been typical of the entire composition board industry because of the pressure applied by pulp mills on the raw material resources. Advances in technology in the pulp and paper industry have made possible the use of more and more shavings and sawdust, which puts further pressure on the amount of residual material available for the board industry.

For particleboard, the very first plants in Europe were designed to produce a product suitable for wall paneling and for some furniture. These initial plants were based on wood waste from manufacturing facilities. In the late 1940s good three-layer boards were developed in Europe from forest waste consisting of thinnings, material that was used for fuel wood, and branches. This material was usually cut into thin flakes for the faces of the boards and thicker flakes for the cores of the boards. This production was aimed at the furniture industry. Until this time, hardwoods such as beech, birch, and oak were usually used for fuel wood. It was found that these species, while not particularly suitable for normal production of lumber, were excellent for use in particleboard. The particleboard industry, therefore, moved to incorporate much of this material into its raw material supply. By 1956 there were 106 European mills producing 724,000 cubic meters of

forecast for the trend extension estimate are those used for individual countries by FAO in its general projection work. The balanced growth is based on a set of population estimates, which assume the stabilization of population by 2001, through successive reductions in the expansion rate. This results in a 1991 population equivalent to that of 1981 in the trend extension alternative. The third projection is a conservative one, called subjective judgment developed on the considerations of market saturation in the developed regions, related to a decline in rates of substitution of wood-based panels for sawn wood and the continuing problems of investment funding of infrastructure and processing industries in developing countries, which will cause the rates of growth of consumption to fall rapidly on a world basis compared to recent levels and to a projected world income growth rate of 5%.

For this discussion the trend extension could be called the optimistic prediction and the subjective judgment a conservative prediction. The important point to observe, both on a world and North American basis is that all panel products are predicted to grow rapidly in the rate of consumption through 1990, according to all three predictions. Consequently, a two-fold problem of securing sufficient raw materials for production and the construction of many new plants needs to be solved.

BOARD GRADES

In the United States, extruded particleboard is exclusively used in captive markets where the board producer utilizes the product in secondary manufacturing. Mineral-bonded products are normally used in special applications such as ceiling tile, roof deck, sound control panels, and building blocks. Commercial standards similar to those of particleboard and hardboard have not been developed for these products as yet. The limited amount of molded product being produced out of comminuted products goes into specially produced products for the furniture industry and doors as mentioned earlier. The manufacturers have requirements they must follow to meet the various applications such as for chair seats, but no universally accepted standard has been developed.

In the case of the platen-pressed material, commercial or voluntary standards have been established to cover most of these products. As pointed out previously, there are overlaps between the product definitions. These standards will be discussed separately with some of the overlaps noted. Such standards are useful to establishing minimum properties and for providing useful data for specifiers, designers, and consumers.

Commercial Standard CS 251-63, "Hardboard," was established in 1963 for the production of hardboard and was an update of previous information. This standard has recently been supplanted by three voluntary product standards. The first, PS 58-73, "Basic Hardboard," was established to recognize dimensional and quality requirements for basic hardboard and to provide producers, distributors, and users with a basis for common understanding of the characteristics of this product. As shown in Table 2.11, basic hardboard is divided into five classes characterized by surface finish, thickness, and physical properties. (A number of these types of tables will be reproduced in this chapter. Pertinent properties will

be shown; however, for complete information on how each property must be evaluated for meeting the standard or specification, the original document must be consulted.) The first four classes—tempered, standard, service-tempered, and service—are ones that have been around for many years. The physical properties cover water absorption and thickness swelling after a 24-hour water soak (which are maximum allowable values), minimum modulus of rupture or bending strength, and tensile strength parallel to and perpendicular to the surface. Many other physical properties are used in design for these products, but the ones just mentioned are those listed in the standard.

New in the standard is the fifth class, which is industrialite. This class was established (mainly) to cover the relatively new medium-density fiberboard. Maximum or minimum physical properties values have been established for this new product following the same format as for the other four classes of hardboard.

Tables 2.12 and 2.13 present the physical properties now required for hardboard siding as noted in the second voluntary product standard PS 60-73, "Hardboard Siding." Much of this material is produced by the dry process.

The third voluntary product standard is PS 59-73, "Prefinished Hardboard Paneling." This standard covers the four classes of hardboard: tempered, standard, service-tempered, and service. The modulus of rupture and tensile strength properties are the same as listed in the basic hardboard standard. Water resistance values are the same as the S2S standards listed in the basic hardboard specifications. Three thicknesses of board are covered: 1/8, 3/16, and 1/4 in. (3.2, 4.8 and 6.4 mm). Requirements are also set for abrasion resistance, adhesion, fade resistance, gloss, and so forth. These requirements can be found in this product standard but are not listed here since they will not be under discussion.

All of these standards also provide requirements for dimensions, thickness tolerances, squareness, edge straightness, and moisture content.

A standard was first produced for mat-formed wood particleboard in 1961. With more experience in the field and far more production developing in the 1960s this standard was rewritten in 1966 and is the present one in force. It is designated Commercial Standard CS 236-66, "Mat-formed Wood Particleboard." Table 2.14 presents the property requirements for particleboard as specified in this standard.

Two types have been established with Type 1 generally made with urea-formaldehyde resin binders for interior applications and Type 2 generally made with phenolic-type binders suitable for interior and certain exterior applications when so labeled. Products are further differentiated by density grade with an A, B, and C level for the interior applications and A and B density grade for exterior applications. At present, the C, or low-density grade, is not specified for exterior board. As a further differentiation, there are two classes in each of the density grades with each class having a separate set of physical properties established for modulus of rupture, modulus of elasticity, internal bond (tensile strength perpendicular to the surface), linear expansion, and face and edge screw holding.

In contrast to the hardboard products, no water absorption properties are specified for particleboard. Hardboard, on the other hand, does not have a linear expansion property specified. Hardboard is noted as having a minimum specific gravity of 0.50 (31.5 lbs/ft³) with no differentiation established for specific gravity when discussing the five classes of hardboard. Particleboard, on the other hand,

Table 2.11 Classification of Hardboard by Surface Finish, Thickness, and Physical Properties

Surface	Nominal thickness (in.) (mm)	Water resistance (max avg per panel)				Modulus of rupture (min avg per panel)	Tensile strength (min avg per panel)				
		Water absorption based on weight		Thickness swelling			Parallel to surface		Perpendicular to surface		
		S1S (%)	S2S (%)	S1S (%)	S2S (%)		(psi) (MPa)	(psi) (MPa)	(psi) (MPa)	(psi) (MPa)	
Class 1: Tempered											
S1S	1/12	2.1	30	—	25	—	—	—	—	—	—
	1/10	2.5	20	25	16	20	—	—	—	—	—
	1/8	3.2	15	20	11	16	—	—	—	—	—
S1S and S2S	3/16	4.8	12	18	10	15	7,000	48.3	3,500	24.1	150
	1/4	6.4	10	12	8	11	—	—	—	—	—
	5/16	7.9	8	11	8	10	—	—	—	—	—
	3/8	9.5	8	10	8	9	—	—	—	—	—
Class 2: Standard											
	1/12	—	40	40	30	30	—	—	—	—	—
	1/10	—	25	30	22	25	—	—	—	—	—
	1/8	—	20	25	16	18	—	—	—	—	—
S1S and S2S	3/16	—	18	25	14	18	5,000	34.5	2,500	17.2	100
	1/4	—	16	20	12	14	—	—	—	—	—
	5/16	—	14	15	10	12	—	—	—	—	—
	3/8	—	12	12	10	10	—	—	—	—	—
Class 3: Service-tempered											
S1S and S2S	1/8	—	20	25	15	22	—	—	—	—	—
	3/16	—	18	20	13	18	4,500	31.0	2,000	13.8	100
	1/4	—	15	20	13	14	—	—	—	—	—
	3/8	—	14	18	11	14	—	—	—	—	—
Class 4: Service											
S1S and S2S	1/8	—	30	30	25	25	—	—	—	—	—
	3/16	—	25	27	15	22	—	—	—	—	—
	1/4	—	25	27	15	22	—	—	—	—	—
	3/8	—	25	27	15	22	—	—	—	—	—
	7/16	11.1	25	27	15	22	—	—	—	—	—
	1/2	12.7	25	18	15	14	—	—	—	—	—
	5/8	15.9	—	15	—	12	3,000	20.7	1,500	10.3	75
	11/16	17.5	—	15	—	12	—	—	—	—	—
	3/4	19.0	—	12	—	9	—	—	—	—	—
S2S	13/16	20.6	—	12	—	9	—	—	—	—	—
	7/8	22.2	—	12	—	9	—	—	—	—	—
	1	25.4	—	12	—	9	—	—	—	—	—
	1-1/8	28.6	—	12	—	9	—	—	—	—	—
Class 5: Industrialite											
S1S and S2S	3/8	—	25	25	20	20	—	—	—	—	—
	7/16	—	25	25	20	20	—	—	—	—	—
	1/2	—	25	25	20	20	—	—	—	—	—
	5/8	—	—	22	—	18	2,000	13.8	1,000	6.9	35
	11/16	—	—	22	—	18	—	—	—	—	—
	3/4	—	—	20	—	16	—	—	—	—	—
S2S	13/16	—	—	20	—	16	—	—	—	—	—
	7/8	—	—	20	—	16	—	—	—	—	—
	1	—	—	20	—	16	—	—	—	—	—
	1-1/8	—	—	20	—	16	—	—	—	—	—

Source: PS58-73 "Basic Hardboard."

Table 2.12 Physical Properties of Hardboard Siding

Property	Requirements		
Percent water absorption (based on weight (max avg per panel))	Primed	15	
	Unprimed	20	
Percent thickness swelling (max avg per panel)	Primed	10	
	Unprimed	15	
Weatherability of substrate (max swell after 5 cycles)	(in.) (mm)	0.010 0.25	and no objectionable fiber raising
Sealing quality of primer coat	No visible flattening		
Weatherability of primer coat	No checking, erosion, or flaking		
Nail-head pull-through (min avg per panel)	(lbs) (kg)	150 68.2	
Lateral nail resistance (min avg per panel)	(lbs) (kg)	150 68.2	
Modulus of rupture (min avg per panel)	(psi) (MPa)	1,800 for 3/8- & 7/16-in.-thick siding 3,000 for 1/4-in.-thick siding 12.4 for 9.5- & 11.1-mm-thick siding 20.7 for 6.4-mm-thick siding	
Hardness (min avg per panel)	(lbs) (kg)	450 204.5	
Impact (min avg per panel)	(in.) (mm)	9.0 229	
Moisture content	(%)	2.0-9.0 incl, and not more than 3% variance between any two boards in any one shipment or order.	

Source: PS60-73, "Hardboard Siding."

Table 2.13 Maximum Linear Expansion

Type of siding	Thickness range		Maximum linear expansion (%)
	(in.)	(mm)	
Lap	0.325-0.375	8.3-9.5	0.38
	over 0.376	over 9.5	0.40
Panel	0.220-0.265	5.6-6.7	0.36
	0.325-0.375	8.3-9.5	0.38
	over 0.376	over 9.5	0.40

Source: PS60-73 "Hardboard Siding."

has three definite density grades. Particleboard specifies minimum values for modulus of elasticity and face and edge screw holding, and these are not included in the hardboard standard. Besides the water resistance properties noted, tensile strength parallel to the surface is specified for hardboard but not for particleboard.

For the Type 2 or exterior-type particleboard, an accelerated aging test is required by the particleboard standard. This test is not required for hardboard used in exterior exposures. When applicable, the minimum average modulus of rupture after aging is not to be less than 50% of the minimum average modulus of rupture of samples not exposed to the aging tests. The calculation for determining modulus of rupture uses the specimen thickness before aging. During the aging tests a very significant increase in thickness can take place, and, if this thickness is used for the calculation, the modulus of rupture will be much lower than what is reported following the specifications of the standard. This is a somewhat confusing piece of terminology, and perhaps the term modulus of rupture should not have been used. What the test is designed to do is determine the amount of strength retention of the board after accelerated aging testing. The intent was to have an accelerated and replicable means of determining the durability characteristics of exterior particleboard and, in simple terms, is in actuality a quality control procedure. While termed *accelerated* this test still takes over two weeks to conduct.

When hardness is designated as an optional requirement for particleboard, the value is to be 800 lbs (364 kg) for A-density panels and 500 lbs (227 kg) for B-density panels.

As with hardboard, this standard also specifies dimensional tolerance for width, length and thickness, squareness and straightness, and specifies that moisture content of the panels at the time of shipment shall conform with one of the following requirements:

- Moisture content consistent with a known end use of the panel.
- Moisture content as specified by the purchaser.
- Moisture content not in excess of 10%.

Table 2.14 Property Requirements of Mat-Formed Wood Particleboard

Density (grade) (min avg)	Class†	Modulus of rupture (min avg)		Modulus of elasticity (min avg)		Internal bond (min avg)	Linear expansion (max avg)	Screw holding	
		(psi)	(MPa)	(psi)	(MPa)			Face (min avg)	Edge (min avg)
						(psi)	(%)	(lbs)	(kg)
Type (use) 1.*									
A. High density, 50 lbs/ft ³ or 0.80 sp gr and over	1	2,400	16.5	350,000	2,413	200	1.38	450	204.5
	2	3,400	23.4	350,000	2,413	140	0.97	—	—
B. Medium density, 37-50 lbs/ft ³ or 0.59-0.80 sp gr	1	1,600	11.0	250,000	1,724	70	0.48	225	102.3
	2	2,400	16.5	400,000	2,758	60	0.41	225	102.3
C. Low density, 37 lbs/ft ³ or 0.59 sp gr and under	1	800	5.5	150,000	1,034	20	0.14	125	56.8
	2	1,400	9.7	250,000	1,724	30	0.21	175	79.5
Type (use) 2.†									
A. High density, 50 lbs/ft ³ or 0.80 sp gr and over	1	2,400	16.5	350,000	2,413	125	0.86	450	204.5
	2	3,400	23.4	500,000	3,447	400	2.76	500	227.3
B. Medium density, 37-50 lbs/ft ³ or 0.59-0.80 sp gr	1	1,800	12.4	250,000	1,724	65	0.45	225	102.3
	2	2,500	17.2	450,000	3,102	60	0.41	250	113.6

Source: CS236-66

* Type 1: Mat-formed particleboard (generally made with urea-formaldehyde-resin binders) suitable for interior applications.

† Type 2: Mat-formed particleboard made with durable and highly moisture- and heat-resistant binders (generally phenolic resins) suitable for interior and certain exterior applications when so labeled.

‡ Class: Strength classifications based on properties of panels currently produced.

It also takes into account that particleboard is a wood product and has a tendency to change moisture content with changes in atmospheric conditions; thus, no specific moisture content is guaranteed when the particleboard panels reach their destination.

With the rapid development of this industry, the market uses of the product have also changed as the particleboard has moved into new end uses in an effort to provide boards designed particularly for the more discrete end uses. The commercial standard is at present being rewritten. The basic change will apparently be the addition of a third level in the class category. These three classes will permit the specifiers to designate with more accuracy the particular board that they wish to use.

The Canadians established a standard for Mat-Formed Wood Particleboard under CSA Standard 0188-1968. This standard has been recently revised to CSA standard 0188-1975. Significant changes have been made in this new standard. Types of board based on the resin have been deleted as unnecessary. The distinction between *building* and *industrial* boards has been dropped. Grades P & Q refer only to waferboard which is an important product in Canada. New grades have also been introduced. The grades and property requirements are shown in Table 2.15. The description of end-use applications has been modified to provide an indication of the interchangeability of various grades of board (Table 2.16).

The physical properties for these boards are generally the same as those for the United States. Of particular interest are higher allowable linear expansion values for some grades of board and a lower internal bond in some grades as compared to United States commercial standards.

The methods for determining the various physical properties discussed are specified in the American Society for Testing and Materials (ASTM) D 1037, "Standard Methods of Evaluating the Properties of Wood-Base Fiber and Particle Panel Materials." It should be noted that some exceptions to the testing procedures are noted in the commercial standards. These test procedures will be dealt with later.

Other specifications are used when considering particleboard or hardboard for particular applications. These are usually Use of Materials Bulletins prepared under the auspices of the Department of Housing and Urban Development (HUD), Federal Housing Administration (FHA). These bulletins are used by the FHA to determine the eligibility of a property as security for an insured loan under the FHA program. The Use of Materials Bulletins are used preliminary to a material's being included in the FHA minimum property standards for one or two living units.

Particleboard floor underlayment has certain standards to meet as specified in "HUD Minimum Property Standards," 1973 edition. Underlayment shall comply with CS 236-66 type 1-B1 and, in addition shall not have a maximum thickness swelling of more than 0.063 in. (1.6 mm) when immersed in water for 24 hours in accordance with ASTM D-1037. For a nominal 3/4-in.-thick (15.9 mm) board, this is 10% swell.

The Use of Materials Bulletin No. UM-32 covers "Mat-Formed Particleboard for Exterior Use." Board properties listed must meet the standards established by the West Coast Particleboard Association specification for exterior-type wood

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construction field, concrete forms, ceiling material, door skins, and panels, are some examples of its use. In recent years the use of hardboard siding approximately 7/16 in. (11.1 mm) in thickness has become widespread. Also, 4x8-ft (1.22x2.44 m) sheets of specially manufactured textured hardboard panels are used for exterior siding on houses. Hardboard is well known to most American families in the form of interior wood paneling which has photographic prints, usually of fine wood, applied. This is an easy-to-use product that the home handyman finds quite useful. This board can be used in many types of other items ranging from small applications in toys to paneling in highway truck trailers and railroad cars. Most of these markets have been well developed by the industry for many years.

Medium-density fiberboard has moved strongly into the furniture field as an industrial core material. It can be finished directly or overlaid with fine wood veneer or plastic laminates. It competes mostly with particleboard in this market.

As mentioned previously, extruded particleboard is used exclusively in the United States for core material in furniture applications and it is a relatively minor amount of the total production. Platen-pressed particleboard is used for four general categories of products. One is for floor underlayment which covers the rough subfloor in housing and over which sheet goods, tile, or carpet is laid. The use of a particleboard underlayment provides a smooth, even floor for this final building operation. Particleboard mobile home decking is another significant use developed since the mid-1960s. Most of the mobile homes now manufactured use particleboard for the floor system. The third major grouping is the furniture or industrial board, and the fourth category is that of ever-present miscellaneous uses which are open to the consumer's imagination as far as how the board is used. It is estimated that production can be divided up approximately as follows for particleboard:

- 50% industrial (mainly furniture board).
- 25% construction (mainly floor underlayment).
- 15% mobile home decking.
- 10% specialty or miscellaneous products (mainly industrial-type board).

The following listing will provide a sampling of a wide variety of uses for particleboard: countertops, shelves, sink tops, dinette sets, tabletops, cabinets, wall cases, tool benches, drafting tables, case goods, sewing tables, desks, pool tables, card tables, cabinet and drawer parts, show cases, chair components, table tennis tops, game boards, fence components, furniture partitions, benches, bookcases, chalkboards, kitchen cabinets, consoles, laboratory furniture, piano and organ parts, signs, door cores, bi-fold doors, church furniture, office furniture, computer cases and panels, children's furniture, garage doors, patio furniture, toys, pleasure-boat interior parts, tool chests, gun cases, casket components, metal work patterns, shuffleboard pucks, school furniture, mobile homes, massage tables, filing cabinets, engine crates, ironing boards, tote boxes, cutting boards, basketball backboards, floor underlayment, decking, sheathing, panels and wainscoting, soffits, wardrobes, interior window and door trim, baseboards, valances, shutters, face frames, stair risers, and treads.

TRENDS

The particleboard industry has been increasing its production at a rate of 15 to 20% every year for a period of 10 to 15 years. A much higher increase occurred in 1973. In 1974, because of the recession, the first decrease in production took place since the industry was established in the United States. Significantly, the decreased level of production would not have been sufficient to cover the market needs of 1970. It is anticipated that this phenomenal growth record will continue into the 1980s, perhaps with some slowing of the rate of expansion. During the past decade, fears have been periodically expressed that the particleboard industry in particular was overbuilt. A case in point was when the massive new production line at Roseburg Lumber came onstream in 1972. However, the consuming public absorbed this new production readily, and the particleboard producers in general during 1973 has their production sold out for three to four months ahead of time. Granted this was a particularly good year, but this has been typical of the industry as its production capacity has been enlarged.

The cost of producing board will rise as production costs will undoubtedly rise as in all types of industry. The low-cost raw material, planer shavings, is rapidly being used up throughout the country. Some areas, particularly in Oregon, have already used almost all of their planer shavings residue in areas where board plants are concentrated. Additionally, the cost of shavings will increase as its fuel value increases, as there will be competition for the residual material if the energy crisis becomes quite severe. It is well known that wood can be converted to power, and at this time sawmills, plywood plants, and composition board plants already have or are seriously considering using some of their material for their own in-plant power supply. In 1976, prices as high as \$23 per ton for dry shavings were being quoted as equivalent value to oil. For years shavings sold for very low prices—about \$3 per ton in some areas. The increased competition for shavings has already driven the price up to \$10 to \$15 in many areas. Such a demand for the residual material can cause some serious dislocations of the wood material supply for board plants which will cause a further increase in the cost of the wood.

Another cost problem associated with the energy crisis is the cost of the synthetic resins, which are derivatives of the petrochemical industry. It is anticipated that these higher costs for resin will continue throughout the 1970s. Costs for gas and oil will also increase, adding to the expense of manufacturing.

It is estimated that the demand for conventional products such as plywood and lumber will exceed the supply in the 1980s at the present growth rate in the United States. At that time, there will not be any additional volume from the commonly used construction species. However, there will still be great amounts of so-called residue materials available, particularly that left in the forest as slash. Also, material classified as noncommercial or low grade can be converted into excellent building products using particles, flakes, and fiber. Examples of these species are aspen, southern hardwoods, and alder; more agricultural wastes and even municipal refuse may be used for raw material.

More fiberboard and particleboard will be used in all types of building. Even now these products are supplanting lumber for casings, door jambs, and face frames on furniture and cabinets. The development of the market for overlaid panels with vinyl polyester, or low-pressure melamine should dramatically in-

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6.

RAW MATERIALS AND PARTICLE GEOMETRY: EFFECTS ON BOARD PROPERTIES

A number of different wood raw materials are used for composition board, ranging from logs to sander dust. Old packing cases are also used for raw material in other countries. Agriculture residues such as flax and bagasse are also of importance in various parts of the world. A wide range of particle types with varying geometries can be generated from solid wood or residues, either directly for the board process or as particles ready for use, such as planer shavings. The types of particles and the expense associated with generating them are significant factors in the cost of manufacturing board. Each type of particle, its inherent geometry, and combinations of various particles have profound effects on the board quality.

AVAILABLE RAW MATERIALS

The degree of freedom in controlling the particle geometry varies widely according to the kind of raw material available to the manufacturing operation. It has been noted that the maximum freedom exists when the available material is in the form of roundwood, preferably green, or in other forms of rather large solid wood. This permits the cutting or reduction of the wood in any way economically feasible within the plant. However, the large volume of raw material available as residue from other wood-processing operations, as noted, often constitutes the major raw material available for use in a composition board operation. Thus, depending upon the particle size of this residue as it enters the board plant, the degree of possible further reduction in size or shape is already somewhat limited. Significant improvement in particle geometry, however, can be accomplished by proper use of milling or flaking machines.

The principal types of raw material available in the United States at the present time, in descending order of freedom in further processing, are as follows:

- ☐ Green roundwood or logs.
- ☐ Veneer peeler cores.
- ☐ Cull lumber.
- ☐ Lumber slabs and edgings.
- ☐ Lumber mill end trim (green).
- ☐ Lumber planer end trims (mostly dry).
- ☐ Veneer log roundup (green).

- ☐ Veneer clippings (green).
- ☐ Pulp chips (green).
- ☐ Lumber planer shavings (dry).
- ☐ Sawmill sawdust (green).
- ☐ Miscellaneous dry woodworking residues from molding and furniture-type plants.
- ☐ Planer mill and similar dry sawdust.
- ☐ Plywood trim.
- ☐ Plywood sander dust.
- ☐ Miscellaneous woodworking sander dust.

Bark is not included in this list of material, although minor amounts are used throughout North America and elsewhere in the world. Most of the bark now being used ends up in the board furnish because the particles were generated from wood that was not debarked. Research has shown that certain board products can be successfully produced from bark. Additional research and development is under way at the present time, and a separate family of bark products should result. Other fibrous raw materials, such as bagasse and flax, are used elsewhere in the world and there is the possibility of using agricultural fibrous material here in the United States.

A 1974 survey of the major types of raw material used in North American particleboard plants is shown in Table 6.1 Softwood planer shavings make up a major share with 47.7% of the total. Softwoods account for 84.6%, with hardwoods being used for only 15.4% of production. It is notable that 3.7% of softwood chips and 2.1% of hardwood chips go into this type of board. Under present accounting systems they are too valuable for pulp; however, this situation may change as demand for high-value panel products increases.

When using any of the grass-type fibrous-type residues, it is important that shiny outside surfaces are eliminated by the splitting action of mills generating the final fiber. Preparation of the furnish is extremely important as the pith and dirt must be removed. In bagasse, for example, high levels of pith are found. Pith, which has no structural strength, is very absorbent and can rob the board of much of the applied resin. As demand for more building products increases worldwide, it is anticipated that more agricultural residues will be used for board.

PARTICLE TYPE AND GEOMETRY

Definitions of the various types of particles have been developed by the American Society for Testing and Materials as part of the "Standard Definition of Terms Relating to Wood-Based Fiber and Particle Panel Materials" ASTM designation: D 1554. The following definitions are based on the ASTM standard.

Chips: Small pieces of wood chopped off a block by axe-like cuts as in a chipper of the paper industry, or produced by mechanical hogs, hammermills, and so forth.

Curls: Long, flat flakes manufactured by the cutting action of a knife in such a way that they tend to be in the form of a helix.

Fibers: The slender threadlike elements or groups of wood fibers or similar cellulosic material resulting from chemical or mechanical fiberization, or both, and sometimes referred to as fiber bundles.

Flake: A small wood particle of predetermined dimensions specifically produced as a primary function of specialized equipment of various types with a cutting action across the grain (either radially, tangentially or at an angle between), the action being such as to produce a particle of uniform thickness,

Table 6.1 Summary of the Major Types of Raw Materials Used in North American Particleboard Plants

	Proportion of total particleboard raw material supply (%)
Softwoods	
Roundwood	4.2
Pulp chips	3.7
Planer shavings	47.7
Sawdust	11.8
Hogged mill waste:	
Sawmill & planing mill	1.7
Plywood plant	9.3
Millwork plant	0.2
Furniture plant	0.3
Particleboard plant	0.9
Unspecified	4.8
Total hogged wood mill waste	17.2
Total softwoods	84.6%
Hardwoods	
Roundwood	6.7
Pulp chips	2.1
Planer shavings	3.1
Sawdust	0.4
Hogged mill waste:	
Sawmill & planing mill	0.2
Plywood plant	0.1
Furniture plant	2.5
Flooring plant	0.3
Total hogged mill waste	3.1
Total hardwoods	15.4%
	100.0%

Source: Mottet 1975, FAO Paper 59.

essentially flat and having the fiber direction essentially in the plane of the flakes, in overall character resembling a piece of veneer.

Shaving: A small wood particle of indefinite dimensions developed incidental to certain woodworking operations involving rotary cutterheads, usually turning in the direction of the grain and because of this cutting action, producing a thin chip of varying thickness, usually feathered along one edge and thick at the other, and usually curled.

Slivers: Particles of nearly square or rectangular cross section with a length parallel to the grain of the wood of at least four times the thickness.

Strand: A relatively long (with respect to thickness and width) shaving consisting of fat, long bundles of fibers having parallel surfaces.

Wood Wool (excelsior): Long, curly, slender strands of wood used as an aggregate component for some particleboards.

Present composition board processes utilize flakes, shavings, and fibers as the three most important particles. Many sizes of each are used in the industry. Hammermilled particles are generated from a number of raw materials such as chips and hogged waste. The only other particle specifically generated for panel products at the present time is wood wool. This is a relatively minor product line. Figure 6.1 provides photographs of the three particles mostly used at present in the United States. It must be borne in mind, however, that these are typical particles, and within each type there is a wide variation in size and geometry. Figure 6.2 shows other particles used in the process, ranging from large shavings and sawdust that require further milling through various flakes and wood wool.

There is a semantic problem with the particle nomenclature. The term *particle* is used generically, but it is also the most descriptive term in the English language for shavings and hammermilled furnish which have no outstanding geometric characteristics. If particles are slender in the grain direction, they are referred to as slivers and, if they are very slender, they are strands. If width is much greater than thickness, the particle is better described as a flake. Reduction in size results in either fibers or very small particles normally called fines. A *fiber* as a particle is actually a group of fibers in the botanical sense. *Particle*, however, is defined in ASTM D 1554 as the aggregate component of a particleboard manufactured by mechanical means from wood or other lignocellulosic material including all small subdivisions of wood.

Particle size and shape, or geometry, are essential characteristics of particle type. This can range from large wood chips or flakes with dimensions equaling or exceeding those of chips used in pulp and paper manufacturing down to fines such as sander dust. Particle geometry, as mentioned previously, is one of the basic factors determining the properties and characteristics of particleboard, along with wood species, type and amount of binder and other additives, and the board structure as determined by mat forming, layering, and pressing conditions. Particle geometry interacts intimately with virtually all these parameters in determining board properties.

Maloney (1977)

Particle geometry has a tremendous influence in the selection and operation of production equipment. This influence is not only on the selection and operation of equipment involved in the particle generation and particle classification, which determines the actual particle geometry, but also on almost all the other major processing facilities. This includes the conveying equipment, dryers, blenders, mat formers, conveyor lines, and even the press itself through the effect on closing speed and on the "daylight" requirement of presses (the maximum opening between platens). It is not possible to plan a composition board operation, or operate it after it is constructed, without dealing with the factor of particle geometry.

The major factors governing the choice of geometrical characteristics of particles to be used in a particular manufacturing operation are: (1) mechanical properties and other characteristics required in the final board product, (2) nature of the available raw materials, and (3) the effect of particle geometry on the total manufacturing cost.

Particle geometry is extremely complex within itself, and, as already noted, has complicated interactions with the other board production parameters. It affects board characteristics in a wide variety of ways and, while one may completely understand how particle geometry affects board properties, he may not be able to completely control the effects in a given board process. A general guide can be developed on how to use particle geometry successfully in a board plant, but it must be remembered that much of the successful generation and use of suitable furnish is still part art and part technological skill.

EFFECT OF PARTICLE GEOMETRY ON MANUFACTURING COST

As will be discussed in detail later, the particle geometry determines to a great degree the final board properties, particularly in bending strength and stiffness. Panel products having high bending strength are not dominant in the part of the composition board industry using planer shavings for raw material. Achievement of superior bending strength and stiffness requires generation of higher-quality flakes or fiber at additional cost. Thus, in determining the answer to the practical question of how to use effectively particle geometry in composition board, the relationship of service characteristics to cost must be considered. This involves not only the cost of the raw material but also the influence that particle geometry has on the cost of preparing the final furnish for board production. For example, it is usually not economical to produce high-quality flakes or fiber for an end product that does not require the bending strength and stiffness afforded by such particles. These high-quality flakes and fibers are more expensive to generate and would end up, in the long run, in competition with particles that were much less costly to produce.

The various types of raw material listed above could have a wide range of cost when delivered to a board plant. The solid wood raw material usually has the highest cost, because, in many cases, it is harvested only for the composition board plant. Thus, all of the harvesting transportation and drying costs are borne by the composition board plant. On a dry-ton basis, the solid wood may cost \$30

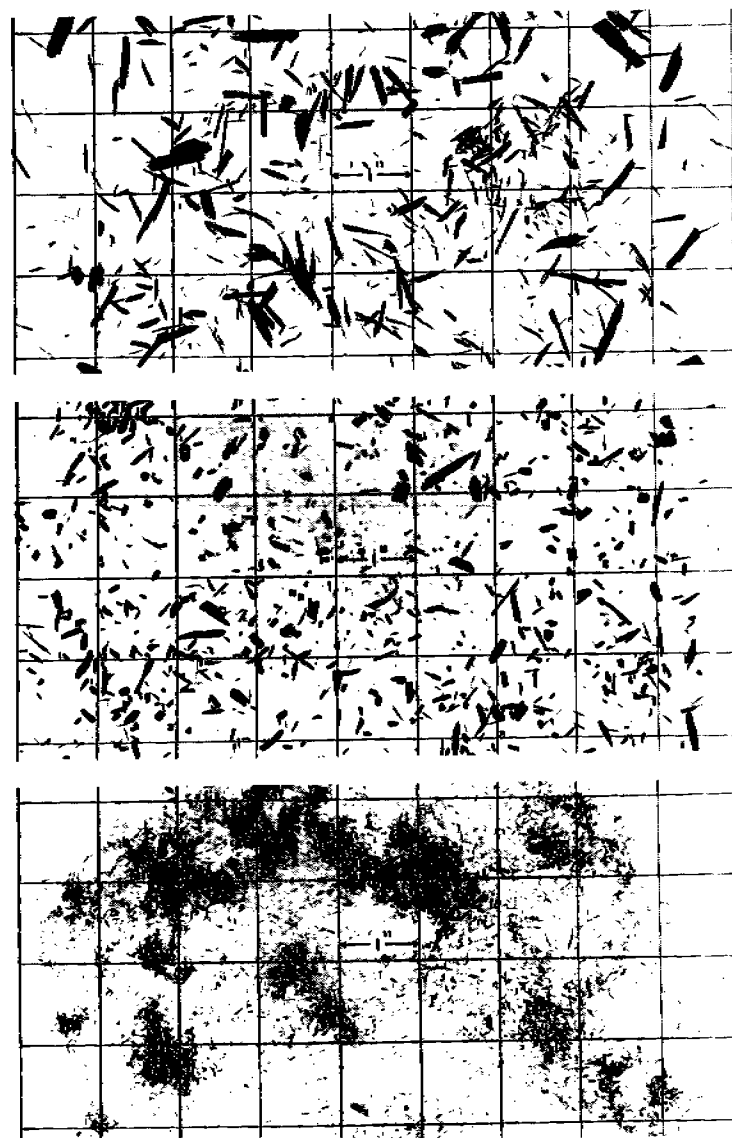


Figure 6.1. Typical particles: top, ring-cut flakes; middle, ring-cut shavings; bottom, attrition-mill furnish from chips (Mottet 1967).

increased by the fact that particles of varying geometric characteristics can be mixed in various proportions to make up the furnish for a board and can be distributed in different layers from the surface to the center of the board. Perhaps the greatest complication in this respect is that this mixture and distribution is not always under control. Changes in particle geometry in the particleboard process can be fairly obvious visually; however, it must be remembered that significant variation can occur in the fiber process as well. These "fibers" are usually a number of individual fibers making up a fiber bundle. However, the thickness, length, and surface quality can be vastly different between a fiber generated from one species under a given set of conditions and a fiber generated from a different species under a different set of conditions. Thus, particle geometry is as important when considering fibers as it is when considering flakes and comminuted particles such as planer shavings or sawdust.

Some of the important research on particle geometry is discussed below. A general summary is then presented on the effect of particle geometry on the most important board properties.

Flake Geometry

The cutting of flakes from solid wood offers the maximum freedom in controlling the size and shape of the particle. While this is not the dominant particle used

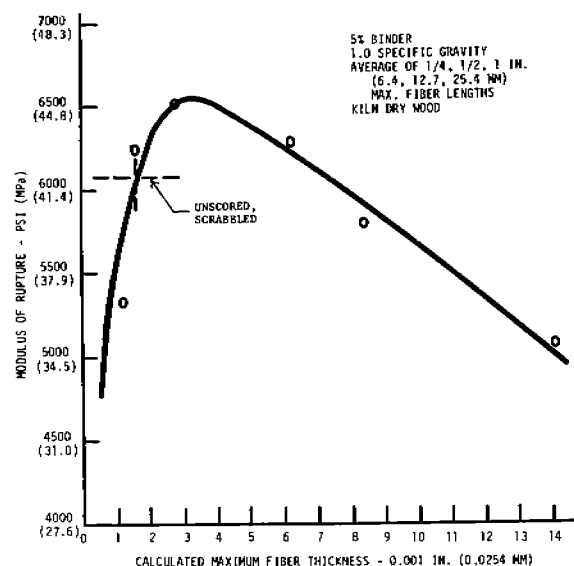


Figure 6.3. Modulus of rupture vs the calculated maximum fiber thickness for board prepared from cross-cut fiber (Mottet 1967).

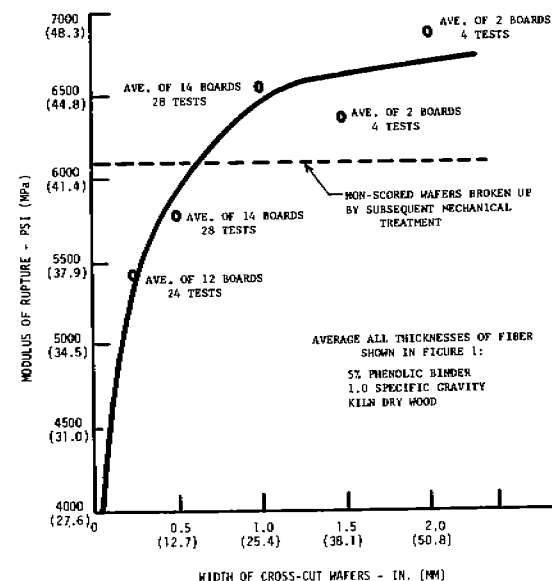


Figure 6.4. Modulus of rupture vs width of cross-cut wafers (Mottet 1967).

in the United States, flakes are predominantly used in other highly developed countries such as those in Western Europe, and Australia and New Zealand where the amount of planer shavings found in the United States is not available. It seems probable that if such low-cost raw material were available in those areas, they would also be the dominant source of raw material supply.

The first references to wood particle shape came early in the development of particleboard, particularly in the 1905 Watson patent. In later patents through the 1930s, flakes again were mentioned as a significant type of particle. The Long-Bell Lumber Company (now International Paper Co.) laboratory in 1949 conducted extensive work on particle dimensions by feeding blocks of wood at controlled rates into a rotating cylindrical cutterhead to yield various thicknesses of flakes. The width of the block was regulated to yield several different flake lengths. The results of this work are shown in Figures 6.3 and 6.4, which indicate that the best modulus of rupture values could be expected from relatively thin flakes 0.003 to 0.004 in. (0.076–0.102 mm) thick. Width of flake was also significant, indicating that flakes 1 1/2 in. (38.1 mm) wide and over were superior. The particular boards referred to in Figures 6.3 and 6.4 were designed to be used as high-density, hardboard-type panels. Thus, the specific gravity of the boards was close to 1.0, which is much higher than the common particleboards now produced.

It should be mentioned here that the term *wafers* as used to describe the flakes in this research was a specially coined word describing flakes with beveled and

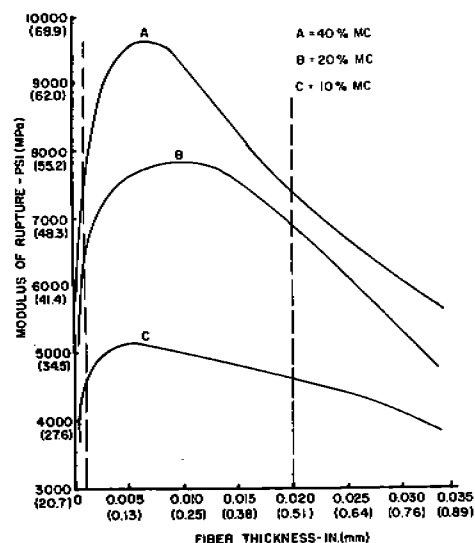


Figure 6.5. Effect of fiber thickness on the strength of pressed fiberboards prepared from Douglas fir cross-cut fiber. (Mottet patent applications in 1953 and 1958.)

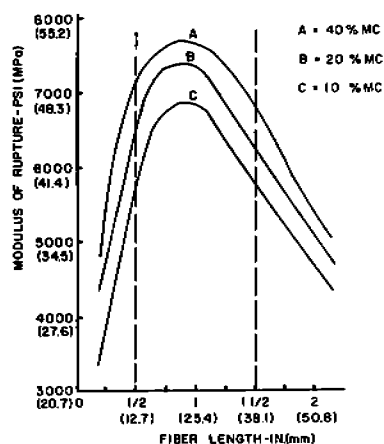


Figure 6.6. Effect of fiber length on the strength of pressed fiberboards prepared from Douglas fir cross-cut fiber. (Mottet patent applications in 1953 and 1958.)

jagged ends. While special machines were designed to make this type of flake, in reality the wafer, as it is now used in production, is a rather thick flake with relatively uniform thickness from one end to the other; and variations are mainly due to machining variables. Figures 6.5 and 6.6 show that flakes generated from material at about 40% moisture content were relatively high in quality. In this study, boards made with thin flakes about 1 in. (25.4 mm) long had the best modulus of rupture values. In this work, it was shown that, in cutting flakes from solid wood, it is important that the sharp bending of the particle at the knife tip be across the grain rather than parallel to the grain in order to prevent the development of numerous fine fractures of the flake, which cause weakening of the flake, and a reduction in the strength of the resulting board.

Figures 6.7-6.10 present some of the information developed by H. D. Turner in his classic research on the effect of particle size and shape on strength and dimensional stability of particleboard. In this work, precisely cut particles in the form of flat flakes, thin strands, helical ribbons and cubes were converted to resin-bonded panels ranging from 0.5 to 1.05 in specific gravity and having 2, 4, or 8% phenolic resin. He studied the effect of particle shape on modulus of rupture, thickness change or springback following two cycles of water soaking and oven drying, and by linear expansion during cyclic equilibrium exposure between 30

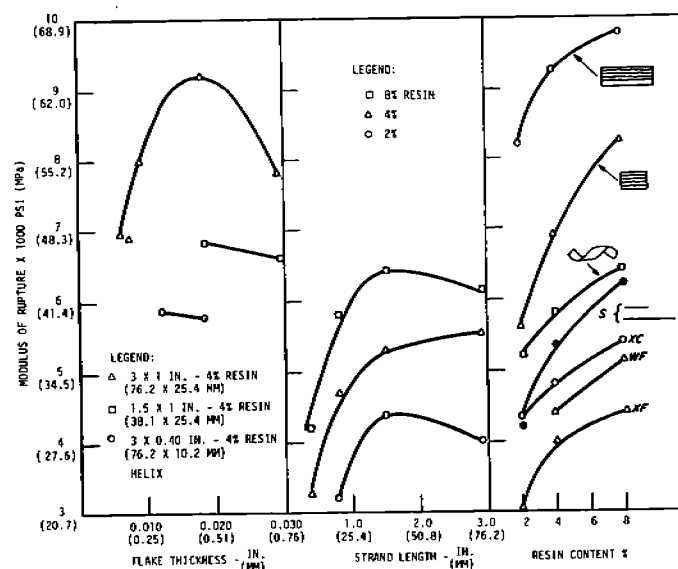


Figure 6.7. Curves showing effects on strength at 0.80 sp gr of flake thickness, strand lengths, and resin content for several wood-particle shapes. S=straight strands; XC=coarse excelsior; WF=coarse fiber of aspen; XF=fine excelsior. (Turner 1954)

within the explosive range from the standpoint of particle size (if fine) and moisture content. From this point on cyclones, duct work, forming heads, transfer fans and collectors, and sanders are all potential explosion hazards. Sources of ignition within the process would include: burning embers, static discharge, foreign material, etc.

As mentioned, the problems from explosions are potentially much more severe than those from fires and explosions can result in catastrophic losses both in personnel and production. Plants must be protected against this catastrophe and a brief review of the factors which influence wood dust explosions is of importance.

Plant experiences with explosions indicate that they have started in the dryer and bins with fire as the ignitor which is carried over into the cyclones, ducts, and felter. Wood particles discharged from the bins, cyclones, etc., combined with dust shaken from beams and ducts, have caused secondary explosions. Such explosions in the equipment have resulted in little equipment damage; but the secondary explosions have injured workmen, and buildings have suffered severe blast and fire damage.

The fiber bins are a major source of explosions. One safeguard is to locate them outside to avoid secondary explosion problems. They can also be protected with a Fenwal explosion-suppression system.

The aforementioned problem with sparks from the sander entering baghouses is causing significant problems at present. Serious explosions have occurred as the rapid transit of the sparks into the baghouse is too fast for the explosion-suppression system to work. Explosion vent doors (blowout doors) can be hazardous to anyone nearby when an explosion occurs. Some baghouses vent to atmosphere, eliminating the need for explosion doors. Another approach is to use a primary cyclone before the baghouse, giving the explosion-suppression system time to react.

Fires and explosions are still occurring at an undesirable level. Continuing development and education are needed to eliminate these serious problems.

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12.

RESINS AND OTHER ADDITIVES

Synthetic resins were the fundamental factor in the successful development of the dry-process composition board industry. Glues common to woodworking and plywood manufacturers for a number of years, such as casein, soybean, bone and hide, and blood have not been found to be suitable for composition board. While synthetics have been the dominant resin used so far, it is also possible to manufacture suitable resins from tannins (natural phenols) and spent sulfite liquor. The amounts of these resins used are negligible at the present time. However, if shortages in the synthetic materials normally used continue, extra emphasis is expected on the development of these types of resins as well as the establishment of production facilities for manufacturing them.

Both the synthetic and natural adhesives will be covered in this chapter. This will be followed by a discussion of the fundamental parameters of resin. Other discussion will cover the other additives either necessary or desired for some products. Prominent machines in use for blending resin and other additives with the wood furnish will be considered in the next chapter.

SYNTHETIC RESINS

Three major synthetic resins types are used in the board industry. By far the most dominant is urea-formaldehyde (UF), followed by phenol-formaldehyde (PF) and melamine-formaldehyde (MF). Another interesting but little used synthetic binder is polyisocyanate.

Urea and melamine resins are also known as amino resins and are the reaction products of amino and amido groups with aldehydes, most commonly, formaldehyde. The reaction causes formaldehyde to condense with the amino/amido compound to form methylol derivatives which upon further heating form the cured, colorless resin. These resins and phenol-formaldehyde resin can be cured rapidly in the presence of catalysts with the application of heat. As noted, the resins are built up by condensation polymerization.

Soluble and fusible (thermoplastic) intermediate products can be isolated during the production of the particular resin derived and these intermediates can be used to fabricate the final products. This is of great importance to the technology of these resins. Most applications are based on the ability to use intermediate condensation products to generate adhesives suitable for manufacturing wood

panels bonded together with high-molecular-weight condensation polymers. The intermediate products are fusible or thermoplastic low-molecular-weight polymers. To convert to infusible or thermosetting products, cross-links are built up between the low polymers giving a three-dimensional structure in the cured resin.

About 90% or more of the world's composition board production is made with UF resins. They are the lowest in cost and have the fastest reaction time in the hot press, and they are easy to use. Additionally, they are white or colorless. However, they do not produce boards with good exterior exposure resistance. Thus, UF boards are not suitable for exterior applications. In some parts of the world they are used in protected exterior exposures, where they are covered with suitable coatings such as paints. The PF resins have found the most favor to date when exterior-type products are desired. The liquid types are reddish in color and give a darker shade to boards, or possibly show as tiny red spots. Much of the deleterious effect can be removed in the sanding operation. MF resins are better than UF resins but cannot match the exterior performance of the PF resins. Melamines are used in some board processes, especially when blended with UF resins. With such a mixture, they enhance the moisture-resistance properties of the UF resin. A recent development in Europe for exterior resin is one made of urea, melamine, and phenol reacted with formaldehyde. It will reportedly cure as fast as urea-formaldehyde resin.

The resins commonly used in the board industry are products of the reaction between urea, melamine, or phenol and formaldehyde. Figure 12.1 shows the generalized diagram followed for the production of UF and PF resins. It should be seen immediately that the key raw materials for the two resin starting materials are natural gas and crude oil, both of which are in demand throughout the world at the present time for uses other than resins.

Only about 9% of the urea goes into the manufacture of UF resins, and these resins are used in other woodworking industries besides that of composition board products. About 58% of the phenol manufactured in the world ends up as phenol-formaldehyde resin. Again, this resin is used in other applications, so that the total amount is not reserved for composition board.

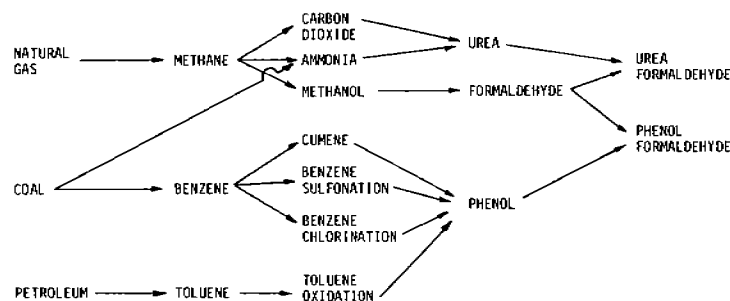


Figure 12.1. Schematic flow chart of phenolic and urea resin feed stocks (Binder 1974).

Other demands for the raw materials for producing urea and phenol resins come from the energy and agricultural industries. Natural gas supplies the methane for the methanol from which formaldehyde is produced. The formaldehyde is reacted with urea, phenol, and melamine to make the resins needed. Ammonia and carbon dioxide obtained indirectly from the natural gas are reacted together to provide the urea. Thus, natural gas is the basic source of almost all the material needed for making urea-formaldehyde resins. Melamine previously was traditionally produced indirectly from coal. However, in recent years the new plants have drawn upon urea as the basic raw material, which means melamine is also dependent at the present time upon natural gas.

The phenol comes from crude oil through the intermediate benzene, or toluene, or cumene. The problem faced here is that toluene may be required as part of the new fuel necessary to make the 1975 pollution-free automobile engines function properly. These new fuels cannot use lead and toluene is part of the substitution for the lead. Also, benzene is a critical raw material for use in pesticides which are badly needed for food production. At the present time there is about a 25% deficiency in pesticides around the world, and consequently there is a critical demand from the agriculture industry for this raw material.

With the great amount of urea production now going to fertilizer, and the demand for benzene and toluene by other products, the outlook at the present time is not bright for an expansion of the supply of the raw materials needed for synthetic resins. While there is a greater demand for these basic raw materials at the present time, part of the shortage problem has occurred because new refineries and new production facilities for resins have not been constructed at the level needed over the past ten years. The return on investments for the giant chemical complexes needed to generate these raw materials has not been high enough to encourage companies to make such investments.

Oil shortages, crude oil price increases, increased demand for petrochemical feedstocks, and lack of oil refining capacity, have all contributed to the price and availability problems of synthetic binders. An oil company has the choice, based on economics, of utilizing its crude oil supplies to produce gasoline, fuel oil, or petrochemical feedstocks. The raw materials for the petrochemical industry are the lighter hydrocarbons which are at the top of the so-called barrel of oil; but, gasoline manufacturers and utilities also bid for these raw materials, high in Btu or calorie content and low in sulphur, because they are environmentally desirable as fuel. Energy demands are therefore also complicating the picture when considering synthetic resins.

With the recent worldwide increases in oil and gas prices, however, some new plants and expansions have been announced. It is anticipated that the methanol and urea problem will come into balance within the next few years. It is unknown whether the phenol supply will be sufficient for the proposed expanded composition board industry before 1980. The world supply has been at a deficit already, and large new plants are not planned so far as known; if they are planned, they will not be functional for a number of years. Contributing to some of the problem with the phenol shortage has been plant closures because of fires and explosions. At times these have taken a significant part of the world production capacity out of operation.

It would appear that developing countries that are rich in oil and gas resources would be wise to install complexes for generating methanol and benzene because of their need for food. This may not always be the case, however, as one oil-rich country has recently announced postponing a \$500 million plant that was to produce methanol. The natural gas to be used as the basic raw material will be pumped back into the ground to force more crude oil up through the wells. Evidently they feel they will get more return on their investment by selling the oil around the world.

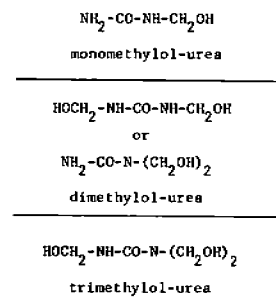
Urea Resins

As is well known, about 90% of the world's dry-process composition board products are bonded with urea resins. Consequently, urea resins have been studied thoroughly in research laboratories and by resin manufacturers. In the early days, the urea-formaldehyde resins normally used for particleboard were very similar to the glues used at that time for plywood. However, much research has gone into developing urea resins that have extremely fast cure rates in comparison to 15 years ago. About 1960 a typical 3/4-in.-thick (19 mm) particleboard bonded with urea-formaldehyde resin would take about ten minutes for curing in the press. At the present time, depending on the system used, this board can be pressed in at least half the time and, in many cases, much less. At the same time, even with relatively sharp increases in resin prices over the last two years, the resin itself is lower in price than in 1960. Thus, a lower-cost resin is available now as compared to 1960, which can cure out at least twice as fast. Thus, without any consideration of inflation, the value of the resin has more than doubled, because of the increased production capacity of a plant based solely on improvements in the resin. This has been an extremely important development, pointing out that research indeed does have its place in this industry. This is one of the reasons for the rapid growth of the dry-process composition board industry.

To chemists the manufacture of synthetic resins is a relatively simple chemical reaction. However, it is not this simple reaction that is used in the industry. If it were simple, most large board plants would probably make their own resins. On the other hand, the ways to produce the sophisticated modern resins are trade secrets. Once in a while a resin manufacturer will take out patents on some of his recent developments, but much of the know-how or art of making the resin will not be revealed. Much of the tailoring of resins to fit a certain process or plant is indeed art based on science. Thus it is impossible to discuss the technical details of making resins because of the trade secrets involved. Consequently, resin technology per se will be dealt with in this discussion in general terms.

Urea-formaldehyde resins are relatively high-molecular-weight polymers of urea and formaldehyde dispersed in a water medium. The reactive end groups of these polymers are predominantly methylol groups. It is also a common practice of resin suppliers to add urea to the resin after the synthesis reaction with the excess formaldehyde. This reduces the level of unreacted formaldehyde in the liquid resin, but also greatly increases the amount of methylol end groups present in the resin. During the curing process of the hot press, a primary source of formaldehyde release from urea-formaldehyde binders is believed to be the deg-

Figure 12.2. Monomethylol-urea, Dimethylol-urea, and Trimethylol-urea: products from reaction between urea and formaldehyde (Kelly 1970).



radation of methylol end groups which are not completely reacted. These low molecular-weight methylol-ureas (Figure 12.2), are believed to contribute very little to the efficiency of the resin, but they do significantly reduce the formaldehyde odor of the liquid resin.

The predominant configuration of the urea-formaldehyde polymer molecule in a liquid resin has not been elucidated, although researchers have been studying these resins for a number of years. The proposed configurations range from linear structure, to a branched structure and even to a possible cyclic configuration. Examples of three proposed configurations are presented in Figure 12.3. It is possible that these three configurations, as well as others yet to be proposed, are present in varying degrees in urea-formaldehyde resins.

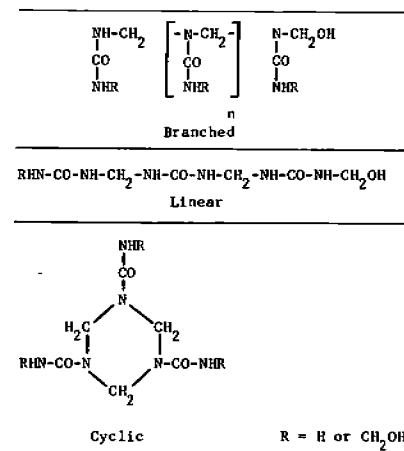


Figure 12.3. Proposed polymer structures of urea-formaldehyde resins (Kelly 1970).

Urea-formaldehyde resins are cured under acidic conditions; this acidity can be attained by using a catalyst, by the acidic nature of the furnish, or a combination of these two. Formaldehyde in the resin serves as a source of methylene bridges between the amide nitrogen of adjacent polymers. Without this formaldehyde, cure rate would be reduced and would be dependent upon the reaction between methylol end groups and amide nitrogens. For a methylene bridge to form between two polymers, these two reactive sites, the methylol end group of one chain and the amide nitrogen of an adjacent chain, would have to be in a favorable position to each other for the reaction to occur. If these two sites were in a position such that mutual contact was difficult, the reaction would either be impossible or would not occur until the sites had moved to a favorable position; i.e., reaction rate would be dependent upon the rate of movement of the respective reactive sites of the polymers.

Cure of a urea-formaldehyde resin can also be effected by reaction between the methylol end groups of adjacent polymers. In this case, water can be split out, resulting in an ether linkage between polymers. This ether linkage can be converted to the more stable methylene bridge by splitting out formaldehyde. This conversion from an ether to a methylene bridge can occur immediately after formation or at some later time. Figure 12.4 presents the above two types of interpolymer linkages.

The presence of formaldehyde in the resin at the time of cure enhances the curing process. Cure without formaldehyde is possible, but not in the time most board producers have come to expect as normal press times.

Formaldehyde in the resin results in high formaldehyde odor and the resultant irritation to personnel in the vicinity of the press. This problem can be alleviated to some extent by adequate process controls. Among these are moisture content of the mat going into the press, length of the pressing cycle, and an adequate ventilation system in the pressing area. Atmospheric conditions such as temperature and relative humidity also have an effect upon the formaldehyde odor in the vicinity of the hot press. It is unlikely that the level of formaldehyde can be reduced to the extent that it is no longer bothersome to press personnel; however,

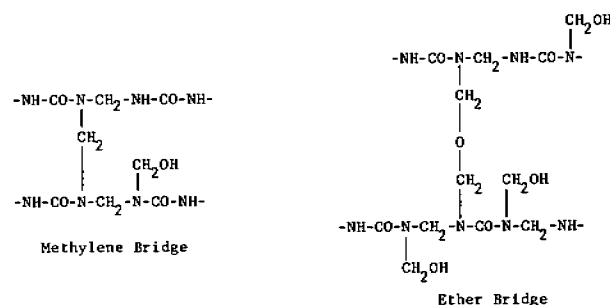


Figure 12.4. Two possible interpolymer linkages in urea-formaldehyde resins (Kelly 1970).

with suitable precautions it may be reduced to the extent that it no longer irritates other plant personnel.

There are several important interrelated production parameters governing the reaction of urea and formaldehyde to form a UF resin, such as the temperature and time of the reaction, the pH value, the concentration of the various reactants, and the mol ratio of the formaldehyde to the urea. Mol ratios of 1.4 to about 2.0 of formaldehyde to urea are reported. With lower ratios there is less free formaldehyde in the final board, but the curing rate of the resin will be slowed.

The formaldehyde odor is a significant problem in UF bonded boards. Formaldehyde in the air is toxic but it is so irritating to the eyes and nose that a person is driven from the area long before he is felt to be physically harmed. The least detectable odor of formaldehyde is reported as 0.8 ppm and the lowest concentration causing throat irritation is 5 ppm. A manyfold reduction in the formaldehyde around the press would be needed to completely eliminate this irritant. Recent developments have improved resins so that much of this problem has been relieved to a great extent in many plants. Formaldehyde is released slowly over long periods of time and this release is increased under hot and humid conditions. This is particularly noticeable in enclosed spaces such as closets which are lined with unfinished board. Good coating with clear finishes or paints, however, alleviates this problem. In overlaid boards, of course, the free formaldehyde is sealed off. Eventually the formaldehyde odor drops to an imperceptible level as the free formaldehyde is dissipated.

Returning to the manufacture of the resin, the reaction can take place about 5.0 to 5.5 in pH. The reaction is arrested by raising the pH to 7.0 to 8.0 and cooling the newly made resin. The concentration of the resin is about 40 to 60% nonvolatile solids. Some water is then distilled to increase the solids content to 60 to 65%. Some plants use the resin neat at this solids level while others dilute to a lower solids content (usually in the range of 50 to 60%) to improve spraying characteristics and coverage of the furnish with the resin.

Viscosities of the resin range as low as 30 centipoise for tack-free resins suitable for fiberboards to 200 to 300 centipoise for most particleboard applications. Higher viscosities are made to fit plants that need a more viscous resin.

A latent catalyst can be added, which acts once heat is applied to the mat in the hot press. Other catalysts such as ammonium sulfate or ammonium chloride (ammonium salts of strong acids) can be added at the board plant. These catalysts are not latent and, once added, the resin has a relatively short pot life. Another term used for catalyst is *hardener*.

The catalysts serve to provide acid which is needed for a fast cure. Some species such as Douglas fir are relatively acid (a pH of about 4.2), and in these cases sufficient acid is available in the wood to effect the cure. However, catalyst in the resin speeds the curing. Catalyst can be sprayed onto the furnish after applying the resin, and this is done in at least one plant.

Some woods or furnishes are so highly buffered (discussed later) that it is quite difficult to develop an acid environment in the furnish enabling faster resin curing to take place. An example is plywood trim bonded with PF glue. The alkaline PF glue results in a furnish that is very difficult to glue, and it took the resin companies a number of years to develop suitable resins for use with this furnish. A side note:

pressure-refined plywood trim appears to be a better furnish, possibly because some of alkalinity is removed during the refining.

Buffering of the resin is important when long storage life is important. Small amounts of ammonia or hexamine can be used. Urea and melamine can also serve as buffer. Resins used for board faces are usually more buffered to allow for consolidation of the mat before curing takes place. Curing, of course, takes place first in the faces in conventional operations because they are in contact with the hot press platens almost immediately. In most cases, it would be advantageous to use a highly catalyzed resin in the board to speed its cure. Ideally, both the face and core resins would cure almost simultaneously.

Mat moisture content, of course, is important as too high a level slows curing. In some plants, higher moisture levels are used in the surface layers to speed the cure of the core resin. Such extra moisture can also be sprayed onto the mat surfaces. This face moisture turns to steam and rapidly moves to the cool core of the board and, in doing so, carries heat to the core. This has been called the *steam shock* treatment.

The curing takes place by an increase in the resin viscosity followed by gelation and finally by forming of the rigid solid common to thermosetting resins. With UF resins, a core temperature of about 212°F (100°C) is needed for final curing. Face temperatures are much higher in the range of 300° to 370°F (149°–188°C) depending upon the press platen temperature. The key for fast press times is to elevate the board core temperature to a level sufficient for fast curing.

Melamine Resins

Melamines are high-cost resins that are better than ureas for exterior exposure but not as good as phenolics. Combinations of urea and melamine resins have been used for products that will be in damp but not severely exposed situations. Fortifying of urea resin with melamine is of value up to an addition of about 20%.

The production of melamine-formaldehyde resin is chemically similar to that of urea-formaldehyde resin. For many years the resin was supplied as a powder because of stability problems. However, recent developments have made it possible to deliver aqueous solutions of the resin. Most applications at present call for a combination of urea and melamine in the resin. This is a particularly important combination for use in the medium-density fiberboard (MDF) industry. These boards range up to about 1 1/2 in. (38.1 mm) in thickness at board specific gravities in the medium-density range. Pressure-refined fiber is the furnish used.

Urea-formaldehyde concentrates or a melamine-urea-formaldehyde *in situ* formulation have been developed as binder systems. These binders have to have the proper tack at the right time to prevent the fibers from rolling up into balls and causing problems in handling and forming. Moreover, such balls usually have an excess of resin on the outside, and this will show up as resin spots on the board surfaces. Very low viscosity is also necessary to allow for uniform distribution of the resin over the fibers, which have very high surface area for a given weight.

One particular binder system developed for fiberboard is essentially an unpolymerized water solution of methylolureas, methylol-melamines, formaldehyde, and an acid-forming salt. It is called an *in situ* binder because the

complete reactions occur in the hot press, whereas conventional resins are partially polymerized when manufactured. Proportions of the urea and melamine in the mix are varied, depending on whether the board produced is for interior applications such as furniture or where more water-resistant bonds are required.

Pope & Talbot, Inc., in Oakridge, Oregon, USA, has developed its own system for adding urea resin *in situ* to fiber. Part of the urea is added to the wood before fiberization with the remainder of the resin chemicals added afterwards. The reaction between the chemicals takes place in the hot press as with the melamine-urea-formaldehyde system.

Phenolic Resins

Phenolic resins have always cost more than the urea resins. In addition, it takes somewhat longer for the resin to cure out in a given board as compared with urea resin. Catalytic systems have been developed recently that have significantly decreased the press time when using phenolic resins. Of more importance in comparison with urea resins at the present time is the previously mentioned shortage of the raw materials needed for producing phenolics. Many plants in the United States have had their phenolic resins allotted at about 65% of their normal use during recent periods of high demand.

Phenol is characterized by the presence of a hydroxyl group attached to an aromatic nucleus (benzene). The major source of phenol is through synthesis from benzene by one of the three processes: sulphonation, chlorination, and cumene. The cumene process is the most important process at this time. Two types of phenolic resin are made: the resol or one-stage and novolac or two-stage. Phenolic resins have three further stages. The A-Stage is a polymer liquid or a liquid dehydrated to a solid. The solid is soluble in simple organic solvents and is fusible (thermoplastic). The B-Stage is the resin solid which is insoluble but can be swelled by solvents. It is infusible but can be softened by heat. The C-Stage occurs when the polymer is infusible, insoluble, and not softened by heat or swollen with solvents. It is a cured thermoset resin.

To make a liquid resol-type phenolic resin, the necessary reactants are first charged into a resin kettle and reacted using an alkaline catalyst. The mol ratio of phenol to formaldehyde ranges from about 1:1.8 to 1:2.2. The reaction is carried to a predetermined point and then slowed by reducing its temperature. These resins are not particularly stable since the reaction has only been retarded. Storage life may range from hours to months. They will continue to cross-link until the state of a completely reacted insoluble and infusible resin is reached. Storing at low temperatures is preferred. The resin as discharged from the kettle is thermosetting or heat-reactive and only requires further heating, a change in pH, or a combination of both, to complete the reaction to an infusible, insoluble state. The change in pH is not normally used in the wood industry. The curing is under the action of the alkali present in the solution. The high alkalinity of such resins can be detrimental in that more water than desired can be absorbed by such phenolic-bonded boards when placed in service.

The novolac resins have been around for over 50 years. They have been commonly used in molding processes and are the type used for powdered resins in

some particleboard plants. They are made by reacting phenol and formaldehyde with an acid catalyst, although alkaline catalyst can be used. The mol ratio of phenol to formaldehyde ranges from about 1:0.8 to 1:1. To produce a hard resin all of the moisture is removed. These resins are permanently fusible or thermoplastic when removed from the kettle. For liquid resin production, an organic solvent can be added while the molten resin is still in the kettle. The hard resin is pulverized for use. Further formaldehyde is added usually in the form of hexa (hexamethylenetetramine) in the amount of 10 to 15%. The hexa breaks down under heat and forms formaldehyde and ammonia. The formaldehyde combines with the resin and converts it into a thermosetting product while the ammonia serves as a catalyst.

Novolacs are quite stable under normal conditions. They are hygroscopic or water seeking and should be stored in a dry place.

The phenolics are slower curing than the ureas. They are more heat stable and require higher press temperatures. Temperatures in the range of 250° to 300°F (121°-149°C) in the core are needed. Platens range up to over 400°F (204°C) in temperature. Catalysts to speed pressing time, such as resorcinol, can be used but this particular catalyst is quite expensive. The final cured resin is heat and chemical resistant.

Phenolic resins for bonding are fairly high in molecular weight. They stay on the particle surfaces and develop durable, rigid, strong waterproof bonds between the particles. Another type of phenolic resin is of interest to board manufacturers: aqueous solutions of low molecular weight. These resins have the ability to penetrate and swell the cell walls of the wood. When cured under heat, these resins strengthen the wood and impart excellent dimensional stability. A particleboard developed at Washington State University called Elapreg uses up to 30% of this resin and has excellent physical properties. It has a high density but requires only sanding and buffing to achieve an excellent finish. This durable product, similar to Compreg, which is made of resin-impregnated veneers, has been demonstrated to be an excellent furniture material. It can be made on standard production lines with the exception that the highest quality panel has to be compressed under 1200-psi (8.27 MPa) pressure in the press. Lower pressures will yield lower-density panels with concomitant lower properties which are still better than those of conventional boards. A technique that will improve board quality without complete impregnation is to use the impregnating resin in the faces only.

Similar approaches have been used to produce high-density fiberboards, particularly of the type used in high-density plastic laminates.

Isocyanates

Brief mention should be made of a more expensive but extremely interesting binder, namely isocyanates. In simple terms, these result in urethane chains. The hydroxyl parts of wood are chemically connected with this binder system resulting in extremely good bonds. Such bonds have good resistance against water, diluted acids, and liquors. This binder is approved for building board in the Federal Republic of Germany.

The advantage of this binder is that no water is contained in the system. All of the binder applied is used as an adhesive. Higher-moisture-content furnish can be used, thus costs of drying are reduced, and the "blue haze" found when drying to low moisture content is eliminated. Less of this adhesive is needed in a given board as compared with phenolic resin. Reportedly, board density does not have to be as high as with phenolic resins because of better bonds and thus there is a saving on wood costs. Bonds are very resistant to water and thus have good exterior exposure characteristics. These binders work well with difficult-to-glue material such as straw. Straw boards so bonded have been made that match phenolic-bonded wood particleboards. Urethanes are hydrophobic, thus some or all of the wax may be eliminated from the board.

Disadvantages include the aforementioned higher cost, which may be balanced by savings elsewhere in the production process. Further, isocyanates adhere firmly to aluminum and some steel, causing problems with bonding to caul plates and press parts. Some release agents, such as glycerine, have been found effective. Another solution to this problem has been to use amino or phenolic resins in the faces, thereby eliminating contact with metal by the isocyanates. The isocyanates must be handled carefully in production to avoid worker health problems.

NATURAL BINDERS

Some natural adhesives, such as casein, soy bean flour, and spray-dried beef and pork blood, have been used for many years for bonding plywood. The U.S. softwood plywood industry used tremendous amounts of such natural adhesives in the past. However, 80% of this production is now made with phenolic resin. Tannins have been successfully used commercially for plywood and particleboard, especially in Australia where tannin has been used for a number of years. Quebracho, a tannin product, is being used extensively in Argentina and Finland.

Recent Indian research has developed a tannin adhesive using a very small amount of formalin. This adhesive has been improved by the addition of a protein. Work has also been conducted on the use of lignosulfonates from spent sulfite liquor in Europe and Canada. Because lignin is a natural substance, this type of binder is being designated as natural in this discussion.

For particleboard and dry-process fiberboard, the same tannins and lignosulfonates used, or being considered, for plywood, are, or may be, utilized. Success has been achieved by replacing all of the synthetic resin with tannins. A simple lignosulfonate system appears to be reaching fruition in Canada for bonding waferboard. Availability of the lignosulfonates may be a problem as there is demand for them by other industries. Some of the tannin formulations require some small amount of formaldehyde and possibly some fortifying resins; nevertheless, the amount of synthetic materials required is dramatically reduced.

Tannins

Natural polyphenols, known generally as *tannins* and suitable for exterior-type glues, are found in a number of wood species and barks. The best-known sources to date have been mimosa wattle (*Acacia mollissima*) from South Africa and

quebracho (*Schinopsis* spp.) from Argentina. These are being used commercially, mostly for plywood, in many places, including South Africa, Finland, Argentina, Brazil, Australia, the USSR, the United Kingdom, and India. Other natural polyphenols are presently being researched, and hopefully commercialization of them will occur in the near future.

Quebracho is extracted from wood or bark and, when reacted with formaldehyde, forms an insoluble water-resistant resin. Because of its high molecular weight, a smaller quantity is needed to produce a resin than with synthetic phenol. Ordinary and bisulphated quebracho are used. Quebracho used with synthetic phenolic resins can improve the bond quality and strength, reduce pressing temperature and time, and reduce the amount of formaldehyde required. Quebracho has great reactivity with formaldehyde; therefore, problems with pot life and viscosity can occur. Both acceleration of cure and improvement of bonding strength are reported in Finland where quebracho makes up 10 to 20% of the total glue solids for plywood manufacture.

A new particleboard plant in Argentina plans to use quebracho formaldehyde binder exclusively. Quebracho can also be added to urea-formaldehyde resins to capture the free formaldehyde which normally evolves from the board after it is in place. About 22% of spray-dried quebracho based on urea-formaldehyde solids is added, and practically no free formaldehyde remains in the board.

At the present time adhesives based on wattle extract are a relatively simple mixture of aqueous solutions of tannin with formaldehyde in the form of paraformaldehyde as the cross-linking agent. The reaction between the two main ingredients takes place in the hot press.

In Australia a wattle tannin-formaldehyde binder with synthetic resin fortifier is used for producing a high-quality flooring-grade particleboard. A typical formulation calls for about 35% tannin, 2% fortifying resin, and 3% paraformaldehyde. Under plant conditions longer than normal press times of 9 to 10 minutes are usual for 3/4-in.-thick (19 mm) boards. A balancing economic factor, however, is that higher mat moisture contents are necessary with levels of about 25% for surface layers and 17% for the core. Thus, far less energy is needed for drying of the particles. Furthermore, the risk of fire in the dryer would be minimized and potential dryer pollution problems may be reduced.

Other research and development efforts are going on in Australia and New Zealand, with particular emphasis on tannin from the bark of *Pinus radiata*, which is a major exotic species in those countries.

In India, tannin adhesive formulations of *Mimosa*, *Acacia mollissima*, and *Acacia mearnsii* have been used in bulk production of different grades of plywood and proved to be suitable. The new tannin-formaldehyde resin adhesives are easily mixed from ingredients without the need for any special manufacturing operation. It is recommended that formalin be used instead because of availability and lower cost.

It has been found that the addition of a proteinaceous material to tannin substantially improves the bond strength, presumably due to a reaction between the tannin and protein. A new catalyst has permitted a reduction in press temperatures to 212° to 248°F (100°–120°C). This adhesive has been adapted for particleboard, and successful tests have been conducted.

Research is in progress at the California Forest Products Laboratory on the possibilities of using bark extractives from four species available in quantity in the western United States and Canada. These include white fir (*Abies concolor*), ponderosa pine (*Pinus ponderosa*), Douglas fir (*Pseudotsuga menziesii*), and western hemlock (*Tsuga heterophylla*). The yields of bark extracts ranged from 320 to 370 lbs of extract solids per ton of oven-dry bark (161 to 187 kg/mt). In addition, much work was done in the western United States in years past on bark adhesives, and it is expected that these efforts will be revived because of the probable problems with supply and cost of synthetic phenolics.

In the California work, conventional three-layer flakeboards were produced with each bark extract using 8% of concentrated extract. After the blending of the extract with the furnish was completed, 1% of powdered paraformaldehyde was added to the blend. During hot pressing, the formaldehyde released reacts *in situ* with the polyphenolic bark components to form the resin system.

Press times at 356°F (180°C) platen temperature were three and eight minutes respectively for the 3/8- and 3/4-in.-thick (9.5 and 19 mm) boards. Strength and moisture tests indicated the board met U.S. standards for phenolic-bonded boards; however, durability was not established.

Sulfite Liquor

Reacted waste sulfite liquor from the pulping process has been suggested for more than 20 years as is attested to by the patent literature. Laboratory and pilot-plant-made particleboard and building fiberboards were evaluated and found to have satisfactory or, in some instances, superior properties.

The system developed by Dansk Spaanplade Kompagni A/S in Denmark was brought to fruition during the late 1960s. Plants were built in Denmark and Finland. About 13% of waste liquor at 50% solids is first added to the furnish. The formed mat is pressed for 1.5 minutes per mm of board thickness at 356°F (180°C). The board is then placed in an autoclave at a temperature of 392°F (200°C). The pressure is slowly raised until it reaches 10 atmospheres. The entire process takes about 100 minutes. Boards made by this process are water resistant and meet minimum physical property requirements.

The plants reportedly are no longer operating because of economic reasons. Press times were too long as compared to fast-curing phenolic resins and, coupled with the autoclave post conditioning, the resulting production costs were too high.

The Eastern Canadian Forest Products Laboratory has pursued research on finding a practical, technical solution for the possibilities of using spent sulfite liquor as a base for adhesives for exterior plywood and as a binder for particleboard. The alternative approach they have used, compared to others tried previously, has been with acidified spent sulfite liquor (SSL). It is used either in liquid or powdered form in a conventional hot-press operation to form a water-proof bond. This process requires only a simple acidification of the spent sulfite liquor to convert the binder under heat and pressure into a water-insoluble bond in the particleboard. The laboratory work has shown that the acidification of the SSL, whether of calcium, magnesium, sodium, or ammonium base, can be carried out in several ways. Among these, the addition of a strong mineral acid, preferably

sulfuric, appears to be the most practical and economical. Press time is similar to that required for a similar board made with phenolic resin. The finished board meets the Canadian Standards Association requirements (CSA-0188-68) for exterior particleboard. The long-term durability of the adhesive bond has not yet been completely established. This resin reportedly can provide tack which powdered phenolic resin does not. Thus, caulless lines can possibly use this resin successfully. Sticking to metal parts reportedly may be a problem that will have to be overcome with suitable release agents.

The final board may have to be reduced in acidity by a post-treatment. Otherwise, there may be a long-time destructive effect on the wood and corrosive effects on metal fasteners. As a result of the promise shown by current research, a plant trial using SSL powdered binder at a waferboard plant was completed recently with promising preliminary results.

RESIN DESCRIPTIVE TERMINOLOGY

A number of descriptive terms are used when discussing resins particularly the major ones for board—urea and phenol formaldehyde. Some understanding of these terms is necessary as they play important roles in the blending, forming, prepressing, and pressing stages of board manufacture.

Storage Life

The self-explanatory term, *storage life*, covers a very important resin parameter. Most liquid resins will have a much longer life if stored under refrigeration and, indeed, some phenolics must be frozen in order to be stored for a few weeks. Adhesive refrigeration, of course, is extremely difficult when manufacturing, transporting, and storing thousands of gallons of resin. Therefore, it is necessary to manufacture resin so that under "normal" conditions it will remain the same for a few weeks. Differences in ambient temperatures, e.g., between summer and winter can make such a task difficult.

In recent years, storage has become even more of a problem because resins have been improved to cure out at rates less than half of those in 1960. Such "hot" resins may be difficult to store because of the latent catalyst they contain, which may tend to start the curing reaction. The viscosity gradually increases as the resin goes "bad," and it finally becomes a solid. Storage tanks full of solid resins cause considerable problems.

For long storage periods such as when shipping overseas, the resins are spray-dried and only the solids are shipped. The resin must then be reconstituted for use.

Some dry phenolic resin is used in board manufacture. It also has storage problems in that ambient conditions can cause it to become lumpy. In such cases the resin must be reground to powdered form if it is to be used properly.

Tack

The term *tack* as applied to board resins carries such a variety of possible meanings it is useful to divide this important property into stages to discuss its

function accurately. A subjective test is used for evaluating these stages. It is known as the cotton pick test and it is a widely used and fairly simple test for characterizing resin properties. It consists of drawing down a 1.5-mil (0.038 mm) film of any liquid resin on a ground glass plate, then pressing the film lightly with a 1-in. (25.4 mm) wad of surgical cotton or fiber tissue paper at frequent intervals. A fresh cotton surface is used for each contact. The time is noted when initial adherence occurs, when adherence under light pressure fails, the amount of pressure required for tack at that point, and the point at which no reasonable amount of pressure yields tack. Due to the effects of temperature, humidity, and air movement on test results, a control resin with known tack properties should be included in each test run.

Fluid stage: The liquid resin film prior to tack development. The resin wets but does not pull fibers in the cotton pick test.

Tack Point: The point in time when a film of resin ceases to be fluid and becomes intensely tacky, as indicated by initial fiber adherence in the cotton pick test.

Tack Loss Point: The point when a film of resin has dried sufficiently to cease being intensely tacky, as indicated by lack of fiber adherence under light pressure in the cotton pick test.

Residual Tack Level: The degree of tack retained by a dried film of resin for one to several hours after the tack loss point, as indicated by the amount of pressure required to cause fiber adherence to the dried resin film.

Dryout Point: The point where residual tack is lost. No amount of pressure will then cause adherence to the resin film.

Another version of this test is to draw a 3-mil (0.076 mm) film on a glass plate, using a Boston Bradley Bar. A cleansing tissue is used for the test rather than the cotton wad. The resin film is gently rubbed every two minutes with the tissue. The test notes four stages, A through D. Stage A is just after the film is formed and is wet and non-tacky. In Stage B, a little fiber is pulled from the tissue as some moisture is being evaporated from the resin. At Stage C, a firm touch is necessary for fiber to be pulled. The test must be performed quickly as heat from the hand will soften the resin film. When Stage D is reached, no fiber will be pulled from the tissue. Because of the subjectivity of this test, differences will occur between the individuals conducting it.

Relating these terms to a typical board process, for example, resin sprayed onto a fiber or particle should remain fluid and not develop tack in the blender. Instead, tack may develop at the former, at the prepress, or even at the loader depending on the requirements of the process. It has been found that tack loss can occur ahead of the former, in the hot press, or at any point between these operations.

Since residual tack governs the integrity of prepressed mats, it must also be controlled. Too little and the mat sloughs or sifts or fractures. Too much and it sticks to prepress rolls, platens, and hold-down bars.

Udvardy and Plester (1972) have worked out a system for numerically rating tack on a scale from 1 to 10 to assist resin manufacturers and plant operators in rating the tack and its profile throughout the production process.

To optimize the performance of any particleboard line, the tack requirement of each processing step must be assessed. Then a resin having this particular *tack profile* is developed for its use. This is important as, in most cases, it is necessary to tailor a resin for a particular plant depending upon its process, requirements, species, ambient conditions, etc. For example, different resins may have to be used for winter and summer operations.

Resin Flow

Flow is another property which is often interpreted differently. Flow means that ability of a resin to remain fluid under heat and pressure, wetting new surfaces and accommodating particle movement before being immobilized by loss of solvent and polymer growth.

Optimum flow is a valuable resin property, because it permits maximum board consolidation and internal bond strength with a minimum loss of surface hardness or strength due to precure. It is especially valuable in the manufacture of thick boards.

Until recently, resin flow was usually gained at the expense of curing speed. However, recent developments in both phenolic and urea resin design have made it possible to gain significant curing speed with little or no loss of flow under most normal processing conditions.

It is easily possible to have too much flow. This causes loss of board strength through excessive resin penetration into the furnish and retreat of adhesive solids from contact points of maximum pressure. This can be a significant problem in relatively porous species such as aspen. Particle and mat moisture content plays an important part in determining resin flow in a given system. The particle moisture must be balanced with the design of the resin for optimum results in the process.

Buffering

Buffering is an easily misunderstood term as it can be confused with pH. The fact that a resin has a high pH does not necessarily mean it is highly buffered, or vice versa. Actually, there is little connection between the two resin properties of buffering capacity and measured pH.

Buffering is defined as the degree to which a resin will tolerate contact with more acidic or basic materials without changing pH. Thus, it is helpful to buffer a urea resin for storage stability when it is desirable to have the pH remain near neutral (7.0 pH) where these resins store well. However, this becomes a distinct hindrance after the resin is applied and the acidity of the wood chip or a catalyst is necessary for lowering the resin pH and speeding the cure.

Buffering can be made to occur at virtually any pH level to serve a particular purpose. Figure 12.5 shows three examples of buffering curves. The average or center of the buffering levels are at pH 7.5, 5.5, and 3.5.

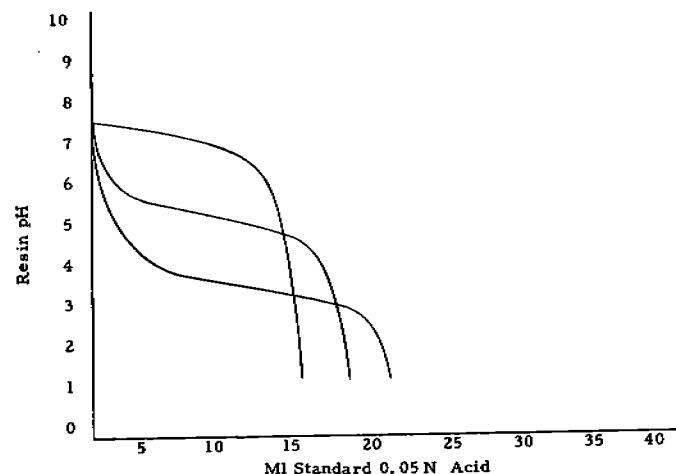


Figure 12.5. Electrometric titration curves of UF resin buffered with different systems (Lambuth 1967).

If three different portions of the same urea resin are buffered, as shown in the graph, to average pH levels of 7.5, 5.5, and 3.5, all three can be described as heavily buffered because of the quantity of standard acid or base required to change their pH significantly. However, the performance characteristics of the three buffered resins are vastly different.

The resin buffered at pH 7.5 will have an excellent storage life, but probably cannot be brought to curing pH by the action of wood acids alone. It will not cure rapidly, or possibly at all, unless an acid catalyst is added.

The resin buffered to pH 3.5 will have a very poor storage life, because of possible pH slide below the neutral range, even if initially adjusted to 7.5. However, it will cure rapidly at moderate press temperatures on even the least acid of wood particles.

The resin buffered to pH 5.5 will neither store well nor cure rapidly, regardless of its initial pH. It is buffered at a pH which is too low for good storage and too high for fast cure. For the resin at pH 7.5, the wood acids probably cannot overcome its buffering capacity near pH 5.5, and an acid catalyst will be required for normal cure times. Nothing can be done for its poor storage life.

These oversimplified examples show that buffering by itself has little meaning or purpose. It must be related to other resin performance properties. An experienced resin technologist can, by studying the wood pH level and the buffering data, determine through his experience which resins will work best. Unfortunately, no tried-and-true simple formula exists for exactly determining the "proper" resin. Only an experimental trial with the selected resin will determine its suitability.

Buffering is a two-way property, operating to hold pH constant in a given range whether the resin is being lowered in pH with acid or raised with base.

Resin pH

Once it was generally accepted that the higher the initial pH of urea resins, the better they would store. However, resins are available today which store well at pH 6.8 or 7.0, while others store poorly at 7.5 or 8.0. The mechanism of storage failure may not even be resin advancement in the normal sense, but an alkaline rearrangement called *pasting*. The storage capabilities of any specific binder resin should be judged on its merits and not on the amount by which its pH is above neutral. Under heat in the press, the resin pH will drop so that an acid condition results for curing the resin quickly.

Phenolic binder resins, unless separately acid catalyzed, will continue to be quite high in pH when stored and used. These resins derive their curing speed in large part from alkali content, but a pH check of finished phenolic particleboard will usually show wood acids have neutralized alkalinity during cure.

Viscosity

For board use, two aspects of resin viscosity are important, each for different reasons, and should be considered separately. One is the measured viscosity of the product as received and stored. The other is the fluid viscosity at the moment of spraying. Since resin viscosity is indirectly related to other performance properties, it is desirable to be able to produce board resins within the range of about 100 to 500 centipoise at 70°F (21°C). This permits the tailoring of other resin properties to the board process. Within this viscosity range, the resins should pump, store, and mix with reasonable efficiency, even when cold.

By contrast, resin viscosity should be low for application. Within reason and in general terms, the lower the viscosity the better. The thinnest resins in the range given above can easily be applied neat, while thicker resins must be warmed or diluted to reduce their viscosity for spray application. In many cases, the addition of wax emulsion alone will thin the resin sufficiently. Wax emulsions at lower solids content are routinely mixed with the resin for application to provide water resistance. With some of the newer short-retention-time blenders, however, high viscosity resins seem to function better.

Extenders

Extenders such as wheat flour are common in plywood glues. Their use is not widespread in composition board resins, but starch extenders are reported as additives in face resins in Europe.

Curing Speed

Curing Speed is another self-explanatory term. A conventional *gel* test to determine curing speed is conducted with 10 cc of the resin in a test tube set in a

boiling water bath. The resin is agitated rapidly for one minute, using a small rod to bring the resin up to temperature, and then the time it takes the resin to gel is read. The resin is agitated occasionally during the test. A "hot" core resin may gel in five to ten minutes, while a highly buffered face resin will take much longer.

Urea-formaldehyde resins cure out at about the temperature of boiling water. Some parts of a mat being pressed into a board never get much hotter, with conventional press temperatures used with UF resins. This is particularly true when considering the board core around the periphery of the mat.

The curing of resin in a board is accomplished under different conditions than the gel test. Experienced personnel can correlate the gel test with actual pressing conditions. It may be necessary to place a small amount of catalyst in the resin under test to match board pressing conditions.

PF resins, as noted previously, require higher curing temperatures. Thus longer press times are required to allow time for the removal of moisture, which holds the core temperature of the board at about 212°F (100°C) until the moisture is dissipated.

Some like to classify curing speed as the number of seconds it takes to cure a millimeter of board expressed as thickness. An example would be 20 seconds per mm of board thickness. This can be misleading, however, as the catalyst and press temperature must be known for complete understanding of this description.

COMPARISON OF PAST AND PRESENT RESINS

Past Resins

It is of interest to review the resins used in the particleboard industry of the mid-fifties and to realize the improvements made. Particleboards were mainly homogeneous, with some layering through mechanical particle separation. In each case, resin requirements were basically uncritical with respect to tack control and other present-day refinements. In many cases the board line was changed to accommodate the resins available.

For instance, when resins were found to lack the residual tack to prevent the edges of mats from sloughing, at least one manufacturer solved the problem by simply bending up the edges of his cauls to support the mat edges (such cauls are still in use). The fines sifted through the mat, resulting in a two-layer board. But the board sold, probably bottomside up. In other cases, water and even urea solution was sprayed on the edges and on top to increase mat strength and for better consolidation.

The production rate was leisurely by today's standards. Typical press times for ¾-in. (19 mm) rough boards were 12 to 15 minutes at 300°F (149°C) for urea resins and 14 minutes and over at 350°F (177°C) for phenolics.

Degradation of hot board strength properties was a serious problem with urea resins, partly because of these long press times and partly due to hot stacking the boards themselves. Except for occasional *stickering*, cooling devices were seldom used. In fact, hot stacking had its purpose as an extension of phenolic resin cure cycles. Quickly cooled phenolic boards were much lower in strength properties than those which had been hot stacked.

The particleboard resins of the mid-fifties were basically conventional ureas and phenolics, reflecting the resin technology and board process requirements of the day.

Present Resins

Today's urea resins are considerably more sophisticated in performance than those used initially. They reflect the tremendous growth of the industry in terms of volume and diversity of individual plants. They are also lower in cost, even with recent price increases due to the raw material shortage problems, since they have over twice the curing speed. Resin tailoring for individual plant requirements is almost universal now. Among the resin properties most frequently optimized for individual process requirements are: viscosity, tack, flow, reactivity, pH, buffering, storage stability, foam control, odor, and wax compatibility. These properties are sometimes even adjusted to help overcome existing but basically undesirable operating conditions, such as foam caused by faulty transfer pumps, or poor distribution caused by improper spray heads.

Thus, today's ideal UF particleboard resin is in reality many different resins, each optimized for a particular board-forming process and furnish type. For example, today's resins, within certain limitations, can be designed to accomplish the following typical options:

1. Resin tack can appear or disappear at almost any point in the forming line for the purpose of making satisfactory mats from most any particle configuration and particle size distribution.
2. Resin reactivity can be adjusted over a wide range to accommodate virtually any reproducible cure condition, wood species, or board construction.
3. Allowances can be made for slow or fast press closing times without undue sacrifice of curing speed.
4. Viscosity can be adjusted for optimum dispersion, whether sprayed neat or dilute, hot or cold, alone or with wax.
5. A variety of storage requirements can be successfully met with respect to both resin thickening and settling.
6. Low formaldehyde odor resins can now be provided for most, if not all, board processes. Very significant advances have been made in this respect.
7. Significantly improved hot board degradation resistance or "mid-exterior" durability can be provided in urea binders at a moderate premium cost.

Some properties of urea and phenolic resins tend to be mutually exclusive, meaning they cannot be optimized in the same resin at the same time. Instead, they are generally reduced to a workable compromise. Examples of these opposite pairs of properties are: reactivity and storage life, late tack development and early tack loss, early tack loss and low odor, curing speed and durability.

A technical solution to at least one familiar pair of opposed properties, speed and flow, has been worked out for both types of resins, permitting faster press times with good board consolidation. Solutions to other mutually exclusive pairs of properties may well result from continuing research on binder resins.

The present phenolic particleboard resins also represent significant technical advances. The changes in resin performance may not seem as dramatic as those of urea resins, due to inherent differences in their performance properties. However, they still reflect real progress in developing improved performance characteristics for board use. As with the urea resins, technology has been developed for phenolic resins which permits selective modifications for particular fiberboard as well as particleboard applications.

To name a few improvements, the press times of today's phenolic board resins are roughly half of those of the early days, or even less, with catalytic systems now developed for even faster press times. Applied resin costs have also been reduced even with recent price increases. The problem of wax compatibility has been significantly reduced, if not overcome. At one time wax emulsions could not be blended with phenolic resins because the alkaline-based phenolic would break down the wax emulsion, causing fluid lines and spray nozzles to plug. The forming tack of some phenolics approaches that of urea resins. Adhesion to over-dried particles is significantly better.

CATALYSTS

Catalysts can be used to hasten curing speed. In some cases they may be blended with the resin immediately before spraying, or special mixers can blend the resin and catalyst right at the nozzles. The use of such a technique is important as plant breakdowns do not result in the loss of extensive quantities of catalyzed resin. Such added catalysts are acid salts for ureas. Catalysts can be a part of the prepared resin and not a simple addition of acid salts as noted previously. Such catalysts are termed *latent*, because they do not become active until heat is applied in the press. In the highly competitive resin business, the latent catalytic systems, as well as resin designs and tailoring schemes, are closely guarded secrets.

Catalysts are definitely not a performance cure-all. They cannot improve production rates and board strength properties simply by an arbitrary addition. The proper level of catalyst may vary tenfold or more from one process to another. For instance, from 0.05 to 0.5% ammonium sulfate (a widely used catalyst) or its equivalent in other materials may be required, depending on exact plant conditions. As a case in point, among plants in present operation, several are successfully using catalyst levels that would be harmful to a number of others.

The latent catalysts are much more complex because of the shipping and storage problems. Under these conditions, the catalyst must be able to remain in contact with the resin for extended storage periods without effect, and then be quickly activated when placed in the press.

One simple method for catalyzing liquid phenolic resin is to add resorcinol, but this is expensive. Paraformaldehyde blended with wax emulsion has been successfully used as a catalyst for powdered resin. This is of importance in speeding the resin cure in phenolic-bonded waferboard. Other catalysts are being used but their makeup is not known. Not as much research has been devoted to phenolic resin as urea because of the heavier use of urea. However, research on phenolic is expected to increase as composition board moves more into the structural field.

POWDERED RESIN

One other special category of binder, mentioned previously, is the powdered or spray-dried products. Both urea and phenolic resins are presently available in dry powdered form, generally containing an appropriate catalyst. Technically, these are known as B-Stage resins; they melt and flow in the press for good distribution before curing.

Spray-dried urea resins have been used primarily in the granuplast or wood flour molding industry rather than in the particleboard industry. One plant is reportedly using powdered urea resin. Powdered phenolic resins, generally classified as industrial resins because of their many non-wood applications, are used as binders for waferboard and certain specialty particleboards.

Powdered resins are also used in conjunction with liquid resins to provide increased binder solids in particular layers or areas of both particleboard and hardboard. For this purpose, each powdered resin type, UF and PF, is compatible with almost any liquid resin of its corresponding type. Spray-dried UF resins generally equal the curing speed of UF liquid resins, while powdered PF resins are considerably slower curing than today's liquid phenolic resins. Cross-mixtures of phenolic and urea resins in liquid or powdered form have not been practical because each interferes with the curing mechanism of the other. However, as mentioned previously, a new European development combines these plus melamine into an exterior resin.

The principal advantage offered by powdered resins of either type is the freedom to use wetter furnish, to a maximum of about 20% moisture content in conventional equipment or up to 50% in special presses. Conversely, powdered binder resins also permit very low moisture input levels, relative to binder solids, particularly in high-density board products and wood molding compositions where blistering is an extreme problem.

Among the disadvantages of powdered resins is a tendency to sift through mats while forming and handling, and much slower cure times for the phenolics compared with present liquid phenol-formaldehyde resins. Also, their price is considerably higher due to the added cost of spray-drying or casting and grinding.

Today's fast-curing liquid phenolic resins do not lend themselves readily to spray-drying or powdering. Even on moist furnish, the removal of solvent upsets their flow properties beyond any practical point. However, other techniques are now available which may permit the conversion of these reactive liquid resins to dry powders with little change in their performance properties.

SPECIALTY PRODUCTS

There are a number of "specialty" resin binders available or emerging commercially. Several of these special binders designed for "nonstandard" particleboard performance requirements are discussed below.

Phenolic resins which impart termite, mold, and rot resistance to particleboards for semitropical applications are available. Termite-resistant urea resins, although technically feasible, are basically inappropriate for this type of end use because rot and termites thrive in a warm, moist environment, which itself tends to

degrade urea binders and thus limit the success of the application for purely mechanical reasons. Phenolic resins are far more resistant to this gradual, long-term degradation. Indeed the wood degrades before the resin.

High-temperature and moisture-resistant urea binder resins are presently available which make possible "mid-exterior" durable particleboard products. These products are considerably faster-curing than phenolic resins and are generally similar to ureas in handling properties. They give ASTM D 1037 accelerated aging test results of about 25 to 35% strength retention, compared with the 50% retention required for exterior particleboard binders. By contrast, straight urea resins fail completely in the first part of the first test cycle. The relative price of these resins, like their durability, is about midway between urea and phenolic resin prices.

A special application of these mid-exterior resins is their use in the core of layered phenolic particleboards, replacing the normal phenolic core binder. They permit much faster cure rates than those of present all-phenolic boards with near exterior durability. High-density boards made in this way are excellent core stock for high-temperature repressing with overlays. By actual exposure test, they may also prove to be sufficiently durable for certain exterior and wet end uses.

OTHER ADDITIVES

A number of other additives are used in composition board of which the most notable is wax or, in other words, a sizing agent. Wax is used in all boards in the United States and in boards of many other countries. However, some countries do not use it for certain products; for example, Canada does not require wax for furniture board. Other additives used in minor amounts are preservatives, fire retardants, and impregnating resins. Various dimensional stabilizers have been tried over the years, but no effective ones outside of the impregnating resins have been found to be economical, and these are economical only in special cases.

Wax

The use of sizing agents, such as wax emulsion in the production of board, appears to be a direct outgrowth of procedures followed in the paper, insulating board, and gypsum board industries. The primary need for a sizing agent is to provide the finished products with resistance to aqueous penetration. In composition board, wax emulsion provides excellent water holdout and dimensional stability in the board upon wetting. These properties are important both to subsequent secondary gluing operations, and to provide protection upon accidental wetting of the board during and after construction. In cases such as with siding, some wetting is to be expected, probably by a wicking action from the bottom side of the siding during rainstorms, and protection is provided by a sizing agent.

The water repellency provided has practically no effect upon dimensional changes or water absorption of boards exposed to equilibrium conditions. For short terms, however, as epitomized by the standard 24-hour water soak test, the presence of wax is very significant. Such repellency is only in the case of water as the absorption of water vapor is not hindered. Many investigators have found

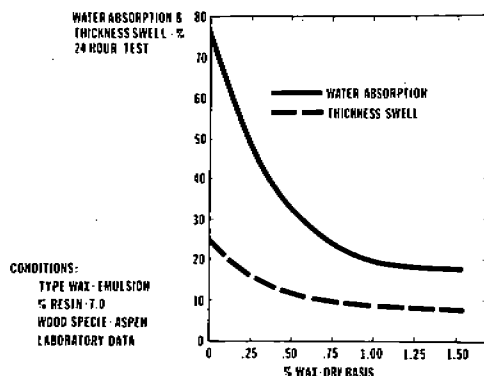


Figure 12.6. Effect of wax on particleboard sizing—water absorption and thickness swell data for aspen (Albrecht 1968).

that the addition of wax retarded water absorption temporarily, but had little effect when the board was exposed to equilibrium condition by water soaking or high humidity. Therefore the presence of wax primarily influences the rate at which the board reaches equilibrium. This property offers the potential advantage of extending the period of time for stresses to relieve themselves in structures.

Another function of wax emulsion in the production of board is to provide slip characteristics to the wood surfaces, thus reducing the tendency of blow pipes, forming stations, blenders, etc., to plug. Controversy surrounds this benefit but it reportedly has enabled plants to increase production without a major equipment expenditure.

Theory of Sizing: Figures 12.6–12.8 illustrate the effect that wax plays in providing resistance to water penetration. In the 24-hour soak test and 7-day humidity test, unsized particleboard is definitely inferior to the sized product. The species of wood involved has a strong influence on the performance of sizing agents. Boards produced from Douglas fir commonly use 0.25 to 0.5% wax solids. Aspen, on the other hand, usually requires 0.75 to 1.25% wax. As noted, wax emulsion does impart sizing characteristics to board. However, a great deal is yet to be learned concerning vapor resistance, although much has been learned about water absorption patterns and characteristics.

The initial penetration of liquids in board is through the voids between the wood particles. These, in effect, are small, irregularly shaped capillaries. The creation of new liquid surfaces, which must occur in water penetration, requires work because cohesive forces between the molecules in the liquid tend to limit the surface of the liquid to a minimum. This work is accomplished by capillary pressure plus whatever external pressure may be involved. Capillary action is illustrated in Figure 12.9. When the liquid wets the surface (contact angle $< 90^\circ$) the liquid rises in the capillary tube. When the liquid does not wet the surface (contact angle $> 90^\circ$), a depressed meniscus results.

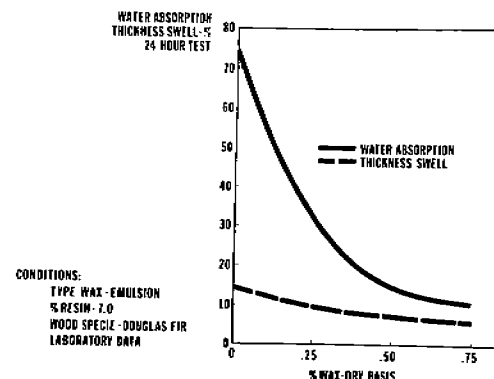


Figure 12.7. Effect of wax on particleboard sizing—water absorption and thickness swell data for Douglas fir (Albrecht 1968).

The amount of free water that enters a board is normally inversely related to its density. A low-density board, for example, usually has larger interstices between fibers. This assumes all other variables are constant. For example, a 55-lb/ft³ (0.88 sp gr) dry-process hardboard made from aspen may absorb less water than a 42-lb/ft³ (0.67 sp gr) particleboard made from Douglas fir.

Sizing, in providing resistance to water penetration, is a rate phenomenon. The rate of liquid flow through a capillary is a function of radius, pressure, and depth of penetration. Although a decrease in the radius of a capillary increases the pressure (height of capillary rise), frictional forces are even greater and rate of flow decreases. A demonstration of this phenomenon is shown in Figure 12.10. Under uniform conditions of board production, an increase in density results in improved

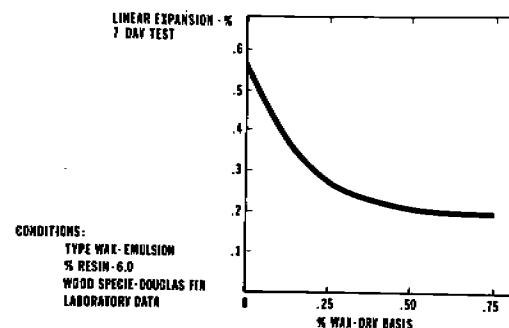
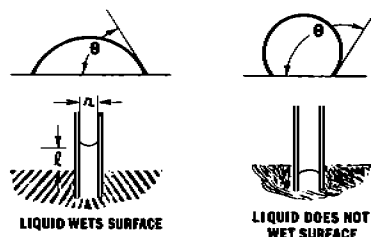


Figure 12.8. Effect of wax on particleboard sizing—linear expansion data (Albrecht 1968).

Figure 12.9. Effect of capillary action (Albrecht 1968).



water-absorption properties. This is seen constantly in board as it is very difficult for water to penetrate into a more densified product in 24 hours. Taken to equilibrium, as mentioned before, the curve will reverse itself as the higher-density board has more wood and therefore more potential for swelling. This is a good example of the short-term value of sizing.

The pressure developed in the capillary increases with decreasing radius and decreases with increasing contact angle. The primary effect of sizing is to make the fiber surfaces less wettable by the penetrant. In observing penetration under the microscope, the pattern does not appear to be the simple flow of liquid through a tube. It seems to jump from one void to another. It is possible the wood fiber surface to wood fiber surface bonds block the capillaries, making it necessary to cross these in order to continue penetration.

It is unlikely that water repellency can be attributed to the coating of fibers with wax. For example, 0.25% wax cannot cover the large surface area involved. The exact mechanism of sizing is often a controversial subject. There is general agreement, however, that the presence of heat is necessary to obtain good sizing. It is assumed that during the press cycle two things occur: (1) steam distillation of the wax occurs to some degree within the mat, resulting in vapor distribution of the wax, and (2) liquefaction of the wax permits it to wick over a large area, similar to a penetrating oil.

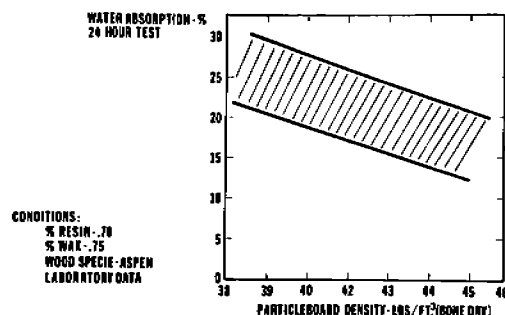


Figure 12.10. Effect of particleboard density on water absorption test results (Albrecht 1968).

In order to obtain efficient sizing of board, it is necessary to coat as much surface area as possible with a thin film of wax. Factors influencing this efficiency are spray application, blending, hot pressing, and hot stacking. Inefficient spraying and blending techniques can many times be overcome through long press times and board stacking periods. An ineffective spray application may result in large volumes of wax being applied to a small surface area. However, if press and hot stacking times are of sufficient length at temperatures above the melting point of the wax, flow-out occurs resulting in more efficient sizing.

An example of this is the relative efficiencies of molten waxes versus wax emulsions. Laboratory work has demonstrated that equal dry pound applications of both products result in equivalent sizing, if sufficient temperature and time are allotted for equilibrium conditions to be obtained. The primary reason wax emulsions have replaced molten wax is the higher efficiencies obtained through improved volumetric distribution of wax emulsion particles over larger surface areas. Under most plant operating procedures, insufficient time-temperature conditions prevail for effective utilization of molten waxes. Mathematically, increasing emulsion volume at constant dry-basis furnish levels should lead to more efficient sizing. This is one important reason for the incorporation of the wax emulsion in the resin furnish.

It should be noted that many plants used molten wax in the pioneer days of the particleboard industry but that few do now. The most noticeable users appear to be waferboard plants where the sticky wax helps the dry powdered resin adhere to the wafers. The press times are slightly longer and hot stacking is practiced, which helps use the wax efficiently.

Wax emulsions consists of minute wax particles of about 1 micron in diameter. Each wax particle is a homogeneous blend of all the waxes used in the original formulation. Each particle is enveloped by a surfactant containing an ionic charge that repels other similarly coated wax particles.

If the emulsion works properly, the water in this droplet is absorbed by the particles as soon as they come in contact. The wax, surrounded by the surfactant, remains on the surface. For the wax to flux or spread out and adhere to the wood fibers, the surfactant must release the wax. Surfactants cover a wide range of materials. Ideally, the surfactant selected should become ineffective when subjected to heat and therefore not function as a residual rewet agent. The heat sensitivity of the emulsion is critical. Utilization of the properties of the wax depends upon the more or less complete destruction of the surfactant in the hot press cycle.

Once freed from the surfactant, the wax particle fluxes and attaches to the wood fibers. How well this is accomplished depends upon the characteristics of the waxes as well as the surfactant. Figure 12.11 shows how a droplet of one emulsion will remain on a chip pretty much as it was deposited after being heated, while a droplet of another spreads out over an incredibly large area of fibers.

The fantastic array of waxes available to the petroleum refiner provides an almost infinite variety of choices in formulating an emulsion. Figure 12.12 represents the wax portion of a refinery's distillation column, arbitrarily separating paraffinic waxes, intermediate grades, and microcrystalline waxes. This column represents only the waxes in one crude oil; and the proportions of various waxes



Figure 12.11. The fluxing property of droplet varies from one emulsion to another (Berrong 1968).

and, in fact, the characteristics of each wax vary depending on the crude oil source. There are literally hundreds of waxes available to the laboratory developing a sizing emulsion.

The melting point of a wax is related to its boiling range as indicated on the distillation column. This relationship is particularly true for the family of paraffinic waxes, since their molecular composition consists of normal paraffin-type hydrocarbons varying only in chain lengths. In addition, paraffin waxes are all tested by the same method—melting point based on the release of latent heat as crystal formation occurs during cooling.

Intermediate waxes and microcrystalline waxes contain a complex mixture of non-normal hydrocarbons. They do not have a sharp melting point and therefore are tested under a different procedure than that used for paraffinic waxes. It is this difference in test procedures that prevents a direct correlation between boiling point and melting point.

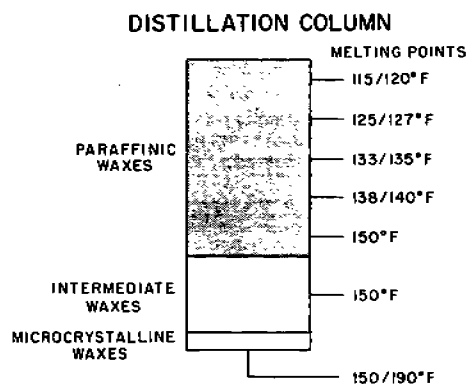
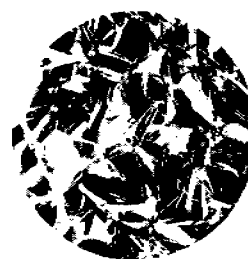
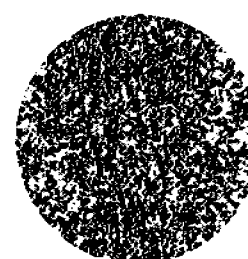


Figure 12.12. Distillation separates waxes into three basic families (Berrong 1968).



PARAFFINIC



MICROCRYSTALLINE

Figure 12.13. Microscopic view shows difference in crystal size of paraffinic and microcrystalline waxes (Berrong 1968).

A wax at the bottom may have as low a melting point as one in the intermediate range. And waxes with the same melting point can have entirely different sizing capabilities. This picture is further confused because melting points of different kinds of waxes are determined by different test methods.

Sizing properties are directly related to the type of crystals present in the wax. Paraffin waxes have long needlelike crystals that provide the best water resistance. The short, side-branched crystals of microwax are relatively ineffective for use as a sizing agent.

A microscopic view of a paraffinic wax and a microcrystalline wax (Figure 12.13) shows how different waxes are in their physical structure. Not surprisingly, this difference is reflected in sizing capabilities. Yet certain properties of both are useful in a board-sizing blend.

The larger crystals provide better moisture resistance. But some of the smaller crystal waxes are desirable to enhance handling characteristics and minimize paintability problems. They help prevent oil bleeding, which would interfere with enamel painting, and they minimize the tendency of large crystals to slow up lacquer drying.

There are exceptions to any generalization relating the physical characteristics of wax to sizing capabilities. These characteristics—melting point, boiling point, oil content, molecular weight, chemical structure and so forth—give the laboratory formulator useful clues to how a particular wax will contribute to effective board sizing, but, in every case, the final formulation is made by trial and error combinations.

Slack Wax: A term used loosely in the industry is *slack wax*. Formerly, *crude scale wax* was a term used to identify unrefined waxes having an oil content up to 6% and the term *slack wax* covered waxes of higher oil content (Figure 12.14). This nomenclature had significance to refinery people since it identified more than the oil content—it also indicated whether the wax was a by-product of light neutral or heavy neutral lubricating oils. The properties of the

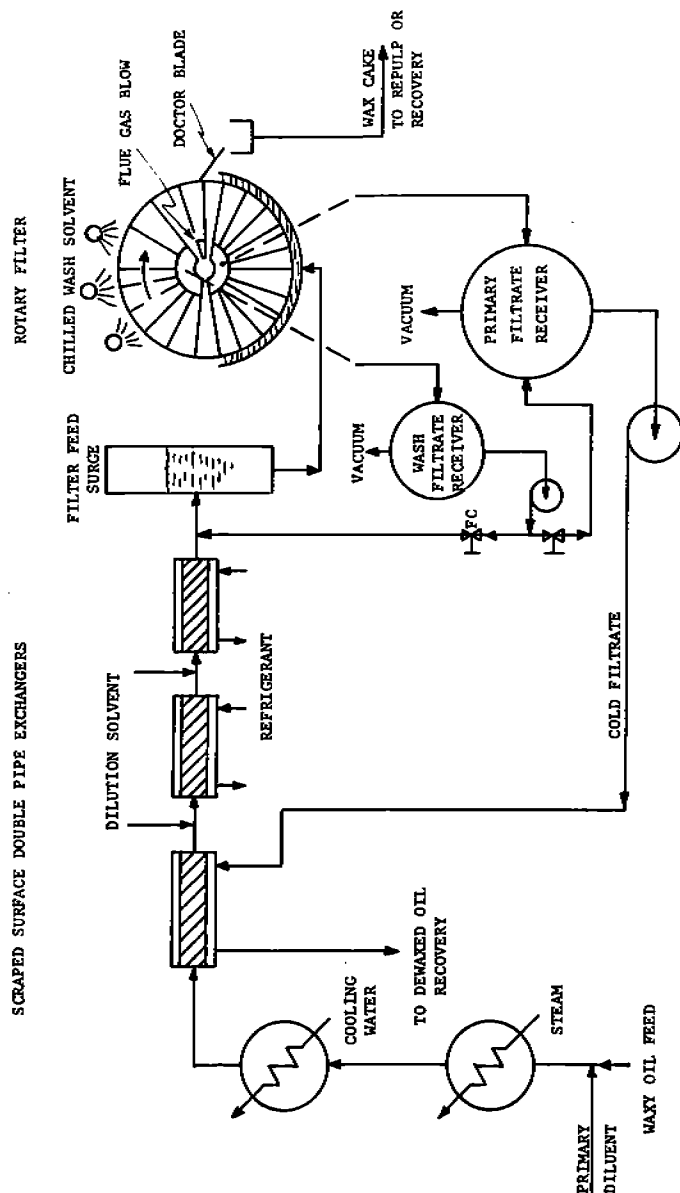


Figure 12.14. A typical schematic of wax production. (General information, courtesy Mobil Oil Corp.)

wax from each stream are considerably different, particularly the crystalline structure. Over a period of years, however, the term slack wax has become generally used by various industries when referring to the total family of unrefined wax.

In respect to sizing of composition board, slack wax can be used in either the neat form or applied in the form of a water-based emulsion. The price per pound strongly favors the use of neat wax, and its usage was fairly common in particleboard prior to 1960. As technology on emulsions improved, it was usually found that equal sizing could be obtained with one-half to one-fourth of the wax formerly applied in the neat form. In terms of cost per thousand square feet, the economics of emulsions versus neat wax currently vary from a break-even situation to a definite cost reduction for emulsions.

Other factors also enter the picture. Neat wax requires a high initial capital investment for storage tanks, pipes, and pumps that must be heated and insulated. This same system requires more maintenance and is more prone to failures than an emulsion system. The design of the blender is also important since neat wax can seldom be sprayed more than a distance of 12 to 18 in. (305-457 mm) without the molten droplets solidifying while airborne. If solidification occurs, positive attachment to individual particles is not obtained, resulting in loss of controlled distribution onto the wood.

Since consideration should also be given to other properties such as paintability, it should be noted that wax can adversely influence both lacquer drying time and the gloss properties of enamel. The type of wax becomes involved, but the most important point is the quantity of wax that exists on the surface of the board. The use of neat wax creates two potential problems. First, a higher percentage is needed to size the board. Second, there is a tendency for wax deposits to build up in the blender. These deposits periodically break loose and eventually become hot pressed into the mat. The economics and avoidance of operating problems have discouraged most particleboard and fiberboard plants from using neat slack wax. One major producer continues to use slack wax in all his plants. It is estimated that it is not used in more than 10% of the dry-process board produced in this country.

Wax Emulsions: Generally speaking, the more fully refined and purer wax grades impart more effective sizing characteristics to board. However, the process steps required in removing impurities, such as oils, increase their unit cost. Wax emulsions are petroleum products. Crude oil is distilled, giving gases, gasolines, fuel oil, paraffin distillates, and residue. Paraffin distillates provide the major source of wax used in board.

Predominantly crude scale wax or slack wax is used in the production of wax emulsion for board use. Manufacturers of wax emulsion use a variety of emulsification systems. These systems may be classified as: anionic, cationic and non-ionic.

The type of emulsifier utilized is dependent upon the end-use requirements. Conditions of resin compatibility, mechanical stability, cost, retention, etc., determine the most optimum system. The emulsification system makes the hydrophobic wax suspended in water as a colloidal dispersion and such a material is easier to handle in the board plant's process. In some cases, sizing properties may be enhanced by the emulsifying system. However, certain emulsifying agents can

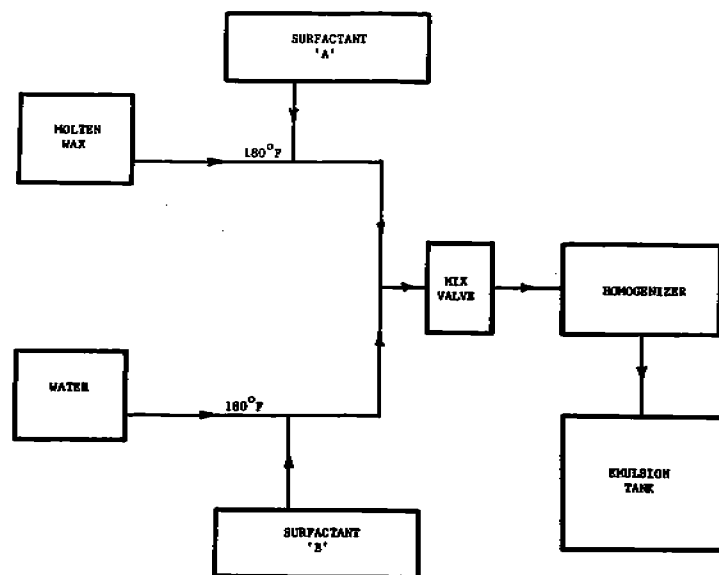


Figure 12.15. Diagram of in-plant production of wax (Mohr 1968).

detract from sizing, making it necessary to minimize their use in the wax emulsions used in board processes.

Most of the emulsions are supplied ready to use by large chemical manufacturing firms. However, wax emulsion can be manufactured at the board plant. This is rarely done in the United States because of economics. In the European industry, this has been an accepted part of the design concept of many board plant systems.

Growth of in-plant systems has been hindered by many factors. Some of these are: reservations concerning performance of a "home-made" emulsion, marked deficiencies in early equipment proposed as suitable for production, and lower commercial prices for wax as competition increased for this lucrative market. Keeping abreast of changes in emulsion technology is also a problem.

Concern has been expressed about three areas of performance: handling stability, sizing efficiency, and the paintability factor. Stability was of concern because even some of the commercial emulsions have had difficulty in this respect. Sizing efficiency was also a doubtful area, although the variation between different commercial emulsions is narrow. The paintability area was an unknown factor since there is no conclusive evidence that such a problem exists at modern and relatively low wax addition levels.

One simple process in use is outlined in Figure 12.15. Molten wax is metered from a hot tank and surfactant A is metered into this stream. Water is metered from a small surge tank and surfactant B is metered into this stream. Both streams

then merge, pass through a mixing valve, and then through the homogenizer. Both wax and water are brought up to 180°F (82°C) by system heat exchangers before the surfactant is added. This discharge of completed emulsion is piped into an emulsion tank. Each material is pumped by a separate pump and the flow rate is monitored electrically. Variation from the set flow level of any material will stop the entire unit.

Figure 12.16 is a diagram of the homogenizer head. It functions somewhat like a three-piston metering pump and is capable of discharge pressures up to 5000 psi (34.5 MPa). The raw material comes into the intake manifold, is drawn into the pump chamber, and is discharged into the exhaust manifold. The emulsion is formed when this discharge is forced through the spring-loaded disc orifice at high pressure.

Figure 12.17 is a diagram of the storing and handling system. No attempt is made to cool the emulsion as it comes from the machine. It is stored and handled hot, and no change in sizing efficiency as a result of this has been noted.

Other Factors Affecting Sizing: Many waxes and wax emulsions are available, and a wide variety of sizing action is possible. Two other factors are involved, assuming the wax is uniformly distributed over the particles, and these are species and hot stacking.

The wood species used in board production determines the amount of wax required to obtain a given degree of sizing. Factors involved are wood specific

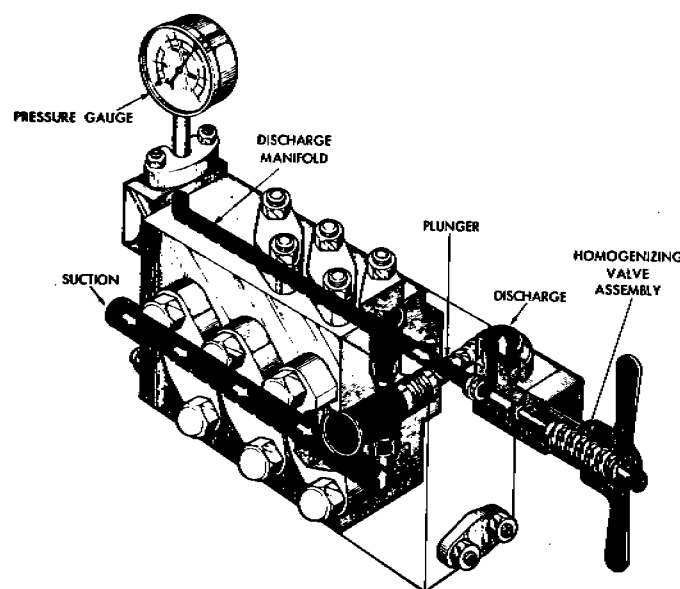


Figure 12.16. Drawing of homogenizer head (Mohr 1968).

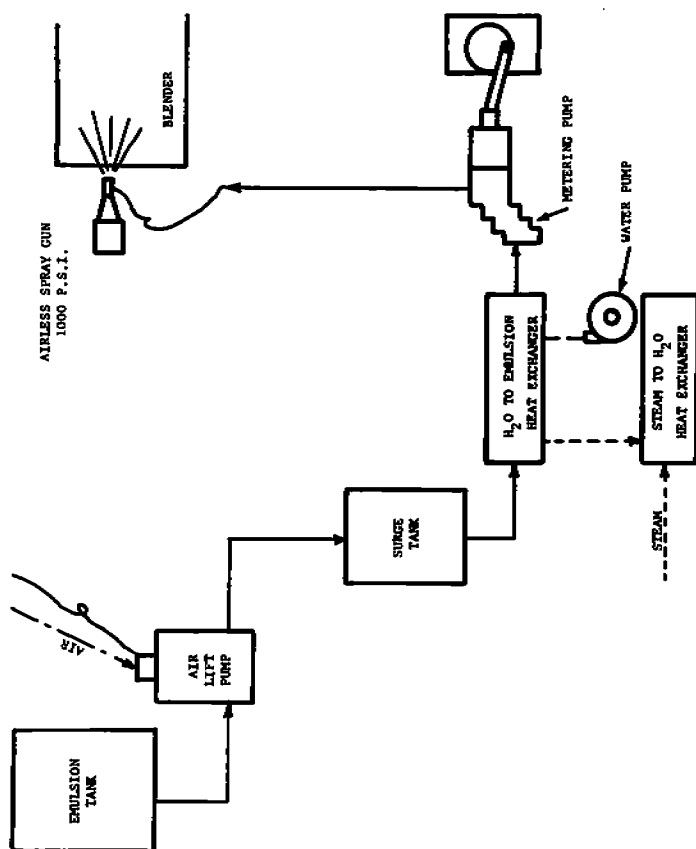


Figure 12.17. Diagram of a storing and handling system (Mohr 1968).

gravity, pH, resin content, internal structure of the species, and particle geometry resulting from plant processing. In addition to structural differences among species, some have natural resinous or waxlike extractives which impart a measure of water repellency to the boards made from those species.

Differences in thickness swell and water absorption are shown for Douglas fir, southern pine, and aspen in Figures 12.18 and 12.19. Twenty-four-hour water soak data are always difficult, if not impossible, to interpret. Note that southern pine has greater thickness swell than Douglas fir but that their water-absorption values are virtually identical. Also fir is better than the other two species in thickness swell without any wax in the boards. This is a good illustration of the species effect. Douglas fir is one of the best, if not the best, commonly used species as far as water-resistant qualities are concerned. It can easily be seen that mixtures of species, especially if the mix is unknown, can cause problems with the amount of size needed in the processing.

Linear expansion is primarily related to orientation of the fiber within the mat. Fibers oriented horizontally result in minimum linear expansion. An opposite extreme is represented by the extrusion method of producing board, where vertical orientation of fibers results in severe linear expansion.

One concern is that the inclusion of wax may lower some of the strength properties below the minimum values of the appropriate specification. Many researchers have worked in this area, and the consensus seems to be that wax quantities of 1% or less have little or no effect on the strength properties of the boards. As wax levels become higher, strengths are sometimes lowered, and this must be compensated for by additional resin, an increase in density, or a change in particle geometry.

Strength degradation from use of wax is normally quickly detected in routine production-control tests, and necessary corrections are made. Other possible side effects from the use of wax may not appear until the board is fabricated into its end use. These are more troublesome as the properties may not be evaluated by the manufacturer of the board. Two problems of this type that have been mentioned are interference in secondary gluing and difficulties in priming or painting. Terminology such as *wax migration* to the surface and *wax on the surface* have been applied to these problems. Perhaps these were problems at one time, but modern technology seems to have solved these problems. It is claimed, however, that the wax in the furnish helps to keep the board from sticking to the caul plates or hot press. In some cases, improved machinability of the board has also been reported.

The effectiveness of a wax emulsion in sizing board is primarily one of time and temperature. With steadily increasing production rates, hot stacking became more of a factor with respect to sizing efficiency. Hot stacking is the predominant requirement for effective sizing under these conditions. Board maintained at temperatures in excess of 120°F (49°C) for periods of one to four days allows for migration of wax over larger surface areas. However, the process of hot stacking has two prime deterrents: (1) possible loss of strength properties resulting from overcure of the resin, and (2) need for increased warehouse space. Most plants, therefore, now have board coolers. This has resulted in an apparent loss in sizing due to elimination of the benefits of hot stacking. Corrective measures have therefore had to be taken in the manufacture of the wax emulsion.

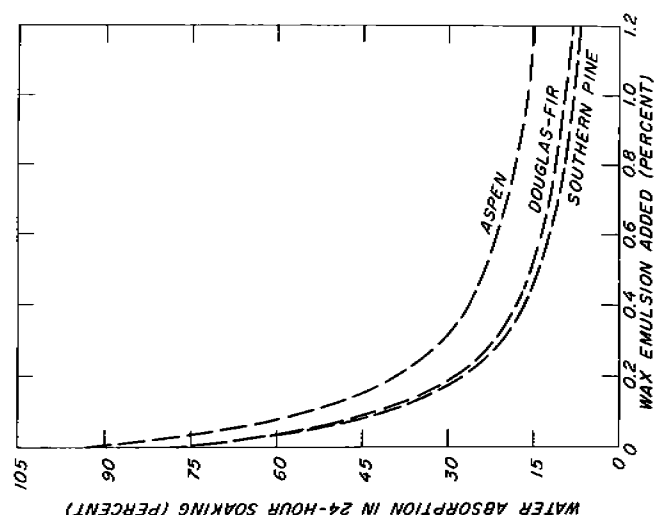


Figure 12.19. General relation between amount of wax in particleboard and water absorption in 24-hour water immersion (Heebink 1967).

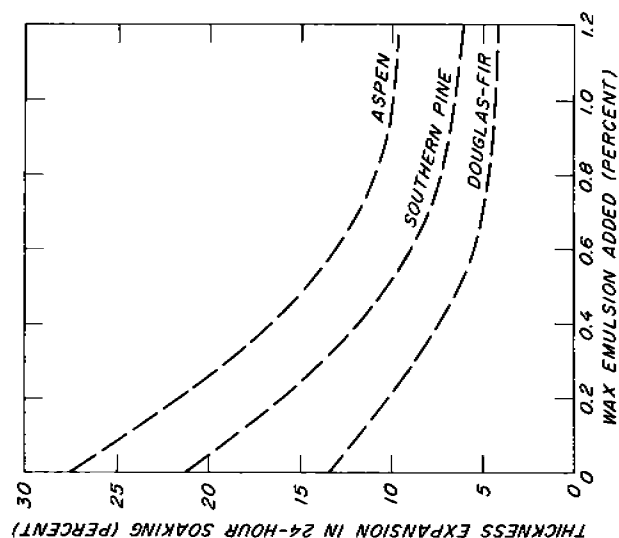


Figure 12.18. General relation between amount of wax in particleboard and thickness swelling in 24-hour water immersion (Heebink 1967).

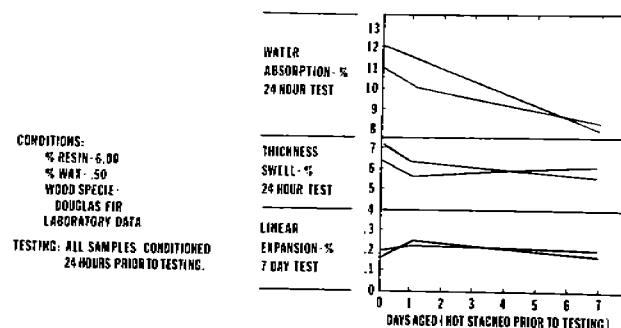


Figure 12.20. Effect of hot stacking in water and/or moisture-absorption properties on $\frac{1}{2}$ -in. (12.7 mm) homogeneous particleboard (Albrecht 1968).

Figures 12.20–12.22 demonstrate the effect of hot stacking board at temperatures of 125° to 140°F (52°–60°C). Figures 12.20 and 12.21 represent data collected on board produced in the laboratory. Boards produced in this work were cooled and then hot stacked at 125°F (52°C). Prior to testing all boards were conditioned for 24 hours. As can be seen, water-absorption results continued to improve over a seven-day period when hot stacked. Thickness swell and linear expansion results leveled off after 24 hours of hot stacking. Figure 12.22 demonstrates the effect of hot stacking on plant-produced $\frac{3}{8}$ -in. (15.9 mm) homogeneous particleboard. Four samples of board were hot stacked (after cooling) at 125° to 140°F (52°–60°C) for periods ranging from zero to eight days in duration. Water-absorption data continued to improve during the entire test period. These results were obtained with one type of emulsion. No attempt was made to determine the influence of different emulsions under hot stacking conditions.

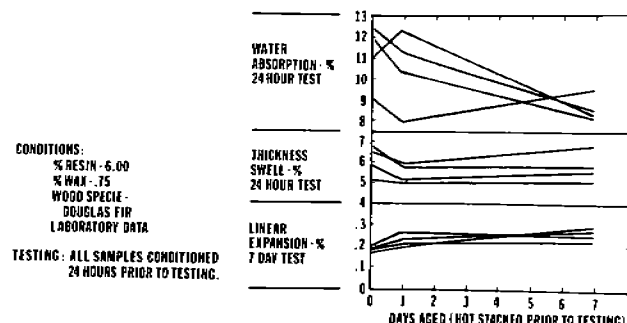


Figure 12.21. Effect of hot stacking on water and/or moisture-absorption properties on $\frac{3}{4}$ -in. (19 mm) homogeneous particleboard (Albrecht 1968).

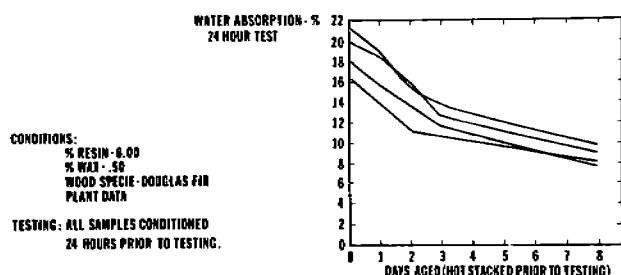


Figure 12.22. Effect of hot stacking on water absorption of 5/8-in. (15.9 mm) homogeneous particleboard (Albrecht 1968).

As mentioned in the discussion of testing, water soak evaluations are conducted under an equilibrium condition of 68°F (20°C) water temperature. Figure 12.23 illustrates the effect of water temperature on absorption test results. As can be seen, a few degrees change in temperature influences this test drastically. Fortunately when board is accidentally wetted, the water temperature is usually lower than 65°F (18°C).

The sensitivity of a board's water-absorption properties versus water temperature is also strongly related to the type of wax involved. If the wax contains components that melt at 90°F (32°C) it will obviously absorb water rapidly at this temperature.

Preservatives

Preservatives are not used widely in the United States. German standards call for such treatment in exterior boards. The popular preservative, pentachlorophenol, used in amounts of about 1.5%, has been found effective in

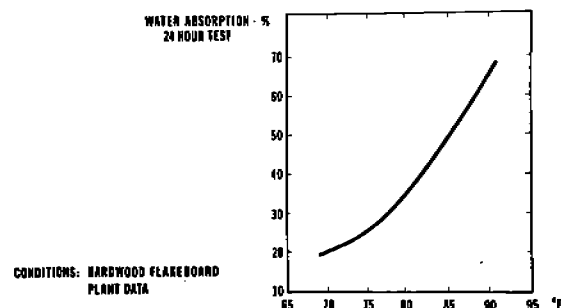


Figure 12.23. Effect of water temperature on absorption test results (Albrecht 1968).

preventing decay and termite attack. It can be made into an aqueous solution of the sodium salt and mixed with the resin, or free pentachlorophenol can be mixed with the resin liquid. The addition of the resin to the furnish provides an even distribution of the preservative over the particles. In production, care must be taken to see that pentachlorophenol fumes are removed during hot pressing.

Other preservatives, such as chromated copper arsenate-type C and ammoniacal copper arsenite, can also be used.

The beauty of treating composition board during the manufacturing process is that little is added to the production cost outside of the cost of the preservative. Treating the panels after production calls for expensive pressure treating.

Fire Retardants

Fire retardants are used in some boards now, but their use is not widespread. Increased interest in safety, particularly in nursing homes, hospitals and multifamily dwellings, is increasing the interest in fire-retardant-treated boards. Fire retardants usually greatly reduce the production of wood smoke; however, some fire retardants contribute their own fumes which often result in an overall higher smoke contribution. It has also been observed that resin can contribute to smoke.

Other properties can be imparted by retardants that are not desirable. One of the most important is associated with smoke reduction, because smoke also contains hazardous fumes. Fume emission usually results from the breakdown of chemicals when heated or in contact with glowing charcoal. Acids of phosphorus and sulfur often form when fire retardants containing these compounds are used. Halides often give their corresponding acids under similar conditions. The use of carbon tetrachloride has been known to form the gas, phosgene (COCl_2). Thus consideration of possible fume emission is important when considering various fire-retardant systems. Additionally, inorganic salts, which under the above conditions break down into strongly acidic compounds, can have a very deleterious effect on wood strength.

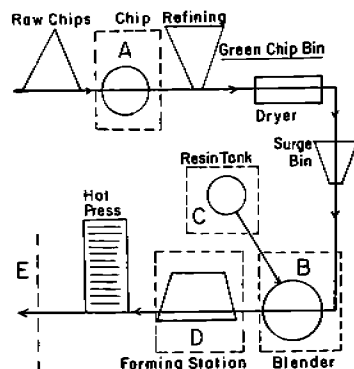
Hygroscopicity is another property of many fire retardants that should be considered. Some very excellent fire retardants will tend to deliquesce in the wood structure, and this can be so severe under the proper conditions that the specimen will actually drip and small stalactites will form on the lower edge.

Preservative value of the fire retardant is one of the additional benefits possible. In the old proprietary mixtures used by lumber treaters, there were usually several different salts used; and one of these was usually a good preservative against biological attack.

However, in board production, where the system is sensitive to complexities, one attempts to keep the fire-retardant system simple and limited to only one salt. Among the salts which have been used in the past, and which are still used for this purpose, are zinc, arsenic, and copper. Others include borax, boric acid, and borate-containing materials as well as organic fire retardants.

Adding Fire Retardants: There are four principle areas where one can add a fire retardant during the board-making process, and one after the process. To begin the discussion in the reverse direction, let us start with area (E) on the diagram shown in Figure 12.24.

Figure 12.24. Schematic drawing of a typical board process (Draganov 1968).



Maloney (1977)

Until a few years ago, all fire-retardant board was prepared by pressure impregnation with a proprietary mixture similar to those used in lumber and plywood. The material to be treated was sent to a treating facility where it was placed in an autoclave and pressure impregnated with an aqueous solution of fire-retardant salts. The product was then removed, kiln dried, returned to the board plant for refinishing, and then sent to the customer. The advantage of this method was that it involved no effort by the producer of the board other than the use of a phenolic resin. It produced good fire-retardant board; however, its disadvantages outweighed its advantages. The principal disadvantage was cost. This method of treatment, in many cases, nearly doubled the cost of the product. The requirement to convert to a phenolic resin of course was quite a problem to many firms. The fire retardant used at that time had many of the poor characteristics mentioned earlier. The board was badly discolored, it was corrosive to hardware and suffered from a hygroscopic nature and, in addition, many of these boards carried high smoke contributions. Generally speaking, it was not a popular product.

Fire-retardant paints containing phosphates can be applied in thick coats over board substrates to provide some degree of fire retardancy.

A system has been recently developed in Canada in which fire-retardant chemicals are first applied to the finished particleboard surfaces and then driven into the board by hot pressing. As far as is known, this process is yet to be commercialized.

One of the first attempts to prepare a fire-retardant board during the manufacturing process was carried out in the forming station (area E, Figure 12.24). This has been used intermittently during the years. The method is simply to feed the fire retardant into the furnish distribution system in the forming station. The result is a heterogeneous mixture with particles of fire retardant interspersed with the furnish. One process operated with either granular boric acid or monoammonium phosphate. The pH of either material is such that the resin system is not seriously affected. The product produced had some reduced physical properties. The forming line was one that used a caul plate.

This method had the advantages of simplicity and minimal equipment investment. It also did not degrade the furnish as do some processes. It was, however, limited to a certain type of forming station. Problems would occur in adapting it to the modern stations which incorporate air-classification. The method of addition almost precludes satisfactory mixing of the retardant and furnish. If such a fire retardant as boric acid is used, 44% water contained in the boric acid is added to the furnish. This extra moisture should not be added just before pressing because resin bonding could not be achieved.

Fire retardant can be added to the furnish in the blender (area B, Figure 12.24) in powdered or liquid form. Such addition is limited to acidic constituents which will not seriously affect the cure of the urea-formaldehyde resin. Phenolic resins could be expected to have fewer curing problems than the ureas. The method has limitations as to the quantity of material that can be added in normal processing. During the normal treatment of furnish with resin-wax in the blender, only 5 to 7% of powdered fire retardant can be added, as this is all that can be reasonably expected to adhere to the furnish. If higher levels are used, fallout of the extra retardant will usually occur.

This problem can be largely circumvented by incorporating 10 to 15% of a powdered urea-formaldehyde resin along with the powdered fire retardant. The powdered resin in contact with the moisture in the furnish becomes tacky and allows more fire retardant to adhere to the wood furnish. Loadings, sufficient to earn a Class A or I flame spread classification, may be achieved by this method. However, the more resin added as a powder, the higher the smoke contribution is likely to be. This method could also be used with the more modern forming stations.

Addition of fire retardant as a powder has not been as effective as liquids. It has been found that fire retardant added as a solution and allowed to penetrate the particles is approximately 30% more effective than if the fire retardant is applied as discrete particles mixed into the furnish.

Fire retardants can be mixed with liquid resin in the resin tank (area C, Figure 12.24). In this method, a finely powdered fire retardant is mixed in with the resin until a suspension is formed. With sufficient stretching of operating factors, as much as 12 to 14% boric acid has been placed in a board in this manner. To do this requires more resin, some added water to reduce the viscosity of the mixture, and larger orifices in the application nozzles for handling the more viscous resin-retardant mix.

Polymeric fire retardants can be added as liquids in standard blenders. Normally, this is a separate processing step which is not incorporated with resin blending. High moisture contents after retardant blending may require further drying. However, if the retardant is added prior to drying, the redrying step can be eliminated.

Treatment at the raw material end is another possibility (area A, Figure 12.24). In this process, treatment is by solution or as a solid salt blended with extremely wet particles. This process makes use of the rapid diffusion characteristic of some fire retardants, especially the borates. The salt is diffused by the concentration gradient into the interior of the particles within a very short time. Rapid drying removes the moisture, leaving much of the fire-retardant salt in the interior of the

wood particles. The furnish is then transferred to the blender and treated in a normal manner.

This method has the disadvantage of requiring more capital investment than those previously discussed, if more dryer capacity is needed. The moisture added to the green particles will increase the demand placed on the dryer and, in addition, it requires a plant layout which has a green holding bin to allow for a brief diffusion time.

The advantages of this method are: it allows the incorporation of very large quantities of fire retardant; it permits the addition of neutral or alkaline retardants; homogeneous products are reported that display good physical properties.

Fire-Retardant Systems: A number of fire retardants have been developed; however, none have found widespread use as yet. Quite a number can be used but they will not all be reviewed here.

One system loads the resin up with about 12% of boric acid which acts as the fire retardant. Usually more resin than normal is needed in such a system. A borate in aqueous solution mixed with green particles and acidified with a mineral acid makes up another system. In another approach, disodium octaborate in a strong solution is added to green particles, which are then dried and treated in the blender with a resin containing boric acid. Still another system uses a bromine treatment which supposedly combines with the lignin liberating hydrogen bromide. The furnish must be neutralized with borax or sodium carbonate to remove the hydrobromic acid formed as a by-product.

A chemical composition of water, sodium fluoride, urea, and mono-ammonium phosphate is used in another approach. However, this is a cumbersome system as the liquor is applied to the furnish in a slurry which means a great amount of liquid must be removed before board manufacture can take place. A mono-ammonium phosphate system in powdered form has been approved for use in another system.

A process used in U.S. manufacture calls for a mixed borax/boric acid composition (disodium octaborate tetrahydrate). An aqueous solution is added to the green particles or, if the furnish is extremely wet, powdered retardant can be added directly, and it diffuses into the wood quickly as noted previously. In board production with urea resin, it is sometimes necessary to add catalyst to cure the resin as the retardant tends to neutralize the chemical field of the furnish.

The system developed in Canada for hot pressing the fire-retardant chemicals into the particleboard uses ammonium dihydrogen orthophosphate and liquid ammonium polyphosphate as the fire retardants.

With any fire retardant, it is important that it is nonleachable. Otherwise in exposed conditions, or in areas of accidental wetting, the retardant is slowly leached out. A relatively new retardant being developed is designed to be converted to a nonleachable state in the wood after impregnation. It was developed by Koppers as an all-weather fire-retardant formulation marketed as NCX. The fire retardant is composed of a group of water-soluble monomers, which polymerize to an insoluble, leach-resistant state when subjected to elevated temperatures as would occur in the drying and pressing operations. The polymerization action is similar to that which occurs in most resins used in the plywood and particleboard industry. Application of the retardant takes place in a conventional blender followed by drying, after which normal board processing takes place.

Manufacturing Fire-Retardant Board: In considering fire-retardant board, the type of board required must first be determined (Class A, B, C, D or I, II, III, IV). Experience has shown many prospective manufacturers are not even aware that there are several classifications.

There is a need to become familiar with fire codes and the extent and variation in the sales area. It probably will be necessary to market a product bearing an Underwriters Laboratories label. All pertinent information must be gathered and evaluated first.

The fire-retardant system should be the one most suitable for the particular plant. Of importance is to plan the installation carefully, particularly if one wishes to obtain label service from firms such as the Underwriters Laboratories Inc. In that case, the manufacturer will be required to standardize his procedures, and changes later can be awkward and costly.

Once experimental boards have been produced, they will have to be fire tested. Usually, a simple test such as the Fire Tube or Schlyter will suffice for developmental purposes. As the experimental board begins to approach the design properties desired, specimens should undergo experimental tunnel tests. Promising products must then undergo official testing, which is the only way to prove the boards meet the desired classification level. Similar efforts will have to be accomplished in getting ratings for fire-door material.

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13.

RESIN/WAX APPLICATIONS AND BLENDERS

Blending of resin, wax, and other additives with the furnish was relatively simple in the pioneer period of the industry. Pouring the resin onto agitated furnish was practiced much the same as mixing cake batter. Little was known about the effects on board properties caused by the many resin parameters already discussed, by resin distribution, resin droplet size, species, and particle size and geometry. Much research since then, however, has revealed the fundamental information needed for at least a partial understanding of optimum blending. Sophisticated control systems and blenders have been developed for implementing this information. The fundamental information will be discussed first in this chapter, followed by descriptions of some of the control equipment and the major blenders. Emphasis will be on the resin and wax application. Preservatives and fire retardants can be mixed with the resin or applied separately. In general, resin blenders can also be used with preservatives and fire retardants.

RESIN APPLICATION

Many factors are involved in applying resin for optimum use. In addition to the ones discussed in the resins chapter are the actual practices of storing and application. Massive amounts of resin are required to run large board plants; thus storage becomes a significant factor. Such a facility must be well designed to handle the resins, run trials, and determine the amount of resin going into the process at any given time. Next a precise method for controlling the ratio of wood to resin entering the blender is of paramount importance; otherwise, the board properties will vary widely.

It should also be pointed out that one of the more necessary features of any good resin-handling system is a quick and efficient means of cleaning all of the equipment, from the storage tank through the spray nozzles or centrifugal atomizers. Storage tanks should have easy access for workmen to get inside and clean the tank. Tanks should have a bottom drain or resin outlet, a valve on the resin line just outside the tank and/or a valve on the line just ahead of the next storage tank to insure against the possibility of noncompatible resins and additives intermingling in the line. Easy-flush facilities and direct-line access for cleaning all lines should be provided if possible. Readily accessible and easily cleaned strainers or filters should be installed in at least two places before the resin applicators to prevent

As with most of these products, density is a very important factor. Higher density, as with the other dry-process products, usually means better properties. It also means higher weight and the possibility of more warping, both of which are undesirable.

Because of the way they are produced, most overlaid molded parts will have an unbalanced structure, because different types of overlay are used on each face. Normally in an unbalanced structure, if more moisture penetrates through one face than through the other, the differential expansion will cause the board or product to warp. However, it has been found with the molded parts that, by using the proper overlay materials, the rate of moisture flow is impeded to such a degree that this warping does not take place.

Molded wood parts can be made to exhibit good acoustical properties, particularly for use in electronic cases, and they can be made to exceed the National Electrical Manufacturers Association (NEMA) specifications for the surface characteristics of high-pressure laminates. They have general mechanical properties similar to or better than the properties of the higher-quality particleboards. These improved properties are associated with the previously mentioned higher density and a usually higher level of resin in the molded products. Also, as in other board products, particle size, shape, and geometry have considerable influence on the properties.

MINERAL-BONDED PRODUCTS

There are three types of mineral-bonded products that are produced. The first type is made of excelsior or wood wool, as it is officially named, and is made in slabs ranging up to about 3 1/2 in. (88.9 mm) in thickness. The second type consists of a product known as wood aggregate concrete. This product can be made as building blocks, full wall sections, or is poured in place as a slab for walls or floors. The third type is a building panel produced with thin flakes.

In comparison to concrete, these products are much lighter in weight. However, they are usually much heavier than the standard wooden building products that could serve the same end use. They are particularly good for acoustical and fire-resistant applications. The various mineral-bonded building products can range from about 18 lbs/ft³ to about 78 lbs/ft³ (0.20–1.20 sp gr).

Binders used for mineral-bonded products are magnesium oxysulfate, magnesite, gypsum, or Portland cement. The most important one is cement because of its high quality and availability in virtually all parts of the world. The cement should be rapid setting to enable a short working time in the process. However, the setting time of the cement is often strongly influenced by substances in the wood. These substances act as retarders to the cure of the cement and are said to "poison" the cement. The most important retarders appear to be wood sugars and/or the group of compounds known as *hemicelluloses*. They can sometimes be removed adequately by washing with cold or hot water. *Mineralizers*, a misleading term, can also be used to help with the bonding. *Mineralizers* are cement accelerators which speed the cure before the poisoning of the cement can occur. Three mineralizers are in common use: calcium chloride in Western Europe, sodium silicate in North America, and aluminum sulfate in the USSR.

In areas where many species are intermixed, this poisoning is a serious problem. Extensive work is going on in the United Kingdom and in the Federal Republic of Germany to overcome this problem. Recent reports indicate that pretreating by steaming or storage in hot water containing certain chemicals has increased the number of species suitable for use in cement-bonded products.

Excelsior Products

As noted in Chapter I the first excelsior boards named Heraklith were produced in Radenthein, Austria, in 1914. The binder used was magnesite. The first boards produced with cement came on the market in 1928. Before World War II, the binding agent used in Germany for the manufacture of this board was a combination of 39% cement, 35% magnesite, and 26% gypsum. However, after the war, the use of cement increased so that it became the dominant binder. Particularly in Europe, the processes and equipment have been highly developed and the dimensions, weight, and properties of excelsior boards are standardized.

This type of product has been made in the United States for many years. However, it has been difficult to determine the exact history of the early plants. It is known that such panels have been manufactured in currently operating plants since the 1940s but board was available much earlier from other sources, particularly one in Chewelah, Washington.

The Chewelah plant was the Thermax Division of the Northwest Magnesite Co. The process was based on the Heraklith process. A sawmill was built to cut large planks which were then cut into excelsior. Two products were produced: Thermax which was a "standard" excelsior panel and absorbex which was a higher-density panel made for acoustical and decorative purposes.

The superintendent of Northwest Magnesite Co. became interested in the manufacture of this type of board as a means of using the flue dust which was extracted from the kiln gases expelled during the burning of magnesite. For the manufacture of Thermax, which was made in 1-, 2-, and 3-in. (25.5, 50.8, and 76.2 mm) thicknesses, western larch and magnesium oxysulfate were used as the raw materials. To produce the cement, fresh flue dust was passed through a ball mill and then reacted with dilute sulfuric acid to form an emulsion. A small amount of caustic magnesite was added to improve the board strength. This emulsion was mixed with larch excelsior and then the material was spread onto a thin, steel belt and passed through a heated dryer or press. Steel belts were operated on the top and sides of the mat to hold to the desired dimensions. Heat was introduced into the shell of the dryer to speed curing. This was a continuous operation and the finished board was cut to the desired lengths as it emerged from the press.

Absorbex was made with cottonwood and caustic magnesite. It did not have the dark grey color of Thermax which was caused by the carbon content of the flue dust. It had a natural light tan color and was used extensively without further finishing. It was, however, a more costly product and this limited its use.

Production reached its peak in early World War II when much of the output went to the armed services throughout the world. However, limited production, and inadequate sales structure and difficulty in obtaining parts from Europe caused the plant to cease production in 1943.

In Germany, spruce has been found to be a popular species for use because it is relatively easy to prepare the excelsior and there are few extractives for inhibiting the cure of the cement.

Excelsior has been produced as a packing material since about 1900, with the first production occurring in the United States. These particles are long, thin wood strands about 19.7 in. (500 mm) in length with the width varying between 0.019 and 0.2 in. (0.5–5 mm). The thickness of excelsior ranges between about 0.010 and 0.025 in. (0.03–0.64 mm).

The prepared excelsior is mixed with the appropriate amounts of cement and water. Much less water is needed in this type of process than in a conventional concrete system because only a small amount of moisture is necessary for the cement to hydrolyze and cure.

In the early days, the excelsior board was produced in relatively small plants. The forming of the mats was done by hand. However, in the modern plants, the formation is now performed by mechanical processes.

For curing the mats into the final board, one system stacks the mats one on top of the other and then applies pressure by means of concrete weights. The mats are left under pressure for about 25 hours. Another system places the formed mats in a press for about 1 1/2 minutes. The mats are then clamped together and removed from the press. After 15 to 20 hours, the boards are taken out of the forming mold and set aside for final curing. While it was mentioned that cement is now the favorite binder to be used, the Austrian system called the Heraklith procedure has apparently remained with magnesite as the binding agent (magnesium carbonate, $MgCO_3$). This board is continuously pressed by press rolls with a setting time in the order of about 30 minutes. It then takes one to two weeks, depending upon the thickness of the board, for final curing of the mortar to take place.

The first system developed by the National Gypsum Company, according to its patent information, encompasses the continuous forming system and a continuous pressing system that uses steam heating for rapid curing of the cement binder. A magnesium oxysulfate cement is used, which consists of a water-borne mixture of magnesium oxide in magnesium sulfate. These two ingredients are combined just before being sprayed upon the excelsior.

First the excelsior is deposited on a solid conveyor belt. After a smooth mat of excelsior is developed, it is then sprayed with the magnesium cement. A typical mixture will be 35% of the magnesium oxysulfate dissolved in water, to which is then added 65% of magnesium oxide. As soon as these two ingredients are mixed together, the cement starts to set. However, normal setting time will be over one hour. In this process, as soon as the cement is applied to the mat, the mat moves forward through a preheating oven. Heated, water-saturated air is blown down through the mat and through the perforated conveyor belt. The temperature of the air ranges from 110° to 140°F (43.3°–60°C). This particular temperature range will cause the magnesium oxysulfate cement to set in a time somewhere between four and eight minutes. The exact time is dependent upon the chemical activity of the magnesium oxide. The mat moves forward into a continuous press. The preheated mat must enter the press before the cement has set. The press itself consolidates the mat to final thickness, and this consolidation must take place before final curing of the cement. The press temperature is about 190°F (88°C). This press is

composed of a solid rubber conveyor belt which is backed up by moving metal platens for forming flat surfaces. As the pressed board emerges from the press, the cement is set sufficiently to hold the board at its desired thickness. The boards then go through a series of drying ovens where heated air is blown through them, removing excess moisture.

This process has been improved so that curing can take place in a steam-heated hot press. These presses range up to 100 ft (30.5 m) long, with the first one-third to one-half of the length built to pass live steam through the mat. Experimentation showed that using live steam with more than 10% moisture reduced the setting time of the cement to as short a time as 30 seconds.

As in the original invention, the cement is sprayed on a thin, excelsior mat and subsequently distributed on the excelsior fibers by means of picker rolls. The picker rolls distribute the excelsior into a thick (12 to 20 in. or 305 to 508 mm) formed mat which is preheated by steam and then passed through the press, where it is compacted to the desired thickness. The press is composed of upper and lower conveyor belts. The bottom one is a perforated stainless steel belt. The belts are backed up by upper and lower platens, each composed of a number of hollow platen members extending crosswise in the press.

Live steam is introduced through the perforations in the bottom platen, and as the steam passes through the mat, the cure of the cement is completed. It takes from 30 seconds to 5 minutes to cure the boards, depending upon the board thickness and other production parameters. It is necessary to get the temperature in the board to 212°F (100°C) to effect the final cure.

The board density may range from 10 to 50 lbs/ft³ (0.16–0.80 sp gr), although 15 to 26 lbs/ft³ (0.24–0.42 sp gr) has been found ideal for most construction uses. The following table provides a typical materials balance for a board of 21 lbs/ft³ density (0.34 sp gr) 12 in. square (30.5 cm) by 1 in. (25.4 mm) thick.

Material	Weight (g)	(%)
Excelsior at 20% moisture	448	33.9
MgO (magnesium oxide)	284	21.5
MgSO ₄ 7H ₂ O (magnesium sulfate)	153	11.6
Water	435	33.0
	1320	100.0

This table shows that about one-third of the mix is wood. The water is mostly removed during the drying. After pressing, the wood consists of about 50% of the board on a dry-weight basis.

It takes about 8 psi (55.1 kPa) to compress the board of 15 lbs/ft³ density (0.24 sp gr) and about 14 psi (96.5 kPa) to consolidate the board of 21 lbs/ft³ density (0.34 sp gr).

The rapid cure of the cement in this process has reduced the importance of the relative activity of the cement ingredients and has provided a situation where a wider range of oxides can be used.

This product is now being manufactured and sold under the trade names of Tectum I and Tectum II. Tectum I is the product just described. Tectum II has a rigid polyurethane foam applied to the top, which penetrates from $\frac{1}{8}$ to $\frac{1}{4}$ in. (3.2–6.4 mm) into the face of the board. The urethane foam has a density of 2 lbs/ft³ (0.03 sp gr) and fuses in place after it is applied.

Tectum is made in thicknesses ranging from 1 in. to 3 $\frac{1}{2}$ in. (25.4–88.9 mm). Depending upon the thickness and supplemental reinforcement, the roof panels can span up to 72 in. (1.83 m). Tectum is also used for ceiling and wall sound control, accent and decorative purposes, and in recent years as a complete side-wall and roof system in residential housing.

Building Blocks

Building blocks using cement for the binding agent have been used for many years. This type of product has been popular in Scandinavia. A number of buildings have been put together with this type of material in the United States.

One pilot plant has been built in Spokane, Washington, where blocks are fabricated by machine in a size 8 in. (203 mm) thick, 12 in. (305 mm) high, and 48 in. (1.21 m) long. This machine can also produce blocks 24 in. (610 mm) long and vary the thickness and height if desired. The blocks are also made with a tongue and grooved top and bottom for the do-it-yourself builder, if he does not want to use the standard procedure of laying up the block with mortar. The larger-size blocks described weigh approximately 100 lbs (45.5 kg) and compare favorably to the weight of a similar piece of wood of the same size. Because of its construction it is nonflammable and has excellent insulation properties. Its density is such that nails can easily be driven into it and it can be sawn, drilled, routed, sanded, and handled much like any piece of softwood.

Because of the ease in manufacturing this type of building product it is not only suitable for small operations in developed countries but it is an excellent product for production in developing countries that have wood residues and cement. As stated previously, cement may be a problem because of the high energy costs associated with its production.

Flakeboards

Elmendorf Research Incorporated has developed a flakeboard with Portland cement as the binder. Its name for this flakeboard is Century Board and at present it is being manufactured in Japan and, on a small basis, in Switzerland under the name Duripanel. The Elmendorf term for long, narrow wood flakes is *strands*. In its process, the strands are first treated to remove any extractive material that may cause problems with the cure of the cement. Portland cement is then applied to the strands, and the coated strands are formed into mats on moving metal caul plates. The cauls with their mats of cement and strands are stacked and subjected to pressures equivalent to those for making plywood, which are retained by clamps until the cement has set. When high-early strength cement is used, the pressing time is about 12 hours. With normal cement, the pressing time may be up to 16 hours. The green boards are solid piled for at least three days, after removal from pressure, and can then be forced dried in several hours. The bending strength of

this board is determined by the strength of the wood strands and not by the full strength of the cement.

This particular board is made in specific gravities of 0.95 to 1.20 (59.4–75 lbs/ft³ density). Three different types are produced, namely: Type A—boards in which the cement-coated strands are randomly distributed in one or three layers and then compacted; Type B—boards in which the cement-coated strands are mechanically deposited in three layers with the strands of the outer layers oriented into parallelism; and Type C—boards in which the outer surface is textured and is composed of cement and inorganic filler.

This type product can be used for floors, doors, load-bearing walls and partitions, and concrete forms. Unlike the excelsior-type product, it can also be used for exterior exposures, and exterior siding is the major utilization.

Recently a group of Swiss companies, together with a German equipment manufacturer (Bison-Werke), have been working with the Elmendorf concept for the production of cement-bonded wood particleboards. At present, an expanded pilot plant is operating producing Duripanel. The type of product being produced is similar to synthetic resin-bonded wood particleboard, as is the process system.

The raw materials are Portland cement, wood particles of the flake type, and any other necessary chemical additives. The wood must be carefully selected because wood extractives or hemicellulose have an unfavorable effect on the cement. The preferred wood species in Europe are spruce and fir.

The preparation of the particles, blending, and mat forming are quite similar to standard board production processes using synthetic resin. An air-classifying type of former is being used, which lays the finer particles on the mat faces. Thus, the board has relatively smooth faces. The mats are formed on metal cauls, then a package of cauls and formed mats is placed into a hydraulic press, where the mats are consolidated to final thickness. The package is rigidly clamped together and heated and humidified for about seven to nine hours to accelerate the curing. The



Figure 3.16. Exterior-wall cladding of the Sandoz AG Laboratory in Basel, Switzerland, (photo of the Durisol AG Dietikon from Deppe 1974).

panels are then strong enough to be handled. The clamps are released, solid piled for several days, then forced air dried. The finished panels are trimmed to size and sanded on one side, or both sides, for dimensioning.

Work is underway at the present time to reduce the pressing or curing time, but care must be exercised in adding substances to speed up the cure. Such substances cannot be used in quantities which impair the board properties, particularly their resistance to fire. Stiffness, bending strength, and tensile strength of resin-bonded particleboards surpass those of the cement-bonded boards. The compression strength of the cement-bonded boards, however, is superior to that of the resin-bonded particleboards.

In Germany, these panels are planned for use as ceiling linings, and interior and exterior paneling. Consequently, their fire behavior is particularly important. Tests so far show that in Europe this particular product has outstanding characteristics in a fire compared with the normally inflammable wood-based materials and fire-retardant wood-based materials.

The development of this type of board in Europe is only in its infancy, although much of the product is in use. Technological problems still have to be solved; however, its excellent behavior in fire makes this a worthwhile endeavor. Figure 3.16 shows one of the applications.

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4.

COMPOSITION BOARD MATERIALS: PROPERTIES AND TESTING

Composition board properties include strength, fastener holding ability, responses to soaking in water, responses to changes in ambient humidity conditions, and changes caused by exposures to severe weathering conditions. All of these properties are important in design, for determining the quality of the product, and for acceptance by the consumer. This discussion will cover the properties now measured, their definition, and how they are determined according to the United States and Canadian procedures. It is recognized that different test and methods of test are found in other countries, but a full discussion of these is beyond the scope of this book. Also to be covered will be standards and their development and the properties required in the developing structural products. Actual minimum properties were reported in Chapter 2. Trying to report all the actual properties of various boards and comparing them to solid wood and plywood is beyond the scope of this book as this is a big subject deserving separate treatment. A simple comparison between types of material cannot be made as design factors must be considered and this complicates the comparison.

PROPERTIES

The strength properties of composition boards include static bending, tensile strength parallel to the surface, tensile strength perpendicular to the surface (internal bond), compression strength parallel to the surface, shear strength in the plane of the board, glue line shear, and impact interlaminar shear and edgewise shear. Important fastener holding properties are lateral nail resistance, nail withdrawal, nailhead pull-through, and direct screw withdrawal. Other properties include hardness and abrasion resistance. Properties associated with moisture include water absorption and thickness swelling, linear variation with change in moisture content, edge thickness swell, accelerated aging, cupping and twisting.

Not all of the properties listed above are important for all of the products manufactured today. Rather, each product has a particular set of properties which are important because of the intended end use. Therefore, the applicable properties are selected for particular end uses, and minimum or maximum allowable values are specified. In general, the physical properties usually evaluated for board products include static bending (which covers modulus of rupture and modulus of elasticity), internal bond, water absorption and thickness swell, and

This steaming plasticizes the wood, enabling the surfaces to be rapidly consolidated and densified. Quite a number of seconds go by, depending upon the board's thickness, before sufficient heat penetrates the board core to achieve the same type of plasticization. However, by the time this penetration to the core occurs, the faces have already been well densified and usually the face resin has been cured out. High-frequency curing of the mats as practiced in the medium-density fiberboard industry was specifically designed to alleviate this particular problem of a greatly unbalanced face-to-core density profile. However, it has been shown in commercial practice that in general with the thicker boards the same type of density profile exists. Density profiles will be discussed more comprehensively later on.

PARTICLE ALIGNMENT

Particles, particularly fibers and flakes, can be aligned to provide panel products with much greater bending strength and stiffness in the oriented or aligned direction. Such orientation again interacts with most of the major parameters involved in producing boards, and manipulation can change the level of strength possible through orientation.

Boards are usually referred to as randomly formed or aligned. Randomly formed boards, however, normally have their particles oriented. Only boards made with particles of uniform dimension in length, width, and thickness can have the particles randomly formed. In such an odd case, it would be like forming marbles into a mat in preparation for pressing into a board. However, virtually all particles used are not dimensionally uniform, such as a sphere or cube.

Let us use flakes to illustrate how a board is normally made of aligned particles even when called randomly formed. Flakes are aligned within the plane of the board. They will not stand on end or on edge if dropped from a mat former onto a caul plate. They are therefore highly aligned in the plane of the board. Consequently, oriented or aligned flakeboard means that the particles are lined up in one direction according to their length. The same general type of alignment exists with fiber and other types of particles formed into a mat randomly and which have a slenderness ratio over one. Such particles will line up according to length, but the more cylindrical type particles will have a more random alignment as far as width is concerned because the width may well be approximately the same as the thickness.

Two ratios should be understood when considering orientation. The aforementioned slenderness ratio is the particle length divided by the thickness. Any particle with a ratio over one will be longer than it is thick and thus will be amenable to orientation. The higher the ratio, the more slender the particle. The second ratio is the aspect ratio which is important when considering flakes. It is calculated by dividing the flake length by its width. A ratio of one means a square flake, which is one that cannot be oriented. A ratio of at least three appears to provide good orientation.

Particles with high slenderness ratios can be aligned to make composition boards strong enough to compete effectively with plywood. This potential may even extend into the structural lumber field. Mechanical means can be used to

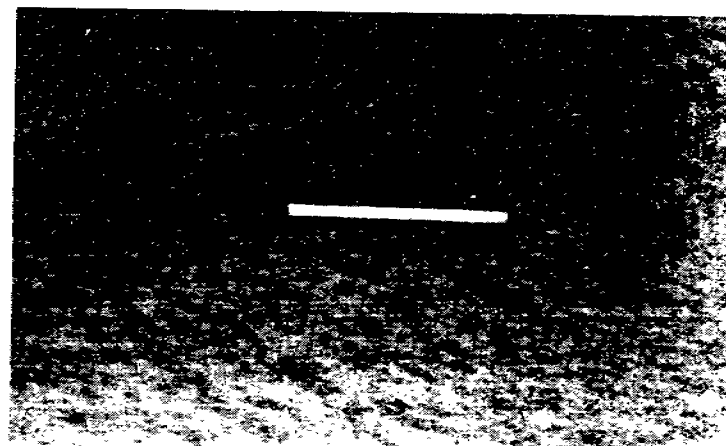


Figure 5.5. Aligned mat of Douglas fir fiber (Talbot 1974).

align some particles, especially long, slender flakes. Panels made with oriented flakes aligned mechanically are coming into the marketplace as the core of veneer-faced composites. Panels made of thin oriented flakeboards cross-laminated into a panel, the same as plywood, have been produced and successfully test marketed. However, small shavings and fiber are quite difficult to align mechanically.

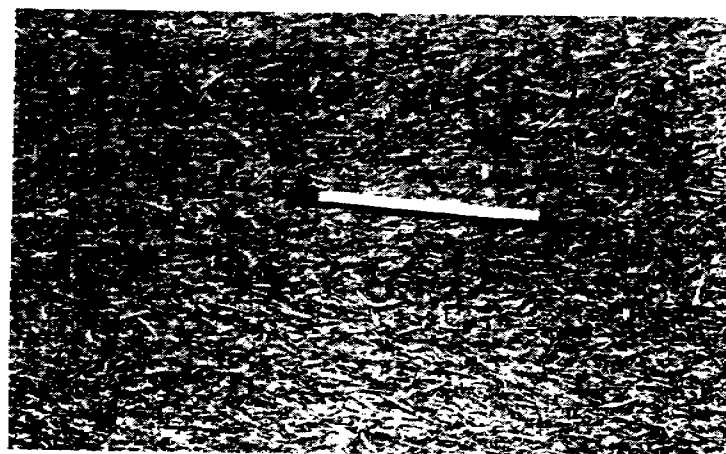


Figure 5.6. Aligned mat of hammermilled Douglas fir particles (Talbot 1974).



Figure 5.7. Aligned mat of hammermilled red cedar mill waste including bark, planer shavings, and hogged solid residues (Talbot 1974).

A new electrical method has been developed at Washington State University, using an electrical field for the orienting, which can orient small as well as large particles. Particles are dropped through an electrical field formed between two oppositely charged plates, and the electric field aligns them. This relatively simple device, using little energy, is incorporated as part of a former. It is now going into commercial application.

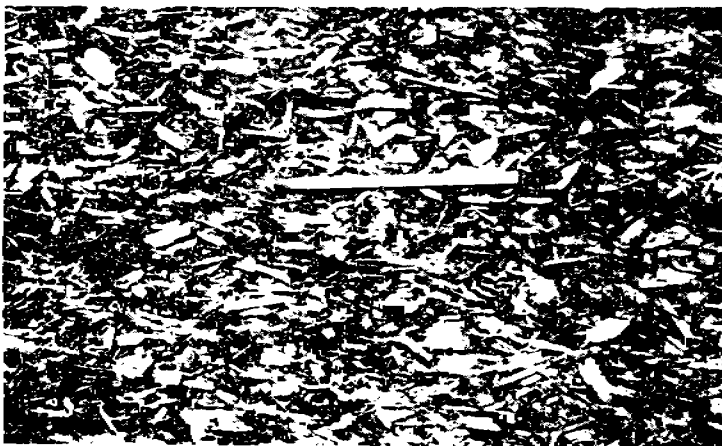


Figure 5.8. Aligned mat of disc-cut redwood flakes (Talbot 1974).

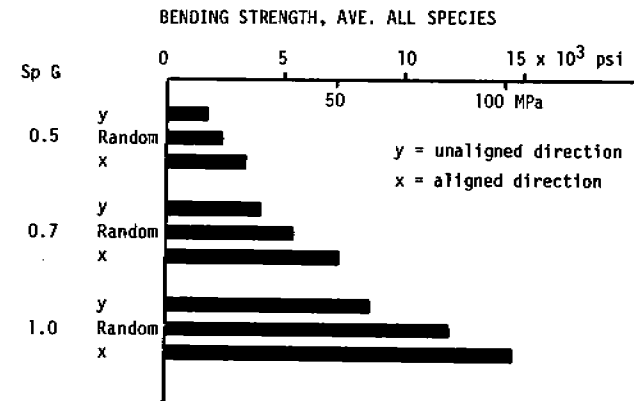


Figure 5.9. Effect of alignment on the bending strength of fiberboard at three density levels averaged over the three species (Talbot 1974).

The great advantage of this system is its ability to align many different types and sizes of particles even in admixture. Further, small particles and fibers can be aligned, which is quite difficult to do mechanically.

Figures 5.5–5.8 show several different types of furnish after being aligned in a mat. Figure 5.9 shows the improvement in bending strength (modulus of rupture) that can be achieved with fiber, and Figure 5.10 illustrates the comparatively high

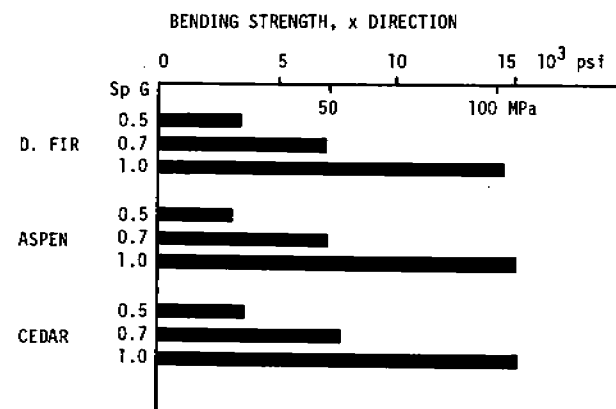


Figure 5.10. Bending strength in the aligned direction for fiberboards of three different species and three density levels (Talbot 1974).

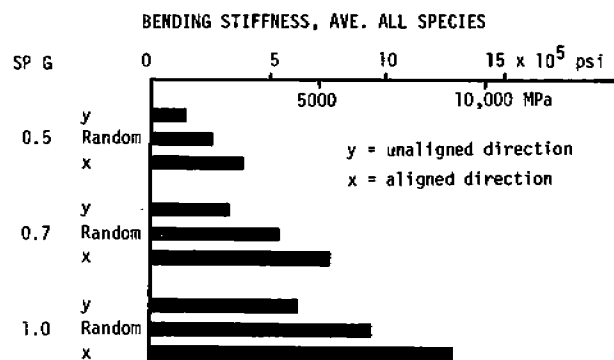


Figure 5.11. Effect of alignment on the bending stiffness of fiberboard at three density levels averaged over the three species (Talbot 1974).

bending strengths that can be developed in three different species. It is of interest that normally weaker species such as western red cedar and aspen approximately match the boards of the normally stronger species—Douglas fir. Similar comparisons were noted in bending stiffness (modulus of elasticity) as shown in Figures 5.11 and 5.12.

Of great import are the properties presented in Table 5.1 showing that boards of hammermilled particles have excellent bending strength and bending stiffness. Even western red cedar bark board had good properties. A combination panel of fiber faces and hammermilled particles in the core had a bending stiffness high

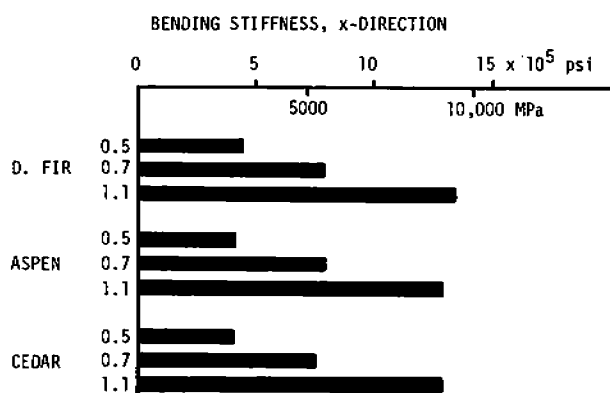


Figure 5.12. Bending stiffness in the aligned direction for fiberboards of the different species at three density levels (Talbot 1974).

Table 5.1 Properties in the Aligned Direction of Several Types of Oriented Board Corrected to 0.7 Specific Gravity

Formulation	Modulus of rupture		Modulus of elasticity		Modulus of elasticity (degree of alignment*)
	(psi)	(MPa)	(psi)	(MPa)	
1. Douglas fir fiber	8,590	59.2	750,000	5,171	2.4
2. Hammermilled cedar bark	3,350	23.1	510,000	3,516	2.6
3. Redwood flakes	7,020	48.4	1,120,000	7,722	3.3
4. Hammermilled Douglas fir particles	4,590	31.6	870,000	5,999	6.0
5. Three-layer boards (No. 1 formulation for faces, No. 4 formulation for the core)	8,500	58.6	1,000,000	6,895	3.8

Source: Talbot 1975.

* Degree of alignment = $\frac{\text{Modulus of elasticity in aligned direction}}{\text{Modulus of elasticity in nonaligned direction}}$

enough to justify design working stresses as great as those of high-quality sawn lumber. Boards of aligned redwood flakes fit into this same category. Thus, structural utilization of many raw materials previously unacceptable for use has become possible—a giant stride forward for the composition board industry.

BOARD DENSITY

The last, but certainly not least, factor to be mentioned is the level of the board's density or specific gravity. It was referred to earlier when discussing the specific gravity of the species used. Board specific gravity is a powerful factor affecting board properties. In most cases, an increase in board specific gravity results in a concomitant improvement in physical properties. This is a relatively easy way to improve properties. Many times no additional resin is needed because of the more efficient use of resin resulting from the increased board density.

In particleboard, it has been found that a board specific gravity of 0.15 to 0.20 above that of the whole wood is necessary to achieve minimum physical properties, unless low-density products are purposely being made. In all composition board, it is very noticeable that an increase in specific gravity improves the physical properties, with the exception of dimensional stability in water soak and exposure to high humidity. Because of more wood in the higher-density board, thickness swell and linear expansion can be greater after absorption of moisture.

In practice, the easiest way to improve most board properties is usually to increase the board specific gravity. The increased board specific gravity results in more intimate contact between the particles in the mat being compressed into the final board. As will be noted later, much resin is lost in interparticle voids in lower-density panels. If the board can be compressed to a higher density, more of

this "dormant" resin is used effectively. Increasing specific gravity not only affords this increase in effectiveness of resin but, of course, causes more wood to be present to resist mechanical loads. This combination of effects results in board strengths being approximately proportional to the square of board specific gravity over the usual specific gravity range.

In places where wood costs are low, increasing board density can be the cheapest way to improve board properties. However, the increased board weight can result in a board harder to handle and in one which is more difficult to cut and machine. If freight rates are a factor, heavier boards can be more costly to ship.

SUMMARY

As perhaps can be seen more clearly now, the production of a composition board depends on the web of interrelated factors described plus many other minor but still important factors that also enter into this vast spider's web. In essence, the process of producing boards is simple. However, interactions occur in each of the process steps, which complicates the whole system. It does provide a situation, however, where numerous products can be made from the same general mix of raw material with proper understanding and control of the process. Man then becomes the master of a complicated situation and uses it to his advantage to produce a consistent and high-quality product, usually from waste materials.

Up until now we have discussed the subject in general terms. We will now turn to more of the basics involved in the process, as well as to discussion of the pieces of equipment necessary to put theory into practice. The entire process was described in a sequential form earlier to provide a general understanding of this exciting new industry. In the next several chapters, the fundamentals of the process will be the subject of discussion.

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3.

MODERN PROCESSING SYSTEMS

For the uninitiated, the dry-process board industry is a confusing welter of terms. However, it is not unlike any other industry, and its distinct nomenclature must be learned to fully understand the process. In this chapter a general overview will be given to this industry so that the reader can understand more clearly the detailed discussions to be presented later. It must be realized, however, that with any generalized description there are always exceptions to the rule, and it will not be any different in this discussion.

This industry is highly mechanized, or, perhaps to be more correct, semiautomated. It is not a completely closed-loop system which can be controlled entirely by a computer program. Decisions by men are still necessary. However, manual input is held at a minimum, particularly as compared to other wood products processing operations.

In the early board plants, first established in Europe, many people were involved in production but, as mentioned, this has changed to the present semiautomated system. It is expected that advances in technology for controlling the process and greater understanding of the optimum methods for producing composition board products can eventually lead to fully automated production systems. As it is now, most plants run with very few men on the production line. However, behind the scenes are a number of highly qualified maintenance-type personnel such as electricians and mechanics. They are needed in this, as well as any, semiautomated or automated industry to keep the many controlling devices and the equipment functioning properly so that they can truly operate in an automated manner.

Preferably the plants run continuously, particularly the larger ones. As with any production facility, it takes a certain period of time to get the process line functioning properly. Once it is functioning, it is easier and more economical to keep the line running without having to shut it down unnecessarily. The dryers, some of them running with a combustion chamber temperature of 1600°F (871°C), must be heated up and cooled down if the plant is not running continuously. Once resin systems are flowing properly and correct amounts of resin are being applied to the wood furnish, it is best to keep them running. A particular process problem can be the mat former where slight changes, such as in ambient conditions or mat moisture content, can cause severe problems in properly forming a mat. Once the former is running properly, it is ideal to keep it running. It is convenient to keep

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hot presses operating continually once the "normal" temperatures ranging from 300° to 400°F (149°-204°C) are stabilized.

Most plants would like to run about 22 ½ hours per day with the remaining time allowed for normal downtime. An operating time of about 350 days during the year is desirable. The remaining time in the year is used for normal heavy maintenance. It is also normal for many plants to shut down for one eight-hour shift during the week for routine maintenance on the production line requiring more than a few minutes. Much of the cleanup needed in a board plant is performed during this time.

The major production lines operate with platen presses. Continuous press systems produce similar boards. The first part of the discussion will present general information on production factors for the platen system, followed by a general discussion on the different process lines. A more detailed discussion of the process steps will then be presented. Extruded board, molded processing, and mineral-bonded products will be presented next and not discussed further as they are relatively minor parts of the industry at this time.

PLATEN-PRESSED SYSTEMS

Dominant Production Factors

Some of the dominant factors governing the production of platen-pressed boards are type of raw material, wood species, particle size and geometry, resin level and type layering by particle size and density, mat moisture content and distribution, and the board density. Interactions between these and other factors result in many different variations, and these will be examined in detail later.

Ideally, it is best to keep each different type of raw material and species separate as it enters the plant, so that it can be metered in desired proportions into the board process. In the early days, with smaller plants, this was relatively easy to do. In fact, some plants could operate on exactly the raw material they found to be most desirable; however, this is no longer the case in most places. A wide range of residuals is brought into the board plant from many primary generators of a vast variety of residual material, making a complete separation very difficult.

As will be discussed later, particle geometry is of great importance in board manufacture. Particles with good slenderness ratios such as fibers and flakes provide products with high bending strength and stiffness, and for such products it is desirable to have such particles on the board faces. Short, chunky particles in the faces are detrimental to the development of these properties. However, such particles are excellent for improving bonding properties in the board core and, consequently, can be used there. Coarse fibers or thick flakes are also usually used in the core when they are part of the furnish.

Resin level is directly associated with the properties of a given board. Most particleboards are made with urea-formaldehyde resin at levels between 6 and 10%, based on the oven-dry weight of the wood. The finer particles used in faces need the higher resin levels because of their greater specific surface area. Phenol-formaldehyde resin, when used, is applied at slightly lower levels. However,

boards made of large flakes such as waferboard, because of their lower specific surface area, require only 2 to 3% of phenolic resin. This is usually applied as a powder. Virtually all other resin is applied in the liquid form.

High-density hardboard is normally made with about 2 to 3% phenolic resin. The high-density product makes efficient use of the resin, as virtually none is lost in interparticle voids, such as found in low- and medium-density particleboards. Medium-density hardboard siding is made at resin levels up to about 6%. Normally, phenolic resin is used. Medium-density fiberboard is made usually with either urea-formaldehyde resin or urea-melamine concentrates applied at about 7 to 9%. Higher resin levels, when used, will result in better board properties. However, this expensive additive is kept at the minimum level required for producing products with acceptable properties. While many properties can indeed be improved dramatically by increasing the resin level, the interaction with other manufacturing conditions is of great importance. Bonding naturally will be improved, but particle geometry is dominant in determining ultimate bending strength, stiffness and dimensional stability.

Resin type determines the board's resistance to deterioration under severe environmental conditions, such as exterior exposure. Normally, phenolic resin is used to gain moisture resistance and improved weatherability. Urea resin is utilized when the board is used for interior applications.

Wax, usually in the form of an emulsion, is added to the furnish to improve dimensional characteristics, particularly those associated with the absorption of liquid water. Molten wax is also used in some of the processes. Levels in particleboard, medium-density fiberboard, and hardboard range between about 0.25% to 1.0%. Some hardboard siding has been reported to contain as much as 3% wax.

Other additives, such as preservatives and fire retardants, can be added for resistance to decay and fire.

All dry-process boards have a layered construction, which is usually of two types: particle size and density. The most obvious is particle layering, where fine particles are on the faces and coarser particles are in the core. The face-to-face density profile cannot always be seen visually and thus its effect on board properties can be overlooked by the untrained observer. This profile usually runs from high density in the faces to low density in the core.

There are three basic board configurations for conventional composition board as far as particle size is concerned. The first is homogeneous, where the mix of particles is randomly distributed throughout the board. A second formulation is the three-layer, where finer particles or thin flakes are in the face layers and the coarser particles are in the core. These boards, depending on the thickness, are made up of about 15 to 20% of fine particles on each face, with the remaining material being made up of coarse core particles. A third configuration is the graduated or multi-layer board. In this case, as illustrated in Figure 3.1, the finest particles are on the faces of the board, and there is a gradation of particle size ranging from the finest on the faces to the coarsest in the core. In boards of layered construction, the face layer thicknesses are usually kept constant and material is added or subtracted from the core to change board thickness.

All composition boards, if manufactured properly, are quite stable and resistant to warp. Those with fine particles on the faces have smooth surfaces which



Figure 3.1. A graduated particleboard mat with fine face particles and coarse core particles (Haigh 1967).

can be treated with standard finishes quite easily. Some of the finishing problems will be discussed later. This type of board is also an excellent substrate for overlaying with thin veneers or plastics.

It should be noted that, either by accident or by design, some boards are made with a two-layer construction. A case in point with dry-process hardboard is a siding product that has very fine fiber on the face that will be exposed to the weather, with coarser fiber making up the rest of the board. Such an unbalanced construction can provide a situation in which the board will tend to warp. Some processes have been refined so that the warp does not occur. In some of the older particleboard plants, two-layer construction occurred by accident because of equipment limitations. Some warp could be expected in these boards. However, by recognizing this fact, plants using the board in secondary manufacture for furniture developed design systems which minimized the warping in the final product.

As mentioned, some boards are made with a homogeneous construction, which means all particles are randomized throughout the board. However, the type of layering by density, mentioned previously as being less obvious than particle layering, also occurs in these types of board. Hot pressing, which will be discussed in detail later, develops a density layering throughout the thickness of the board, commonly called the *density profile*. As an illustration, the most common method of hot pressing $\frac{3}{4}$ -in. (19 mm) board in the particleboard industry is to consolidate the mats in the press to final thickness in about one to two minutes. This yields a board with high-density faces and a low-density core. This method will be covered later under "hot pressing," but, in brief, the mat faces are consolidated first and the resin cured before the mat core is consolidated to final thickness, resulting in the density profile described.

The distribution of the moisture throughout the mat also affects the density profile. It is not uncommon to add more moisture to the faces to assist with the speed of heat penetration to the board core, which shortens the press time. However, this moisture in the faces, which turns to steam, plasticizes the face particles and enhances the densification of the board faces. In boards with the finer particles in the surface layers, more resin is required because of the greater specific surface area of these finer particles. This additional resin usually means a higher moisture content in the faces, which further helps with the face densification. It should be noted that it is also easier to consolidate these finer surface particles because they flow together easier than the coarser core particles. With such an environment, fast closing times in the press tend to accentuate the density profile. On the other hand, slower press closing times result in a decrease in face density and an increase in core. However, this is usually an undesirable situation in that the surface integrity and quality are diminished, which can result in boards with soft surfaces unsuitable for use.

It should go without saying that different densities of board will have different density profiles at different thicknesses and with different press closing times.

In general, the properties of dry-process board are dependent upon the specific gravity of the board in much the same way as properties of solid wood are related to the wood specific gravity. However, it must be remembered that high-strength board cannot be made out of a wood species that is approximately the same in

specific gravity as that desired in the final board. An example would be trying to make medium-density particleboard at specific gravity of 0.64 out of white oak, which has a specific gravity at approximately this level. The pressing operation consolidating the particleboard and curing the resin is the same general type of function as gluing two pieces of wood together with a clamp. In normal gluing, a pressure of about 150 psi (1.0 MPa) is necessary for a good glue joint to be formed. The same type of pressure needs to be applied in the board-pressing process for obtaining good wood-resin-wood bonds throughout the final product. Using a relatively high-density wood for making medium-density particleboard would require very little pressure for consolidation into the final board. Thus, the surface of the adjacent wood particles would not come in intimate contact and poor glue bonds would occur. Consequently, for the dry process, the species going into a given specific gravity board must be lower in specific gravity, except for low-density boards which usually have low physical properties.

For hardboard, those boards made with fiber refined at atmospheric pressure must also be significantly higher in specific gravity as compared to the wood species used for generating the furnish. With the relatively new pressure-refined fiber, however, it is possible to produce medium-density boards using fiber from species having specific gravities much closer to that of the final board. This is a significant breakthrough, as species previously difficult to use for board products, because of their greater density, can now be used.

The fine pressure-refined fiber presents an anomaly when considering the specific surface area of the fibers, which is much greater than that of a comparable shavings- or flake-type material. It would be expected that the pressure-refined fiber would require several times as much resin as the larger particles, given the same composition board density. Surprisingly, this is not true, and the pressure-refined fiber requires about the same level of resin as the larger particles on a weight basis. This is an unexpected development, but one that has assisted in the rapid growth of the medium-density fiberboard industry.

Moisture content is a significant factor, in addition to the aforementioned distribution throughout the mat during pressing. Most composition board mats enter the press somewhere between 7 and 11% in moisture content. This level can be somewhat higher, ranging up to about 16%, particularly in some plants outside the United States. Unless special provisions are taken, moisture content of the mats cannot be higher than about 11%. Otherwise, the board will tend to blow, blister, or delaminate as it comes out of the hot press. Much of the moisture in the mat turns to steam during the pressing operation. This steam develops a significant vapor pressure within the board. Consequently, much of the vapor must be vented before the press is opened; otherwise the aforementioned destruction of the board will take place. In addition higher amounts of moisture will prevent the proper curing of the resin, which will also contribute to the blowing, blistering, and delamination problems.

The Different Process Lines

Before getting into a detailed discussion of the platen-press system, it seems proper to first provide an overview of the process. Afterwards, each step will be

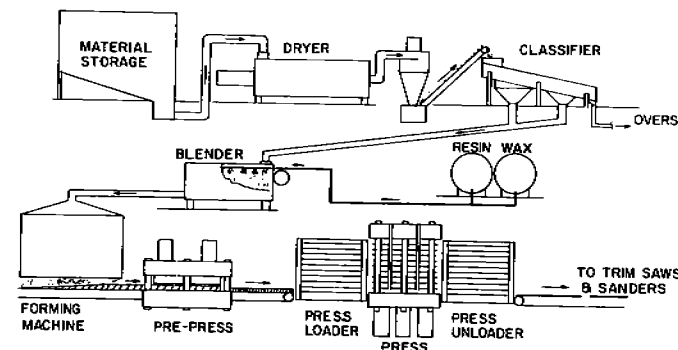


Figure 3.2. Diagram of a typical composition board plant. (Courtesy Washington State Univ.)

discussed in more detail as it relates to the fiber, particle, and the combination of particle and fiber types of board plants. Figure 3.2 is a drawing showing the general layout for a platen-pressed board plant. Not all of these pieces of equipment will be necessary in each plant because of the types of products being manufactured and the raw material being handled.

All-Fiber Production Lines: There are two general types of all-fiber production lines. The first produces relatively high-density hardboard products ranging in specific gravity from about 0.75 to above 1.0. These are the plants producing relatively thin board, which first came into operation in the late 1940s. The medium-density fiberboard lines are the newest member of the all-fiberboard process. Specific gravity of this product is normally in the range of about 0.72 to 0.93. It has particularly good properties for furniture, as the fiber provides boards with better bending strength and stiffness than can be achieved with shavings-type boards, while at the same time yielding boards with what is known as *tight edges*. The relatively fine fibers, when consolidated into the final board, provide board edges with little or no porosity as compared to shavings-type boards.

In the furniture industry, a medium-density particleboard usually will have to be edge banded with wood or a plastic material for many applications, particularly when the edges are to be profiled. The medium-density fiberboard, on the other hand, can be profiled and finished directly, eliminating the need for edge banding. Another advantage it has over some conventional particleboard is less tendency for developing "telegraph" or showthrough. In veneer or plastic overlaid particleboard, changes in moisture content can cause the outline of the thicker surface particles, and sometimes even the core particles, to show through the face of the thin overlay. This showthrough is caused by differential swelling and shrinking of the larger particles. Much of the telegraphing problem has been overcome in the particleboard industry by the use of finer particles throughout the board and only very fine particles on the faces. However, medium-density fiberboard is in an advantageous position because no large particles are in the board at all.

Particle and Flake Production Lines: In the United States and Canada, some of the plants producing what is known commonly as particleboard use an all-granular-type furnish such as planer shavings. The products produced go heavily into furniture applications, floor underlayment, and mobile home decking. Other plants are using a combination of ring-cut flakes, plus the small particulate material available from planer shavings and sawdust. The products go into the same market as the all-shavings-type boards. Another type of board is being made with all flakes and goes into the same market. Either ring or drum flakers are being used for generating the flake furnish from some type of solid wood material. This type of system is most applicable in those areas with green roundwood available, such as aspen, but other species are also used.

Another type of board product is the one made of all flakes for structural and decorative uses. These boards are made of relatively large flakes cut with huge disc flakers, although drum flakers are also used. This product, known as wafer-board, is being used heavily for construction purposes in Canada at the present time, as stated previously.

Production Lines Using a Combination of Fiber, Flakes, and Granular Particles: The ideal composition board plant would appear to be one which could handle virtually any type of residual material, plus solid wood, which is available for board production. In this way, advantage could be taken of the particular characteristics of the raw material. Also it would give the plant the option of adjusting its process line to make the optimum products out of the raw material available.

Such a plant would include providing individual storage areas for each type of raw material according to geometry, species, and moisture content. It would include a variety of particle-generating equipment ranging from hammermills through flakers and atmospheric and pressurized refiners. It would also call for sophistication in the separation of particles so that the proper sizes with the right geometries could be used efficiently in the final board. Such a plant does exist at Dillard, Oregon. The Roseburg Lumber Company has built its Resin-Tite Fiberflake plant to operate on a wide variety of raw materials. It has two production lines—an older one producing approximately 700 tons (635 mt) of board per day, and a new one producing approximately 1300 tons (1179 mt) of board per day, depending on the board density and thickness. The old line is a caul system, and the new one is a caulless system, with a 20-opening hot press capable of producing 8x25-ft (2.44x7.62 m) boards. It is the "Cadillac" plant of the industry and is taking advantage of different ways in which particles, shavings, flakes, and fiber can be melded together to make superior board products.

Roseburg is using combinations of planer shavings, ring-cut flakes, and pressure-refined fiber in its production. The pressure-refined fiber is being produced from plywood panel edge and end trim, which has been a difficult material to use in particleboard. With the combination of particles going into this particular board, it can easily be seen that this is a hybrid type of composition board plant. It is using both hardboard and particleboard techniques. It is demonstrating the rational approach of using technical knowledge advantageously to produce a good product without being concerned particularly with the exact name of the resulting manufactured panel, but rather with its end-use characteristics and properties.

The board is being sold as a particleboard. However, this plant can also produce products made completely of pressure-refined fiber.

The Process in General

At first, the raw material is brought to the board plant and placed in some type of storage area. If it is relatively small particulate matter that can be used directly in the board process, some type of classification by size may be performed immediately and the material fed into the plant. Larger material must be reduced to flakes, particles, or fiber using the proper equipment, depending on the type of product being produced.

It has been pointed out that particle geometry is the most significant factor involved in most composition boards, as far as final physical properties are concerned. It is of particular importance in the conventional particleboard product. Some plants, because of the wood species of the planer shavings being used, find it difficult to obtain fibers or long, thin particles for use as face material. Chunky material does not have the right slenderness ratio (length/thickness) for use on the faces of particleboard. The chunky material, however, does work well in the core of a board, as there is good interparticle contact resulting in efficient applied resin use. This helps develop relatively good internal bond properties.

The furnish, or in other words the particles used for board manufacture, is handled as a single entity to a homogeneous board processing line. For layered boards, the furnish can be handled as a single entity until mat forming, where it is separated into coarse- and fine-fraction sizes. However, it is usually simpler to handle the face and core material separately throughout the process.

After the particles are prepared, the next general step is to reduce to 2 to 4% moisture content in a dryer. Plants operating with residual material generated from kiln-dried lumber and using powdered phenolic resin may be able to operate without a dryer, as the moisture content is low enough in the material as received.

Out of the dryer, the furnish may be classified into predetermined sizes as required for the production process. It is usually much easier to classify material after drying, particularly if the original raw material is green or wet. In the wet condition, the finer particles tend to cling to the larger ones and efficient classification is not obtained.

The furnish then proceeds to a blender, of which there are many versions. In the blender, resin and wax are applied to the furnish. Additional moisture can also be added if it is needed, as well as a catalyst if required. In some dry-process hardboard plants using liquid phenolic resin, the resin and wax can be added to the raw material before drying. The resin and wax are blended simultaneously with the furnish as it is being generated in the attrition mill. Thus, the attrition mill functions as both a particle generator and a blender. The phenolic resin has a higher curing temperature than the urea resin and can therefore pass through the dryer without being cured. The urea resin cannot be handled in this way, as it will cure out in the dryer. When drying this resin-treated furnish, it is not necessary to go to the very low moisture content of 2 to 4%. The final mat moisture content, ranging from about 8 to 11%, then becomes the specification for the material emerging from the dryer.

After blending, the furnish moves to the forming station, where it is laid down into mats. A number of different systems are used for performing this operation. Another term used besides forming is *felting*, which is a carryover from paper industry terminology. Depending on the board specifications of thickness, type of particle, and specific gravity, the mat thickness can range from less than 1 in. to over 12 in. (25.4 mm–305 mm).

Depending on the process, the formed mat can be partially consolidated to final thickness in a prepress. This is particularly important if the mat is very thick, as the thickness must be decreased sufficiently for it to fit into the hot press. As will be discussed shortly, the prepress is a necessary part of all but one type of caulless process line.

Multi-opening, single-opening, continuous, or stack presses can be used to produce a platen-pressed board. In the multi-opening system, the proper number of mats is accumulated in the press loader and then all are inserted simultaneously into the hot press for consolidation under heat and pressure into the final boards. In general terms, a $\frac{3}{4}$ -in.-thick (19 mm) particleboard made with urea resin can be pressed in four to six minutes at temperatures ranging from 300° to 375°F (149–191°C). Boards produced with phenolic resin require slightly longer press times and higher press temperatures. Various kinds of catalyst systems can be used to speed up these press times. With single-opening presses, a heavily catalyzed resin system is used to speed up the press time because of the limitation of only one board being pressed at a time. It has been reported that press times of less than two minutes have been achieved, producing $\frac{3}{8}$ -in.-thick (15.9 mm) board on a single-opening press line. Naturally, thinner boards require less time and thicker boards more time in the press.

After the boards are pressed, they are removed by some type of unloading system and usually advanced through a cooler before being stacked. This cooler is important, particularly in lines using urea-formaldehyde resins, as the board temperature must be reduced before the board is stacked into a pile. The resin bonds of urea-bonded boards that are stacked without adequate cooling will deteriorate. In some cases, water absorption properties affected by the wax additive are enhanced by hot stacking. Phenolic boards can normally be improved in properties if they are hot stacked after pressing, but they are not always so stacked because of process line arrangements.

After either cooling or hot stacking, the boards are edge trimmed and moved through the sanding system. Some hardboards, as well as sheathing-type panels made of flakes, are not sanded, but in general most of the composition board products are sanded to dimension the boards to final thickness and to remove any surface imperfections before final processing. Layered boards with fine particles on the surfaces tend to have soft faces caused by resin precure about 0.020 in. (0.51 mm) thick, which need to be sanded off.

Many boards are shipped to market in a standard 4x8-ft (1.22x2.44 m) size. However, it is becoming more and more the practice to cut the final board to some predetermined size as specified by the customer. Hardboard lap siding is cut into the 4- to 12-in. (102–366 mm) specified widths. Particleboard, hardboard, and medium-density fiberboard are cut into a multitude of different sizes, depending upon the customers' needs. One of the more complicated parts of the plant process

line is the cut-to-size operation which can be processing hundreds of different sizes during one operating shift. Some plants have gone to computers for programming the most efficient cutup of the boards into the final products. The cutup saws are very sophisticated, and some are controlled by punched cards or tapes. A number of plants also have finishing lines for applying filler, wet finishes, and overlays.

Process Details

Particle Preparation: First, the raw material must be assembled. It will usually come into a plant by truck or rail from other wood products plants in the form of residue such as planer shavings, pulp chips, plywood trim, sawdust, and in some cases solid or roundwood. Roundwood is especially harvested for board plants in some cases. This is very popular in countries other than the United States. Planer shavings are the dominant raw material used in the United States because of their low cost and availability. If a sawmill happens to be located nearby, the planer shavings and sawdust can be air-conveyed to the board plant, which provides an even lower cost raw material because of minimal transportation costs.

If at all possible, as the raw material comes in, the plants will attempt to segregate it by type of material, moisture content, and species. As will be developed later, all of these factors play important parts in board production. The finer types of raw materials are stored in huge buildings and protected from the elements. Large silos can also be used for storage. At one time, much of this type of raw material was stored outdoors. However, recently promulgated Environmental Protection Agency regulations have made it mandatory almost everywhere to store small particulate material indoors. This is to prevent the wind from blowing the small particles onto adjacent property. Larger materials such as logs, slabs, and pulp chips can be stored outdoors.

Particulate-type raw material can be conveyed into the board plant by means of screw augers operating from the bottom of a silo, belts, or flight conveyors. Material from a number of such silos can be mixed together to randomize species and material type variations. A particularly popular technique for handling this type of raw material is to use front-end loaders (as shown in Figure 3.3) for feeding the material into the plant. The raw material can be blended together much in the way one would prepare a large batch of food. The loader, for example might be used to intermix several different species. One scoop of Douglas fir shavings, one scoop of hemlock shavings, and one scoop of white fir shavings could be dumped into the hopper leading to the raw material conveyor. These scoop loads can also serve to mix materials of various moisture contents. This is a rather crude but effective means of controlling the raw material input. A more sophisticated procedure is to use constant-weight feeders.

Usually, some type of milling is required. For those plants using fiber, the raw material will be reduced by means of either atmospheric attrition mills or pressurized refiners. Green material such as chips, shavings, and sawdust can be milled into an acceptable fiber under atmospheric conditions, after first steaming the raw material. In at least one plant, however, green raw material is ground into fiber without steaming.



Figure 3.3. A typical front-end loader. (Courtesy Washington State Univ.)

For grinding under atmospheric conditions, both single- and double-revolving-disc types of mills are used. The previously mentioned steaming softens the lignin which is nature's glue holding the fibers together. Consequently, with presteaming a better fiber can be produced than with unsteamed raw material. This technique is well developed and used in many plants. If a very dry raw material is used, it is best to add moisture first to assist in the grinding of the fiber. The addition of water works best with small material such as shavings, as the water can easily penetrate into the particles. There is not sufficient time in a process line to allow water to penetrate into large particles such as chips.

The better-quality fiber is normally made from pulp chips. It is simply a case in which relatively long fibers can be generated out of this type of residual. It can easily be seen that long fibers cannot be generated out of very small particles such as dry planer shavings and sawdust. However, while some plants are still operating on chips, they have found it advantageous from the economic standpoint to substitute the lower-quality raw material, which is usually planer shavings and sawdust, for some of the pulp chips. This is a case of maximizing overall profits, although some of the fiber quality is sacrificed. Changes in the rest of the process line can be implemented to overcome some of the problems encountered with shorter-length fiber. This is particularly true in the case of high-density hardboard, where full use of the synthetic resins added as binder can be achieved.

Atmospheric attrition mills refine raw material into fiber under ambient conditions, whereas the pressurized refiners do so under steam pressure. The pressurized refiner is of particular value in producing good fiber out of dry raw material such as plywood trim or furniture waste. This material, of course, is first chipped or hogged into small pieces for feeding into the refiner.

The pressurized refiners operate in the same way as the atmospheric attrition mills do with one notable exception. Unlike grinding with the atmospheric attrition mill, the raw material passes from the steam-pressurized digester into the refining section while still under pressure, and the refining takes place under this same pressure. This particular type of system has been used in the board industry for only a few years. Much of the science or art of grinding this type of fiber is yet to be understood. However, the fiber is much finer and has different characteristics than that usually ground in the atmospheric attrition mill. The wood is broken down closer to individual fibers in the pressurized refiner than is possible under normal atmospheric attrition mill operating conditions, although fiber of similar bulk density can be generated in either mill. The material ground will tend to be bundles of several wood fibers rather than individual fibers.

Most of the newer plants producing fiber-type products use a pressurized refiner, and a number of the older ones have converted from atmospheric to the pressurized type. Using the pressurized refiner, as mentioned, is a particular advantage when utilizing residues of low quality. Specifically, these are dry hardwood residuals from furniture plants, low-quality hardwoods, and dry plywood trim. Just a few years ago, it was difficult to use any of these raw materials successfully in a board plant. Therefore, a great benefit of the pressure-refiner has been the generation of good fiber out of previously unusable or difficult-to-use raw material.

There are inherent variables operating in both of these refining systems that can cause a wide variation in the quality of the fiber generated. Besides moisture content of the raw material and variations in the steaming conditions, the variations in the raw material such as particle size and species, the variables inherent in the grinding process such as steaming time and pressure, disc diameter, plate pattern, loading rate, and the gap setting between the grinding plates can all influence the type and quality of fiber which can be generated.

As noted, most of the standard particleboard in the United States is produced using planer shavings as the basic raw material. While shavings are the dominant raw material, other residuals are included for use in the furnish in most plants. This is done to improve certain board properties and, in some cases, because of an inadequate supply of shavings. These other residues include solid wood materials such as planer trim ends, low-grade lumber, sawdust, and plywood trim. The solid wood material can be reduced by means of hogs or chippers into large chiplike material. The final breakdown into the desired particles can be achieved by using hammermills, ring refiners, ring flakers, or disc refiners or attrition mills. Some plants have combinations of these various machines.

For conventional particleboard, it is also sometimes necessary to reduce part of the granular material into fine fibrous material for use as part of the face furnish. To some extent, this depends upon the species being used. Some species normally will break up into very fine particles while being planed, and this will provide sufficient small material for the board surfaces. On the other hand, some species will tend to come off the planer as relatively large particles, and if fine material is required for the faces, part of these larger particles will have to be reduced into small ones. Ring refiners, hammermills, disc refiners, or attrition mills can be used for this type of milling operation. If at all possible, a fine fibrous-type material is

generated because this provides a better particle for developing bending strength and stiffness while maintaining smooth faces on the boards.

If flake-type material is desired, several options are available. For producing higher-quality flakes, it is necessary to first start with green material either in slab or log form. This material can be chipped and then ring-flaked for the production of a quality flake. A very popular piece of equipment for the production of large flakes in North America, for use in structural flakeboard plants, is the disc flaker which has a flaking disc 93 in. (2.36 m) in diameter. Stock is fed edgewise against the disc, and the knives mounted in the disc slice off flakes to predetermined sizes.

Different types of drum flakers are available for reducing wood stock into flakes. One type takes roundwood, slabs, or rough lumber that is cut into predetermined lengths before it can be fed into the flaker. Another type takes random-length pieces of wood stock and reduces them to flakes. This flaker is widely used throughout the world but has only found minimal use on the North American continent to date, although it is an excellent machine. It is particularly appropriate for cutting flakes from small roundwood such as forest thinnings.

Drying: Several different types of dryers are available. These include single- and multiple-pass rotary-drum, stationary-drum and tube-flash dryers. Most of them are direct-fired and operate at very high temperatures using natural gas, propane, or oil for the fuel, although more sander dust is now being used to reduce fuel costs. These dryers can have very large combustion units where the heat is developed by open flames. It is possible to generate temperatures up to about 1600°F (871°C). When dryers of this type are used, it is imperative that the small particulate material pass rapidly through the dryer. If there is any hangup of material within the dryer, it will almost immediately catch fire and cause serious problems. Dryers are one of the more hazardous pieces of equipment in a plant because of the fire and explosion danger.

When there is a wide mixture of raw material as far as moisture content is concerned, it is advisable to treat the wet material separately from the dry. Normally the dryer handling the wet material will run at a higher temperature for fast removal of moisture. If a fairly dry material enters one of these dryers, it will almost immediately catch fire because the throughput rate is relatively slow for handling the wet material. Material such as planer shavings from kiln-dried lumber and plywood trim will be relatively low in moisture content as it enters the dryer. Most kiln-dried lumber is about 15% in moisture content; therefore, it only has to be dried very briefly to bring it down to the nominal 2 to 4% moisture content desired. Dryers handling the lower-moisture-content material will usually function at lower temperatures and higher throughput rates than those handling green material.

Particle Classification: Most classification is performed after drying, because wet or green particles tend to stick together. For particleboard, variations of screens and air-classifiers can be used to make the particle separation. The same type of separation can be made with flakes after they are cut. However, in many applications the cut flakes are treated as a single material for making homogeneous boards, and only very large and very fine material may be removed.

For hardboard and fiberboard, air-classifying of fiber to obtain fine material for faces can be used, but it is more common to prepare face and core material

separately if layered board is to be made. Classifying of blended furnish at the mat former can also be done to select the finer fibers for faces. This is true for both the fiberboard and particleboard type of operations.

Blending: The next step is blending resin and wax with the furnish. If the board is to be homogeneous, all the material will pass through the same blender or set of blenders which function identically. In the case of multi-layer boards, separate surface and core blenders are generally used. This allows control of the amount of resin applied to each. Normally more resin is applied to the surface furnish than to the core furnish because of the higher specific area of the face particles, compared with the core particles. It is possible to apply resin to the face and core material simultaneously, but this type of blending is not as widely used as it once was. Catalysts can be added with the resin or immediately after blending. The wax, usually in the form of an emulsion, is also added at this time, either separately or mixed with the resin. Other specialized additives, such as fire retardants, need separate provisions for their addition. They may be added in the resin-wood blender or elsewhere in the process line.

Most resins are a liquid, but some plants use a powdered phenolic resin, and it is reported that at least one plant is now using a powdered urea resin instead, because of its lower cost. One way to apply the powdered resin is by tumbling the particles in a rotary drum with the powdered resin. In this type of operation, the molten wax or wax emulsion is applied ahead of time so that the powdered resin can adhere to the small, sticky drops of wax. Another method being used is to apply the powdered resin to the furnish as it is being reduced in size in an attrition mill. Thus, the attrition mill is simultaneously grinding the particles and blending the powdered resin, in much the same way as in the dry-process hardboard lines, where liquid phenolic is blended with the fiber in the attrition mill. A particular advantage in using powdered resin is that the moisture content of the furnish does not have to be lowered to the nominal 2 to 4% level. This has a twofold advantage: one of reducing the need for drying, and the other of reducing the fire and explosion hazard in the dryer.

Blenders applying liquid resin can be classified into two general types. One is the long-retention-time type which slowly blends the furnish with the additives, taking several minutes for completion. The second is the short-retention-time type which completes a blending in a matter of seconds. Both types have been used in the United States since the inception of the dry-process industry. Long-retention-time blenders gained the most popularity through the mid-1960s, but most plants now favor the short-retention-time type.

The additives are sprayed upon the churning or cascading furnish through air or airless atomizing nozzles, or they are applied by the use of centrifugal resin applicators. The intention is to get a fine dispersion of the resin over all of the furnish. A number of different approaches have been taken for applying the resin and wax to the furnish.

It was mentioned previously that, for hardboard fiber blending, liquid phenolic resin and wax can be added in the attrition mill simultaneously with the grinding of the fiber. It was also noted that ureas or melamines cannot be added as subsequent drying would cure the resin. Thus, such blending cannot be used in medium-density fiberboard plants. A partial exception is a process where part of the resin

system is added in the attrition mill and the remainder after drying by means of a short-retention-time blender. The resin is then formed *in-situ* during hot pressing.

An early plant used specially developed urea-melamine concentrate for the binder system. This particular resin system has little to no tack. Tack simply is stickiness. A tack-free resin is a prime requirement for use in the fiber process because the slightest amount of tack will cause the fibers to adhere to one another, forming balls and causing many problems in handling and forming. Excess resin tends to accumulate on these fiber balls, resulting in undesirable "resin spots" on the surfaces of the pressed board. Such resin spots cause problems with appearance and with the adhesion of finishes and adhesives for applying overlays. The urea-melamine concentrate developed for this system has worked very successfully. However, competitive systems have been developed and are in successful use. It should be pointed out that all tack in the resin applied during the attrition milling of the fiber, such as in the hardboard production, is lost during the drying operation.

Short-retention-time blenders such as attrition mills and high-speed paddle types have been used successfully for applying urea resins to fiber.

Forming: In the next step, the blended furnish moves to the mat former, of which there are many different designs. Mat forming is extremely important as a misformed mat will yield a board with widely varying properties because of differential specific gravity throughout the board. A homogeneous board naturally is laid down with a random mix of the furnish. Multi-layer or graduated mats are laid down using appropriate equipment for keeping the particle sizes separate.

Particleboard formers meter the furnish by means of spreader rolls, belts, air, or combinations of these upon a caul plate, plastic sheet, or fabric belt. Fiber is usually formed onto a fine-mesh wire screen. It is handled by air or is forced through a screen to separate the fibers before they fall upon the screen. When forming fiber, a vacuum is pulled down through the fiber being formed. This vacuum compresses the fiber mat, and such compression is necessary because the bulky fiber yields a mat very thick in comparison to those found in the particulate and flake-type mats. Very thick mats cannot be inserted into the "daylight" of the hot press. As will be mentioned, prepressing is also necessary for further consolidation of the very fibrous mat.

Prepressing: The mats then move down the line, where in some cases they are prepressed. Prepressing consolidates a loosely formed mat into a relatively rigid "cake" which has a certain degree of cohesiveness. The mat is also reduced in thickness so that a press with minimum space (daylight) between the platens can be utilized. Prepressing can be accomplished by using either a platen, caterpillar tread, or belt prepress. Prepressing is not always necessary, particularly when using a caul system, but it is a must with all but one of the caulless systems. With low-bulk-density, pressure-refined fiber, it is usually necessary to reduce the mat thickness in order that the mat will fit into the press. Normally, a belt prepress is used with this system.

Pressing: After prepressing, the mats are then rough trimmed to length and, in most cases, width. The trimmed mats proceed to the hot press, which can be either a multi-opening, single-opening, stack, or continuous type. The mats can be carried on metal cauls, wire-screen belts, steel belts, or, for the caulless system,

on plastic sheets or fabric belts.

The caul is a metal plate of steel or aluminum used as a support tray on which the mat is formed and conveyed. Special wire mesh can also serve as a caul. This support tray carries the mat through the prepress, if it is used, and on into the hot press. It stays beneath the mat until it is finally hot pressed into a board and is removed after pressing is completed. Cauls were used for all of the early plants in the United States, and it was not until the mid-1960s that the caulless lines became popular. Cauls are normally used with multi-opening and stack presses.

The caulless system uses multi-opening presses. Although a small single opening press could also use the caulless system, its small size would not make the process economic. Briefly, with the caulless system, a forming sheet, which can either be a rigid or flexible material, is used for receiving the furnish dropped from the former. This forming sheet transports the formed mat into the prepress for consolidation. For successful prepressing, the resin used in the furnish must have a certain amount of tack which assists in holding the partially consolidated mat together. In addition, particles with high slenderness ratios (length/thickness) are of value in providing some of the mat integrity. The desired particle geometry of fiber provides sufficient mat integrity for operation in the caulless system.

After prepressing, in the most popular U.S. caulless system, the mat is removed from the forming sheet or belt on which it was formed and is transported into the press loader. When the press opens and the previously pressed boards are ejected, the press loader travels forward into the hot press carrying the prepressed mats. The loader goes to the far end of the hot press and then is slowly withdrawn. As it is withdrawn, the mats are carefully deposited directly onto the hot press platens or plates. As soon as the press loader finishes its operation, the press is closed and the mats are consolidated into the final boards. Other systems use different techniques to deposit the mat upon the press platens.

The press loaders are elevator structures that move up and down, receiving each new mat as it arrives. The process line is timed so that the press loader is ready with a full load of mats when the press is opened and the previous set of pressed boards is ejected. Once the newly pressed boards are removed from the hot press, the freshly formed mats are inserted; and the hot press consolidates them under heat and pressure into boards.

The boards are unloaded into an elevator structure, similar to the press loader, after pressing is completed. If the plant is using metal cauls for handling the mats and pressing the boards, the finished boards are then separated from the caul plates and usually advanced to a board cooler. The caul plates are then returned to the forming station where a new mat is laid down.

Single-opening presses function with either a steel belt or wire screen that carries the formed mat into the press. While the board is being pressed, another mat is being formed either by a traveling former, which moves back and forth over a stationary section of the belt or wire screen at the front of the press, or by a stationary continuous former which deposits the mat onto a moving belt conveyor. In the case of the continuous former, a speed-up conveyor is used to accelerate the finished mat forward, where it is then transferred to the metal belt carrying the mats into the press.

Most multi-opening presses employ simultaneous closing which permits faster

press closing without blowing off the mat surfaces. The same density profile is developed in all boards because all boards are pressed alike.

At the completion of the press cycle, the press opens; the belt travels forward, carrying the finished board out and the freshly formed mat into the press. The single-opening presses are usually rather large, ranging up to 8 ft wide by 65 ft long (2.44x19.81 m). Even larger ones are possible. As in the case of the multi-opening press, the finished board usually passes to a board cooler for a short period of time so that board temperature can be reduced before stacking or further processing.

The final board thickness is controlled in the press by pressing to gauge bars or "stops," which are set between or outside the press platens, or by electrical means which hold the press platens at the proper spacing by what is known as *position control*.

With continuous presses, the formed mat is constantly being carried into and through the hot press. This is a platen-pressed type of board and should not be considered as extruded. Continuous pressing was a viable part of the industry in the 1950s. It then fell into disfavor for a number of years. However, it has recently made a comeback, particularly for pressing thin boards which can be classed either as hardboard or particleboard depending on the final board properties.

Another type of pressing is the stack press, which is not widely used. It will be discussed later, but basically it produces a platen-pressed board.

An exception to the pressing methods discussed previously occurs in the semi-dry hardboard plants. Mats are formed at moisture contents of about 25 to 30% (oven-dry basis). Screens similar to those used in the wet-process line are used to transport the mats. During hot pressing, these screens allow rapid venting of the moisture from the mat. The bottom surface of the pressed board has a screen impression, termed *screen-back*, like that found on wet-process hardboards. Only relatively thin boards can be made with this type of pressing.

Finishing: As mentioned, boards are usually cooled immediately out of the press or, at times, hot stacked. Skinner saws are used to trim the panels to final dimensions. Trimmed material can be recycled to the particle generation area or used as fuel. Huge belt sanders, which may have as many as eight heads (four above and four below) and are 8 ft (2.44 m) wide, dimension the board to final thickness. The sander smooths the surfaces and removes any soft material (pre-cure) from the faces as well as surface blemishes caused by scratches or other blemishes on the caul plates or press platens. An exception to sanding may be found with products such as waferboard where surface smoothness is not a primary requisite or with hardboard products that have tight, hard surfaces created during the hot-pressing operation.

Heating mediums used in press platens include steam (the most popular in the USA), hot oil, or hot water. A combination of one of these plus radio frequency (RF) is being successfully used, primarily for pressing medium-density fiberboard.

After sanding, the panels are graded. They can then be shipped or cut to smaller sizes. Complicated loading procedures are required when shipping the cut-to-size pieces because of the many different sizes. As previously mentioned, some plants also prefinish panels with fillers, wet finishes, wood and plastic overlays, edge bands, and edge machining before shipping.

Post Treating: Several different post treatments can be performed. Boards can be impregnated with preservatives and fire retardants. Hardboard can be heat treated or oil tempered to improve properties, particularly those associated with dimensional stability and water absorption.

EXTRUDED PARTICLEBOARD

Kreibaum

It has been noted that the most popular method of producing particleboard is through the mat-formed system where the mats are compressed into the final board, usually by means of a platen press. Those boards being produced by continuous methods result in a board similar in properties to those manufactured by the platen press. Another method of producing particleboard is by means of the extruded pressing system. The first system was developed by Otto Kreibaum in the years 1947 to 1949 in his factory at Lauenstein, Federal Republic of Germany, and is called the Okal method. A few plants have been built in the United States to produce extruded particleboard either through this system or with similar ones developed by United States firms. However, since the first few plants were built approximately 20 to 25 years ago, no new ones of this type have been constructed. A new and different type will be mentioned later. Those in operation in the United States are captive plants which produce board used in another part of their business. These particular boards cannot meet the standards established for the platen-pressed particleboard. They must be overlaid with some other material such as thin particleboard, veneer, or a paper or plastic laminate.

The preparation of the furnish for this system is not much different from that used for the mat-formed process. The raw material must be first reduced to a small size similar to planer shavings. Many different species have been tried successfully in this process, as well as different forms of raw materials such as round wood, wood with bark, forest thinnings and twigs, standard waste from sawmills, and plywood plants, and agricultural residues.

The raw material is dried to somewhere between 4 and 6% in moisture content. Resin is then added in a blender at levels of 4 to 6%, based on the oven-dry weight of the wood. The quantity of resin, as in the mat-formed process, depends upon the desired properties of the final board. Most boards of this type are made with urea resin.

A former as used in the mat-formed process is not necessary. The blended particles are brought directly to the aperture of the extrusion press. This press is a heated die that is either vertically or horizontally oriented. The particles are spread out over the cross section of the heated die, and a reciprocating hydraulic ram then forces the particles through this die. The width of the die establishes the width of the board, and the distance between the die surfaces establishes the board thickness. This is a continuous process and is illustrated in Figure 3.4.

With a vertical die, an even feed of the particles into the die can easily be achieved. Also, a separation of the fine particles from the larger particles, which tends to happen when the die is oriented horizontally, is prevented. After each stroke of the hydraulic ram, more material is fed to the die and forced through by

extruded
particleboard
1977

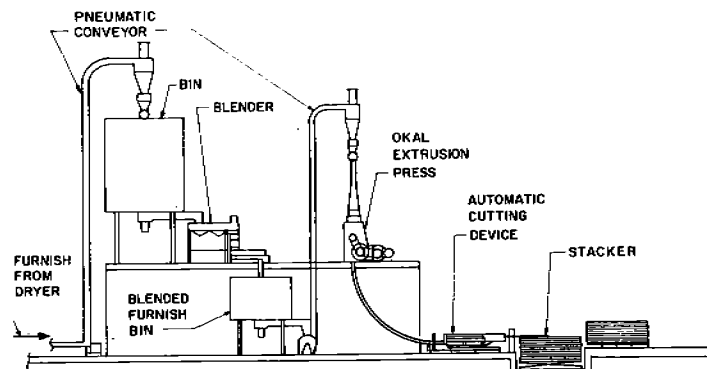


Figure 3.4. Schematic outline for the preparation of extruded particleboard by the Kreibaum method (Kreibaum 1957).

the next stroke of the ram. In this way, a continuous board is produced. A schematic drawing of this press is shown in Figure 3.5.

Normally, the board is in the hot die for only about 30 seconds and then it runs through a heating zone for another 40 to 60 seconds, depending upon the thickness of the board, for final resin curing. The density of the board depends upon the quantity of the particles being loaded into the press and the thickness is established by the cross section of the die. For producing thicker boards, tubular channels are inserted into the middle of the die. This can only be done with a vertical die. These channels are also heated and serve to heat the board being pressed from the inside. Such inner heating along with the heat from the hot die speeds the cure of the thicker boards. The final board thus contains tubular openings, which reduce the overall weight of the thicker boards. This type of thick board is used for the production of wall panels. It is possible to use these openings for installing the electrical wiring in a building. As the thinner boards leave the vertical press, they are brought to a cut-off saw by means of a gentle slope as shown in Figure 3.6. The cutoff saw then cuts the continuous panel to the desired lengths. The thicker boards cannot be bent in this way and are brought to a saw in the vertical direction.

The properties of these extruded particleboards are quite different from those manufactured by the platen system. In a platen system, the particles tend to be randomly oriented in a plane parallel to the surfaces of the board; thus, good bending strengths and stiffness are developed, taking advantage of the fiber length in the particle. In the extrusion system, the particles, as they are fed into the extruder, also lie flat. However, as can be visualized, they are randomly oriented in a plane perpendicular to the board surfaces. Thus, the extruded board has very low bending strength and stiffness as these properties depend on resin bonding between particles only. Fiber length in the particles is oriented in the wrong direction for developing good bending and stiffness properties. These boards have

very little thickness swelling in moist conditions because of the orientation of these particles, since wood expands very little along the grain. Conversely, the linear expansion can be quite severe because what is thickness swell in platen-pressed board or solid wood becomes linear expansion in the extruded board.

To develop adequate bending strength and stiffness and to restrain the extreme linear expansion, extruded boards must be overlaid with some type of thin particleboard, veneer, or plastic laminate. Figure 3.7 shows a sample of this overlaid extruded board that was accidentally wetted. As can be seen, the high linear expansion of the extruded board core as related to the low expansion of wood veneer overlay resulted in the composite panel shearing apart in the center in a dramatic manner.

Another problem that occurs with this type of board, particularly those of thinner cross section that are curved from the extrusion die down to the cutoff saw as shown in Figure 3.5, is that some of this bow can be retained in the final board.

The relatively low production rates in these plants, plus the need for upgrading some of the physical properties of the final board, have prevented this extrusion board processing system from becoming a major factor in the United States or Canada. Even in other parts of the world where more extrusion plants are operating, the platen-type system for producing particleboard is by far the most popular.

Rib-Wood

Recently, a new extrusion system called Rib-Wood has been announced. It has a relatively low capacity but it is an important addition to the arsenal of composition board producing equipment and should be of great value to those wanting to

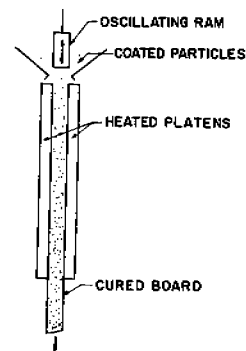


Figure 3.5. Principle of particleboard manufacture by extrusion. Particles are forced by oscillating ram through die, consisting of two parallel heated plates. Distance between platens is fixed, and is equal to the thickness of the board (Suchsland 1972).

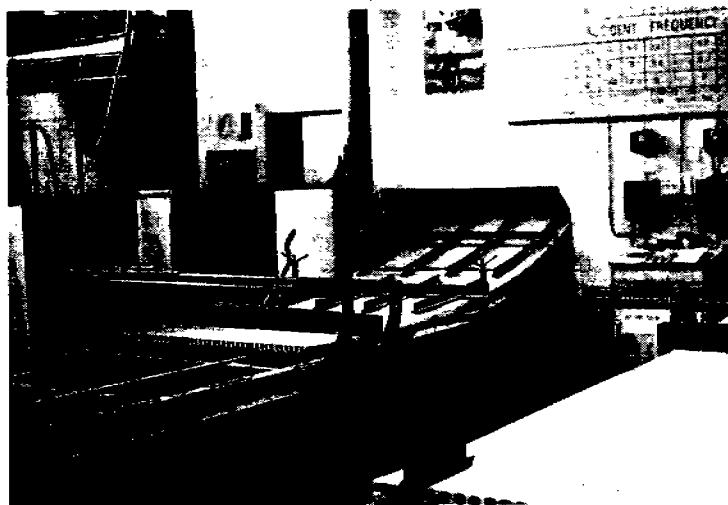


Figure 3.6. Extruded board leaving the die. (Courtesy Washington State Univ.)

manufacture smaller amounts of product from their residuals. The first commercial machine will produce a continuous sheet 40 in. (1.02 m) wide with 13/16-in.-thick (20.6 mm) ribs every 2 in. (50.8 mm) across the width on one side (Figure 3.8). Relatively small particles are used to minimize detrimental particle orientation. The board density ranges from 40 to 65 lbs/ft³ (0.64–1.04 sp gr). Gluing Rib-Wood panels together at rib ends or staggering ribs forms a hollow core panel 3/4 in. to 3 in. (19–76.2 mm) thick (Figure 3.8). It has a high-density surface that will take 1/28-in. (0.91 mm) veneer or 0.028-in. (0.71 mm) high-pressure laminate without crossbanding, which is an important feature. Overlaying is planned for this product.

Board width can be varied on different machines for various products, and mold variations will change with thickness, by length and distance between rib center.

Standard processing equipment is used except for the extruder. The extruder is heated to 400°F (204°C) and cures board at about 40 in. (1.02 m) per minute. A reciprocating ram is also used in this system for driving the furnish through the extruder.

MOLDED PRODUCTS

Molded composition board can take one of several forms. One type of molding consists of a product with over 25% of an adhesive binder mixed with wood flour. Such a product may be classified as a plastic. A familiar product of another, but lower-quality, type is a toilet seat which can be made with slightly larger particles

and less resin. Another type of product is a panel which has embossed pattern imprinted on its face either during the pressing operation or by a post treatment. This is done with standard platen-pressed panels. A third type of molded product is that made with particles, fiber, or flakes for furniture parts, boxes, and counter tops. Figure 3.9 shows examples of this type of product.

While the molded product segment of the industry is relatively minor, it is of interest for at least two reasons. One is that, while molding wood composition material has not been particularly economical up to now in the United States because of competition from all-plastic material, the great increase in prices for petrochemicals has possibly changed the economics of producing wood molded parts. Consequently, it may soon be economical for a significant expansion in this industry. Such molding has been taking place in Europe for quite a number of years. The second reason for interest in molded products is the future possibility of molding structural composite building panels that will have very high strengths. Such a molding has been visualized all along by those involved in the dry-process industry. Some initial work has been done along this line, but much is yet to be learned about molding such large pieces of material. Experience in molding the smaller pieces such as the furniture parts should be invaluable in assisting with the development of the molded structural board industry.

Embossed Faces

The imprinting of a wood-grain type or other pattern on faces of hardboard has been quite successful. (*Embossed* is the descriptive term used in this discussion

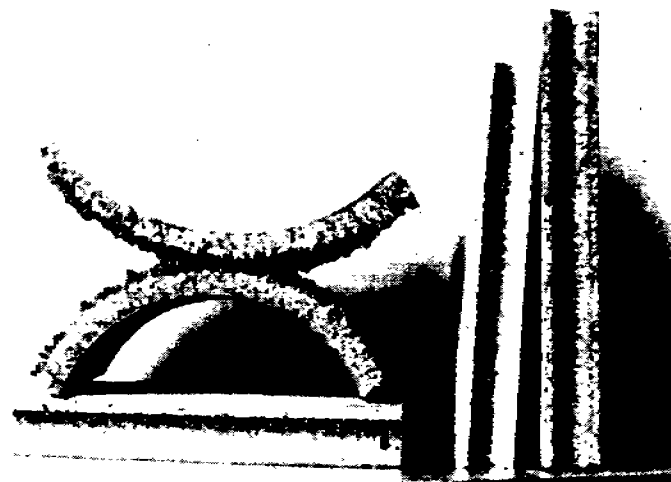


Figure 3.7. This extruded board with veneer overlay was accidentally water soaked and has sheared apart. (Courtesy Washington State Univ.)

7.

PARTICLE GENERATION, CONVEYING, AND STORAGE

As we have seen, some particles are produced elsewhere, particularly in the case of planer shavings, where much of the material as received can be used in the composition board plant. The same is true with some of the sawdust and some of the particles from other millwork waste. Very small particles must be accepted in the shape received as little milling can be performed. However, other previously comminuted particles can be cut and refined to the advantage of the board properties. Costs are low in handling particle generation in this particular situation, but the particle geometry has for the most part already been dictated by other woodworking processes.

On the other hand, a number of particles can be generated from the larger shavings and other material listed under "wood raw materials." The opportunity for producing "engineered" particles, then, is at hand. The best type of particle or particles needed for a particular product can then be prepared. Several different machines are available for this operation, ranging from chippers and hogs for reducing larger pieces to attrition mills for generating fiber. Hammermills, ring flakers, attrition mills and ring mills can be used for producing smaller particles or fibers out of shavings and chips for use in particleboard. Ring flakers, disc flakers, and drum flakers produce flakes. Excelsior machines are used for generating the strands necessary for excelsior or wood wool products.

Each particle has its place in the scheme of production. Fiberboard plants will exclusively use attrition mills. Flakeboard plants will concentrate on one of the various types of flakers. Standard particleboard plants based on granular material will use combinations of hogs, chippers, hammermills, ring flakers, ring mills, and attrition mills; and if they wish to move into higher-strength products, some type of sophisticated flaker or pressurized refiner may be part of the equipment.

Particle generation used to be a relatively simple concept as far as types of machines were concerned. Flaking, hammermilling, and attrition milling covered the types of generation being performed. Nowadays, these same general types of machines are used, but there is a wide variation within each grouping as well as newer developments. Machines range from chippers, hogs, and cuttermills for rough particle generation through hammermills for either rough or final particle preparation to drum flakers, disc flakers, knife-ring flakers, wing-beater mills, turbomills, counter-rotating mills, cross-stream impact mills, double-stream ring refiners, counter-rotating double-stream ring refiners, atmospheric attrition mills,

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and pressurized attrition mills. Such a variety of machines leaves the mind reeling over which one or ones should be employed in a board plant.

The raw material for the board industry, as already noted, can be roundwood, slabs, edgings, end trim, shavings, sawdust, annual plants, etc. The generating conditions vary widely according to size, wood species and moisture content. To obtain particleboards with good strength, smooth surfaces, and equal swelling, manufacturers ideally want a homogeneous material with a high degree of slenderness (long, thin particles), no oversize particles, no splinters and no dust. Depending on the manufacturing process, the specifications for the ideal particle size are different. For a graduated board, wider tolerances are acceptable; for a three-layer board, the core particles should be longer and surface particles shorter, thinner, and smaller; for a five-layer or multi-layer board, the furnish for the intermediate layer between surface and core should have long and thin particles for building a good carrier for the fine surface and to give the boards high bending strength and stiffness. This is particularly important as the fine surface particles on the top of the mat will sift through towards the core before pressing is completed, leaving a rough texture rather than smooth surface.

Fibrous material for hardboard or medium-density products is usually generated as a homogeneous blend and is used this way, or the finer material can be separated or ground specifically for use in the board faces.

In considering the various machines available, care must be exercised to choose the one or the combination that will economically produce the desired particles. Energy requirements, maintenance, ruggedness, flexibility, capacity, capital cost, and operation cost all must be considered.

The machine or combination of machines must do the best possible job of particle generation. Few oversize or undersize particles should be tolerated. Conditions change in our rapidly changing world, including the type of raw material available. Thus, flexibility is needed in machines to handle these changes as well as those necessary on the production line for shifting to a different product.

Capacity depends on the type of infeed material, its moisture content, and the type of particle desired. The capacity must be sufficient to take into account normal wear in the machine. As parts become worn in the machine, the capacity as well as the quality of particle may decrease, because no machine remains the same as it was new without a major overhaul.

Uniform and controlled feeding systems are needed with, perhaps, the exception of chippers and hogs. Many do not realize the importance of a uniform feed as related to the quality of the final product in particle-generating machines. Vibrators, double-screws, and high-speed single-screws with a short pitch are used to provide uniform feeds. Flight conveyors, bucket conveyors, and slow-turning single-screw conveyors provide pulsating feeds which are anathema to quality particle generation.

The machine price and the investment cost for a complete particle-generating installation should be considered. This includes the machine itself with all accessories, such as drives, safety devices, motors with slide rails, switch gear, cables, feeding equipment, foundations, supports, discharge transport, erection, and freight. The total investment should be in reference to the capacity as this will give a specific figure in dollars per ton of hourly capacity.

Besides the depreciation, and most such equipment is relatively short-lived, the operating costs are mainly for labor, electric power, and wear. With good control equipment the installation should work without an operator, although some means of observing the complete installation is necessary. Machines having knives, however, need men for knife changes, knife setting, and knife sharpening. When calculating power cost, the installed motor size is less important. The actual metered power consumption for a complete installation should be taken into account, however, including all necessary auxiliary equipment and transport systems. An accurate figure, however, is often not obtainable before starting the installation.

Larger motors are preferable, in North America in particular, not only because they have more spare capacity for overcoming short-time overloads, but because the plants are usually operating well over the designed capacity.

In the following discussion, various types of particle-generation equipment will be examined with special emphasis on the more important pieces of equipment.

HOGS

Hogs are relatively crude machines for breaking larger pieces of residue material, such as plywood trim, down into smaller ones for further refining. Figures 7.1 and 7.2 show the cutting action of two types of hog. These types of machines have been around the forest products industry for years for use in preparing residue material for fuel, and the term *hog fuel* is well known.

CHIPPERS

Chippers, which are sometimes called *hackers*, particularly in Europe, prepare the familiar pulp chip from roundwood or other wood residues. The rotating-disc

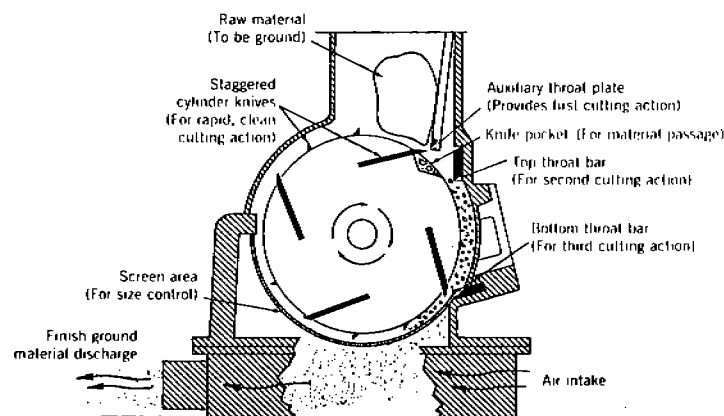


Figure 7.1. Schematic view of knife-type hog. (Courtesy Mitts & Merrill.)

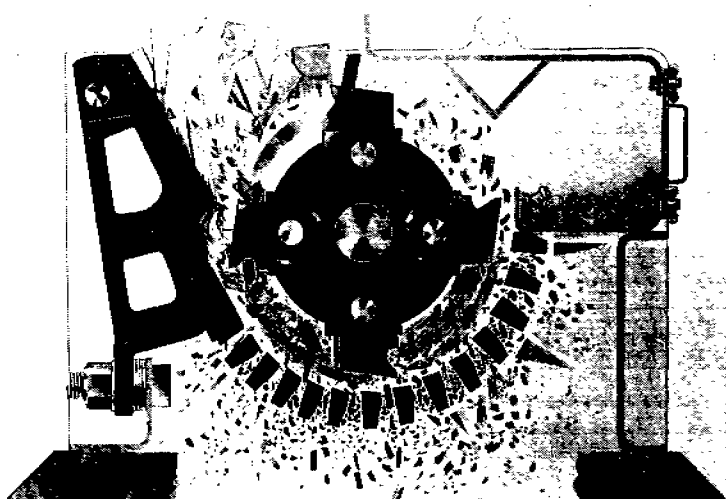


Figure 7.2. Sectional view of the No-Nife hog, showing how the fast-revolving hammers cut the wood by impact. (Courtesy Williams Patent Crusher and Pulverizer Co.)

type, as shown in Figure 7.3, is popular for use with larger-diameter raw material. Another type uses two conical discs and an infeed set at 90 degrees to the shaft. Drum-type chippers (Figure 7.4) are used for chipping veneer, slabs, edgings, and small-diameter wood. Screens can be built into drum chippers to reduce oversize particles as illustrated in Figure 7.4. In the composition board industry, chippers are used to reduce roundwood or other large material into a predetermined chip size for further refining. In operation, the knives cut across the fibers at an angle. The wood splits in the fiber direction because of a shearing action caused by the cutting and the hard impact of the knife striking the wood. A new chipper is now in operation to make very large *maxichips* for further cutting into long, slender flakes for use in oriented flakeboard. These chips are cut approximately 3 in. (76 mm) long.

CUTTER MILLS

Short wood offcuts and mill ends can be chipped better in a cutter mill (Figure 7.5) because the feeding system of a drum-type chipper can cause trouble with such short material. Cutter mills for boards (Figure 7.6) are specially constructed to chip all kinds of boards (offcuts from cut-to-size operations, rejects, laminated boards, furniture parts, and so forth). These cutter mills usually have a screen that has small-size perforations.

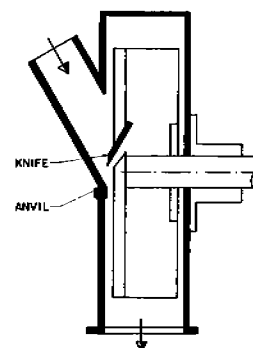


Figure 7.3. A disc chipper (Fischer 1972).

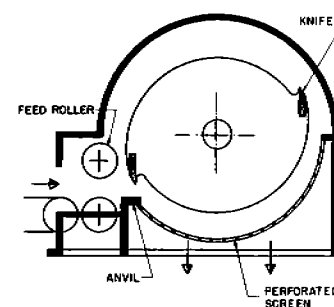


Figure 7.4. A rotary- or drum-type chipper with screen (Fischer 1972).

HAMMERMILLS

Hammermills (Figure 7.7), wing-beater mills, and similar-type machines use a beating action to reduce material. Particles which are too large after the first impact are pushed along the screen and are further reduced by friction and by squeezing between the edges of the screen holes and the beaters. The size of the screen perforations determines the size of the ground material. Beaters in hammermills are free-swinging hammers or steel strips. Wing-beater mills have an impeller with stiff arms, armoured with wear plates (Figure 7.8).

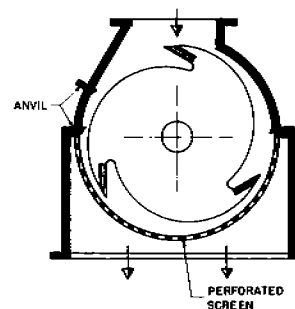


Figure 7.5. A cutter mill or chipper for mill ends (Fischer 1972).

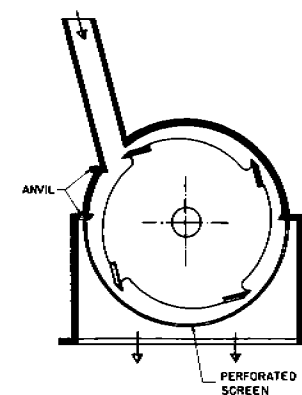


Figure 7.6. A cutter mill or chipper for boards (Fischer 1972).

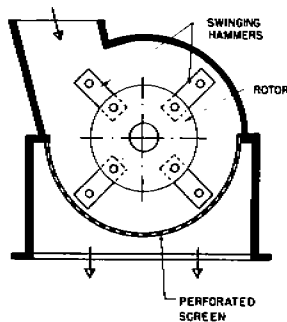


Figure 7.7. A hammermill (Fischer 1972).

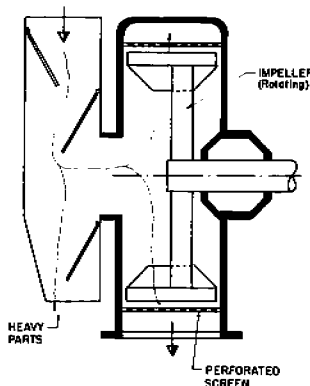


Figure 7.8. A wing-beater mill (Fischer 1972).

Hammermills and wing-beater mills are simple machines with low-cost wear parts. However, since size reduction is accomplished by splitting and breaking the infeed material into smaller pieces, little control of particle geometry is possible. When using a small-size screen, a high percentage of unwanted dust will also be produced. Because of their simplicity and ease of operation, these mills have been used extensively in the United States. Different screen sizes and screen openings enable varying sizes and geometries of particles to be generated.

When handling material with a higher moisture content, machines with a stationary screen-ring tend to plug. In this case, machines with a counter-rotating screen-ring are preferred. They assure a steady self-cleaning of the machine housing behind the screen (Figure 7.9). An additional advantage of the counter-rotation is a higher throughput capacity, and with a given screen perforation, a finer grinding is achieved in comparison to a stationary screen-ring.

IMPACT MILLS

Impact mills use as their principle the fact that wood particles thrown against a grinding path will split mainly along their fiber length (Figure 7.10). Impact mills operate with very high air speed (more than 300 ft—91.4 m—per second) to get the wanted hard impact. High air speed, however, does not necessarily produce large amounts of air. The air intake cross section is designed to limit the air throughput.

In the sophisticated ring refiner (Figures 7.11 and 7.12), heavy particles with a relatively small surface (in particular cubical ones) will hit harder against the grinding path than lighter particles of dust. As a consequence, particles already fine in size do not become much finer. A further sifting effect in the machine is caused by the airstream, because it will take the fine material away from the grinding path and lead it through the screen. The few larger-size particles, which

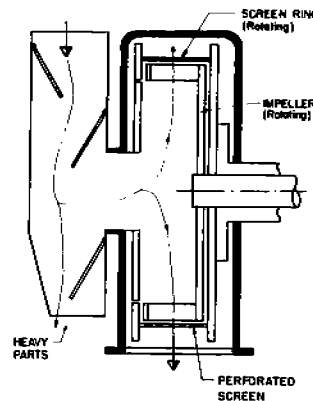


Figure 7.9. A counter-rotating mill (Fischer 1972).

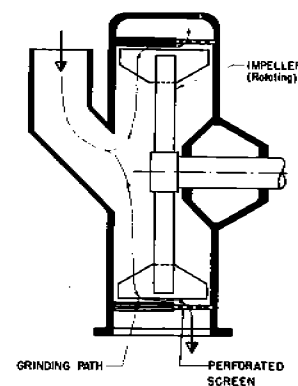


Figure 7.10. A cross-stream impact mill (Fischer 1972).

were not ground fine enough on the grinding path, are crushed between the impeller blades and screen.

For material with higher moisture content, counter-rotational machines are in favor, as illustrated in Figure 7.13, which is the same principle as discussed previously under "hammermills."

Impact mills have little wear, because there is little friction and no sharp edges are needed. The specific power consumption is comparatively low, because there is little braking effect. Flake material can be handled well; thus, little unwanted dust is generated. The amount of air going through the machine affects cooling and

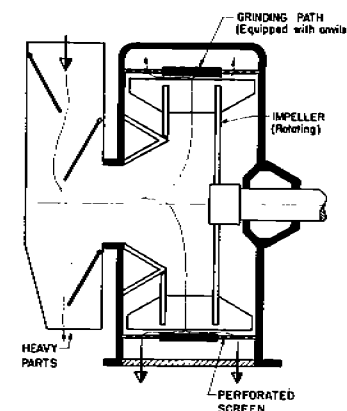


Figure 7.11. A double-stream ring refiner (Fischer 1972).

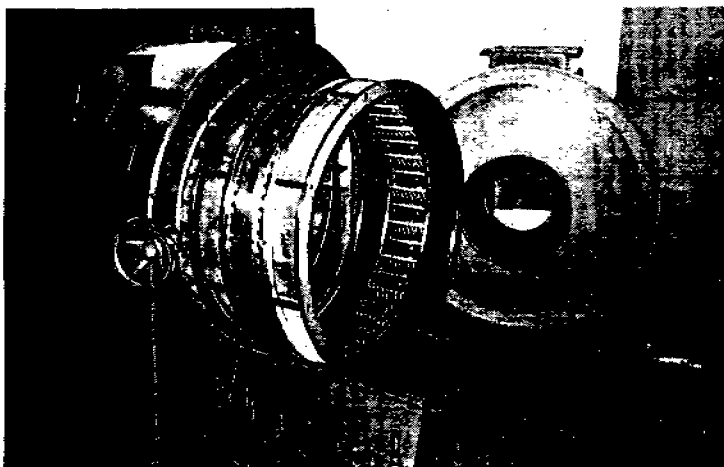


Figure 7.12. View of a ring refiner. The easy-to-change grinding path is sitting in front of the refiner (Fischer 1972).

cleaning. Anvils for the grinding path are available in different patterns, and screens can also be used with different perforations and shapes. This makes the machine very flexible and useful for different materials, such as splinters, sawdust, and planer shavings. Many plants throughout the world are now using impact mills to process fine surface furnish, and their use is increasing in the United States.

ATTRITION MILLS

Attrition mills are also known as *ring refiners* or *disc refiners*, and in the board industry, the term is generally interpreted to cover machines which grind down wood chips, sawdust, and planer shavings into fine fibers. The impact mill (ring refiner) just discussed can accomplish somewhat the same result. The fiber generated for composition board, either in the particleboard or fiberboard area, is really a bundle of fibers and not a particle made up of a single fiber. The pulp and paper industry requires much smaller fibers than those normally used in composition boards. To obtain such fine fibers, some chemical cooking may be used to assist in breaking down the lignin in the wood. This technique can also be used in the composition board area and in some cases, such as in wet-process hardboard, it can be of value. The refining of raw or steamed wood is extensively used to produce fiber for mat-formed products such as insulation board and hardboard. As the industry moves more and more towards using high-density species, the possibility exists that some type of chemical cooking or pressurized refining may also be used for preparing fibers out of difficult-to-mill species for the board processes.

The actual particle shapes usually take a variety of forms such as splinters, chips and fine shavings, long or undulated fibers and fiber bundles. The grinding process is a mechanical one and the grinding path is adjustable to produce a desired product.

Attrition mills or disc refiners mainly use attrition and shear as the particle generating principles (Figure 7.14). In this way, a fine defibration can be achieved, and fibers with a high degree of slenderness can be obtained. Steaming the feed material and grinding under high-temperature pressure increases fiber length. The raw material is fed into the center or "eye" of the mill and is thrown towards the outer periphery of the plates by centrifugal force as it is converted into fiber between the plates.

It should be mentioned that there is a combination impact and attrition mill called a *turbo mill*. This is a counter-rotating machine without screens (Figure 7.15). The ground material leaves the grinding chamber through an adjustable gap. Turbo mills are not sensitive units and thus need little maintenance. For coarser reductionizing operations, they are still in use in the board industry. For fine grinding, impact mills work more economically.

Attrition-type mills have been used for many years in the paper, insulation, and hardboard industries. Two general types are available: the single-revolving-disc and the double-revolving-disc designs. Each is operated at atmospheric pressure on raw, presteamed, or chemically treated wood feed material. These machines are also available for operation at elevated temperature and pressure. The choice of types will depend upon the types of raw material and the desired product result.

The type of fiber refined by means of these two types of attrition mills is usually quite different. In addition, the variations in the raw material particle size, species, moisture content, and the variables possible in the grinding process, such as steaming time, pressure, refiner-disc diameter, plate pattern, loading rate, and

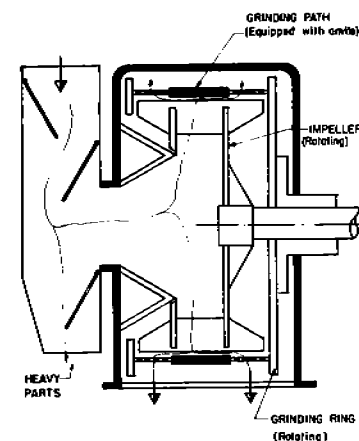


Figure 7.13. A counter-rotating, double-stream ring refiner (Fischer 1972).

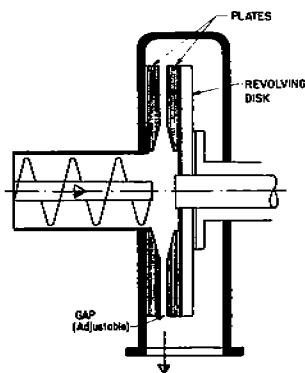


Figure 7.14. A disc refiner (Fischer 1972).

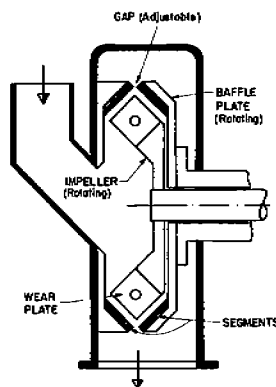


Figure 7.15. A turbo mill (Fischer 1972).

the gap setting between the attrition mill plates, all influence the type and quality of fiber that can be generated. In general terms, the pressure-refined fiber is much finer in character than the atmospherically ground fiber. The wood is being broken down closer to individual fibers in the pressurized refiner than is possible in the atmosphere refiner. However, even with the pressurized refiner, the fiber generated in board practice is usually bundles of several wood fibers rather than individual fibers. Figures 7.16–7.18 are photographs of various fibers ground by atmospheric attrition milling and pressurized refiner-milling. This illustrates to some degree the differences that can be expected between these two types of fibers. It is very noticeable that the raw refined material did not yield a very fibrous furnish. Better results are attainable on low-density species.

When using atmospheric refining, the ideal raw material appears to be green wood chips, particularly of lower-density species such as softwoods or low-density hardwoods such as aspen or cottonwood. Even without presteaming, a fairly acceptable fiber for certain products can be ground in atmospheric attrition mills when using green raw material of the low-density type. However, drier material such as kiln-dried planer shavings cannot be ground into any type of acceptable fiber without at least presteaming. To produce the better fiber, moisture must also be added to this very dry material to assist in the grinding operation. The words shavings and sawdust can mean many things as to size, condition, and shape. In general, the smaller the size, the poorer the fiber quality will be.

Most plants using refiners to produce fiber for high-density hardboard were originally built to use green chip material. Some plants still are operating on such raw material; however, it has been found more profitable in the overall economic picture for most companies to sell their green chips for pulp and paper production and to bring in lower-quality material for the board plant, consisting mainly of planer shavings and sawdust. Sometimes such use of residuals is limited to 10 to



Figure 7.16. Dry-process fiber from steamed chips ground at atmospheric pressure; magnification 6 X (Rauch and Cheney 1970).

20% of total needs. The newer medium-density fiberboard (dry formed) plants are also using residuals other than chips for raw materials. Chips, of course, are still used for a raw material, particularly in cases where the chips are not especially suitable for pulp and paper and when companies' profits are maximized better by producing boards out of these chips rather than selling them for pulp.

Better-quality fiber can normally be made from pulp chips. It is simply a case where relatively long fibers can be generated out of pieces that are about $\frac{3}{4}$ in. (19 mm) long. Fibers are not as long as the chip since attrition milling reduces their length. Extremely long fibers also can present problems in handling through the remainder of the process line. Fiber length will also be influenced by the attrition mill type.

The two types of attrition mills or refiners will be discussed separately. The general operating principle of the two basic refiner types is the same; however, they do produce somewhat different products. Results will also differ with the processing of raw, presteamed, chemically treated wood or the use of pressure and elevated temperature with refining.



Figure 7.17. Dry-process fiber from cold refined shavings and sawdust; magnification 6 X (Rauch and Cheney 1970).

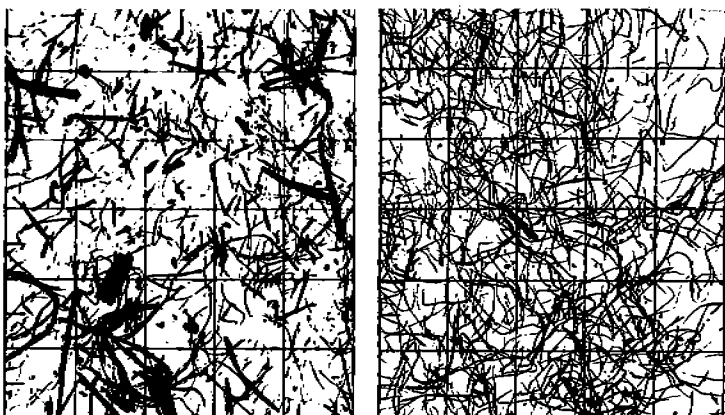


Figure 7.18. Comparison of atmospherically refined, left, and pressure-refined, right, fiber of white pine (both types of fiber about 1 lb bulk density). Grid spacing = 0.10 in. or 2.54 mm (Maloney, Talbott, Strickler, and Lentz 1976).

Atmospheric Refiners

There are two types of machines: (1) a single-revolving disc, and (2) a double-revolving disc. Figure 7.19 shows a cross section of a single-revolving-disc mill which has a built-in motor. The shaft motor rotor and disc at the right-hand side can be moved horizontally by means of a hand wheel on the right-hand end. This adjusts the space between the face of the rotating disc and the stationary surface, which is part of the mill door. Feed material passes into a spout at the left and is fed in between the plates or surfaces of the rotating and stationary discs. The feed material is thrown by centrifugal force towards the periphery of the machine and is ground into the fiber enroute. The resulting product is discharged at the bottom of the case which surrounds the discs. These machines may have screw-type feeders instead of a spout and they are available with a variety of disc diameters and motor sizes.

Figure 7.20 illustrates a double-revolving-disc mill which is equipped with two motors, one for each disc. The left-hand disc has spokes through which feed material passes from a spout which may or may not be fitted with a screw-type feeder. The disc on the right-hand side is driven in the opposite direction by its separate motor. This latter disc motor rotor and shaft may be adjusted to or from the left-hand disc by means of a hand wheel, as shown. This gap can range down to 0.001 in., which is impractical for operation, up to about 0.060 in. (1.52 mm) or more. As can be seen in the figure, the opening between the plates is usually widest near the center of the discs and tapers down toward the periphery of the disc. This sets the stage for a gradual reduction of the larger material to the finest fiber. Double-revolving-disc mills are also available with a variety of disc diameters and a variety of motor sizes.

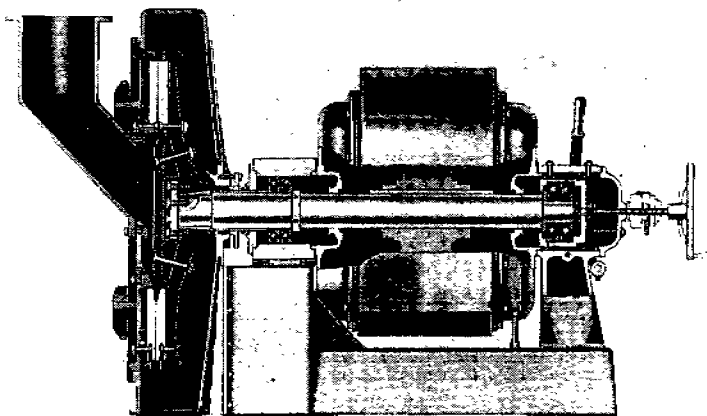


Figure 7.19. A cutaway view of single-revolving-disc mill (McNeil 1967).

In comparison to the single-revolving-disc mill, using a given disc speed, the double-disc mill will have twice the relative rim speed as the single-disc mill because of the counter-rotating operation. The double-disc mill is extensively used for generating fiber for the fiberboard operations.

The previously mentioned blending of phenolic resin and wax simultaneously with the conversion of the raw material into fiber is extensively used in dry-process hardboard operations. The feed end or left-hand shaft is extended through the outer bearing and is rifle-bored throughout its length. The outer end is fitted with a rotary joint which is connected to a metering pump. Resin, usually phenolic at about 15 to 20% in solids, is fed to the center of the mill, where it meets the

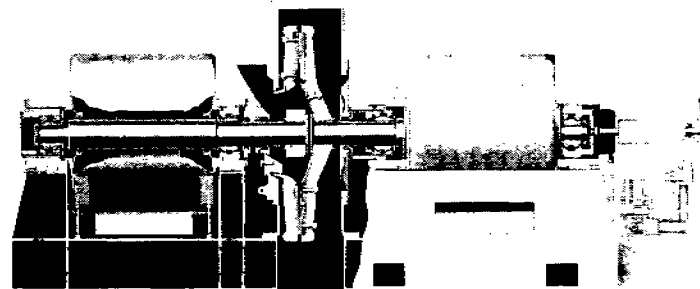


Figure 7.20. A cutaway view of double-revolving-disc mill (McNeil 1967).

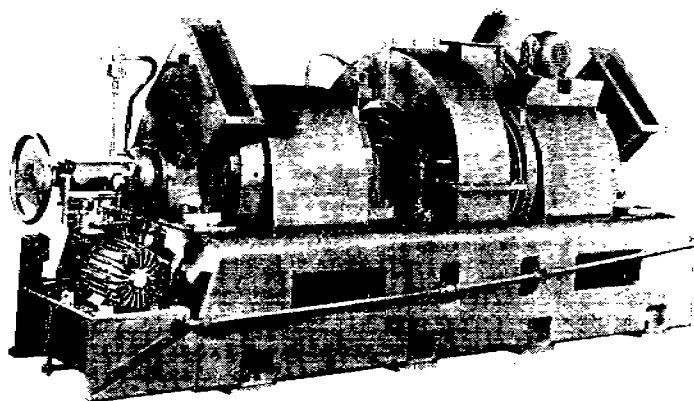


Figure 7.21. Photograph of a double-revolving-disc mill (McNeil 1967).

incoming chips or wood waste. The resin distribution is excellent, and this system has replaced most of the blenders previously used. Attrition mills can also be used as blenders with previously refined fiber or particles, as will be discussed later. However, the binder cannot be tacky or viscous or heat sensitive.

Figure 7.21 illustrates an atmospheric double-revolving-disc mill which is equipped with a twin-screw feeder, circulating oil lubrication, hydraulic means for holding a manually adjusted head or disc position, and openings for forced ventilation of the main motors. The latter feature is quite important in dry-process operations, and outside clean air can be supplied to prevent an accumulation of wood dust in the motor, which could cause a fire. This same idea is used for single-revolving disc-mill motors.

In general, disc mills of the atmospheric type are available with most standard motor speeds, but 1200 and 1800 rpm are the most common types for 60-cycle current. Although larger single-disc mills are made, a 250-HP (187 kW) size is about the largest practical type for most particle operations. Fiber operations can utilize from 300 to 3000 HP (224 to 2238 kW) depending upon the process type. Double-revolving-disc mills are usually limited to 300 to 600 HP, total, (224-448 kW) for particle or dry-formed hardboard operations. Both types of mills are available in either carbon or stainless steel construction. Particleboard feed stocks usually have a low moisture content and are therefore not corrosive, while many wet or steamed feed materials are corrosive to carbon steel. Thus, these considerations must be taken into account before determining which type of construction to use for a mill.

The feed to and through a disc mill in a dry or semi-dry operation is improved if a suitable metering-type feeder is utilized. The stock quality does not change greatly with minor feed volume variations, but a variable motor load could cause electrical trouble due to overloading.

Three other items are desirable for disc mill applications on dry-process refining:

1. Balanced case wipers which are two balanced metal lugs. They are attached in diametrically opposite positions to one rotating disc. They serve to sweep or fan away any material which may tend to remain in the mill case and constitute a fire hazard.
2. Case vents in the refining cases of double-disc mills will permit ventilating air to circulate through the case and assist in maintaining a low temperature.
3. An air suction pickup means to receive stock as it is discharged from the mill and convey it to the next process stage. It is desirable to arrange this means so that air is pulled through the mill. Such action increases capacity in many instances, cools the mill interior, and aids in preventing an accumulation of material.

It has been pointed out that single-revolving-disc mills are available with up to 250 HP (187 kW) at 1200 or 1800 rpm. They appear to be most suitable when a coarse type of product is required. Such mills usually have a 36-in. (914 mm) disc diameter, although smaller and larger ones are produced. They may be fed through a spout or screw feeder, as shown previously, depending upon whether the feed is free-flowing or requires pushing or driving. Mills with much greater power are made; but in most cases they cannot be used on particle stock, because the required amount of feed to load them will not be accepted by the mill. For example, chips with a moisture content of about 50% will have power rates which vary by species and product type from 6 to 12 lbs (2.73-5.45 kg), oven-dry basis, per horsepower hour (HPH) (0.746 kWh). Feed rates of 18 to 40 tons (16.3-36.3 mt) per day (oven dry) would be required to load the machine. It must be recognized that the maximum feed which a mill will accept is not an exact science and will vary with the plate style, plate condition (wear), wood species, moisture content, and plate setting. Coarse particle stock power rates and output will change considerably from the finer stock.

Although there can be some overlap in the performance of single- and double-revolving-disc mills, the double type is generally regarded as the best unit for generating slender or fibrous material. The opposing rotation of the disc provides a relative speed of 2400 to 3600 rpm. In addition, the predominant particle orientation between the discs seems to be radial which tends to reduce the fine or short portions of a given stock.

The size of double-revolving-disc mills in the particle or dry-process fiber field is limited by practical considerations. Power rates tend to be low with as much as 14 horsepower days (HPD) per dry ton (251 kWh) on fiber of the type used for dry-formed hardboard or as little as 2 to 3 HPD/ODT (36-54 kWh) on particle stock. Practice in the fiber field with chips at 50% moisture seems to indicate that a 500 to 600 HP (373-448 kW) unit is large enough, assuming atmospheric refining. With both double- and single-revolving-disc mills, the determination of maximum size is not an exact science.

There are many styles of grinding plates available in several alloys. Selection of the right type in any given case is sometimes a trial-and-error procedure. They can

be found in either a flat or tapered design. Since it is impossible to see between the operating plates, we can only guess as to what goes on. Actually, usage has provided useful background, and the fact that many producers find a given style to be satisfactory cannot be ignored. A great number of plate styles are available among the manufacturers of mills and plates. Following is information on a few of the most popular types used for grinding.

Figures 7.22–7.24 illustrate the two opposing discs in a set. There are usually six segments on each disc. Notice that plate 36301 has no dam at the outer edge and that the outer edge of plate 36302 has a dam (Figure 7.22). Actually, the dams on opposite sides are staggered to form a wave-type path for the material being ground to pass through. Other versions of this same design involve differences in the length of the large breaker ribs, which extend to the inner edge, and dam arrangements at the inner side. This style, or some variation of it, is frequently used to make a low-bulk-density fibrous stock from damp or steamed wood for medium- or high-density boards. It has also been popular in pressurized refiners.

Figure 7.23 illustrates plate designs which are mirror images of each other. Again, one set of six segments each is mounted on each opposing disc. This style is used without the outer dam when a coarser product is required. It can also be used without any dams for maximum coarseness. These plates with the outer dam have

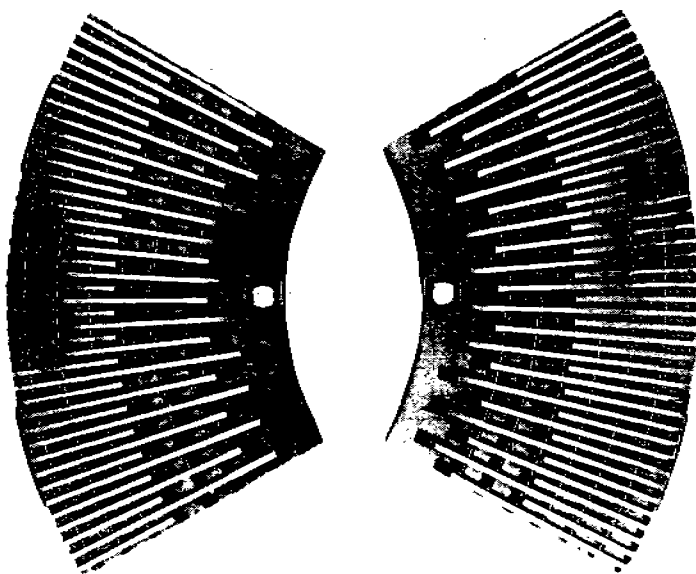


Figure 7.22. Opposing segments of discs: left, No. 36301; right, No. 36302 (McNeil 1967).

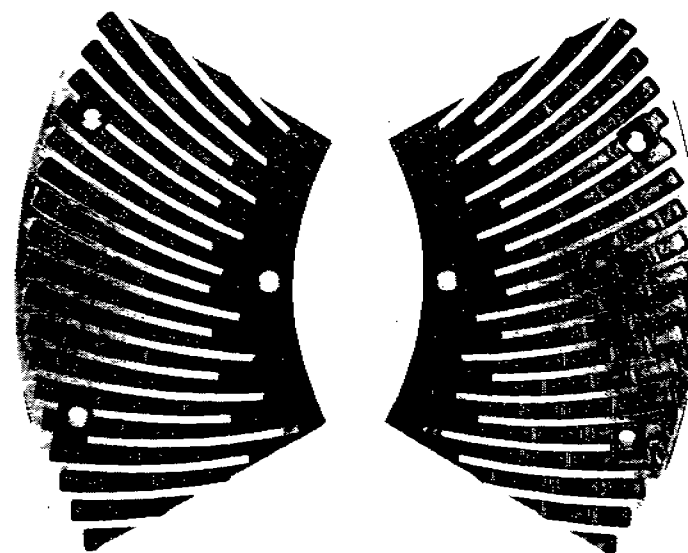


Figure 7.23. Opposing segments of discs: left, No. 36504; right, No. 36505 (McNeil 1969).

been very popular in the board industry. If used on fibrous stock for medium-density products, the bulk density could be somewhat more than that obtained through the use of the plates shown in Figure 7.22.

Figure 7.24 shows the waveline design which is useful for making coarse stock from various raw materials. They are not usually suitable for fibrous products.

Now that the general operation of an atmospheric disc refiner has been related, the critical factors governing actual refining will be presented. One of the first considerations is the type of raw material and final product. If it is a mixture of sawdust and shavings, perhaps a large percentage of the total requires no milling or only a light treatment for particleboard. Separation of such material by screens, or other means, and bypassing the refiner could reduce refining equipment investment. Also, feeding fines through a mill will only make them finer. The separate milling of the fractions could be advantageous if a size-graduated formation is employed for the final board. If waste material contains large pieces, they should be reduced in a hog or chipper to a maximum size of about 1 to 1¼ in. (25.4–31.8 mm).

The moisture content of feed material has a considerable effect upon particle shape. If a large percentage of fines or wood flour is wanted, a moisture content of 10% or less is desirable. Dry wood makes a chunky rather than a fibrous particle.

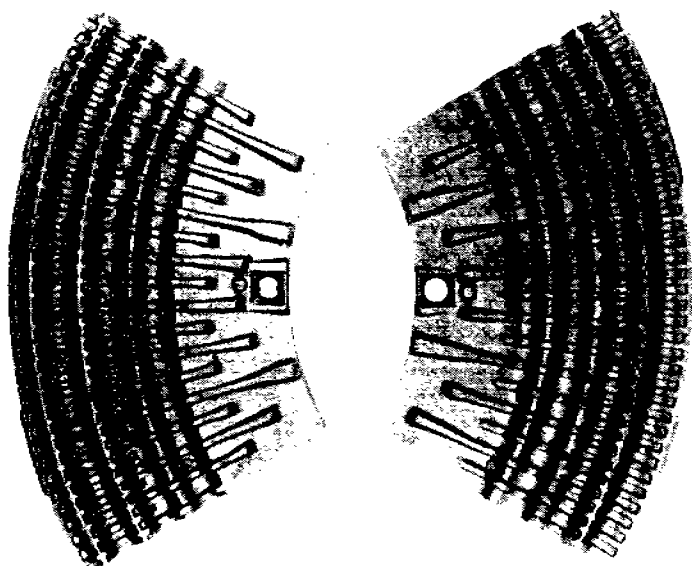


Figure 7.24. Opposing segments of waveline discs: left, No. 36708; right, No. 36709 (McNeil 1967).

which is large or small depending upon mill treatment. The particle becomes more fibrous in any mill as the moisture content of the raw material reaches the 40 to 60% level. If a fibrous type of particle is desired from a dry material, hot or cold water soaking may be used in some suitable and controllable manner. If the raw material is large, the water addition will be largely a surface type. A more costly and sometimes more satisfactory procedure involves steaming for five to ten minutes at a pressure of 80 to 120 psi (552–827 kPa). Usually water must be added to raise the moisture content.

If small dry particles, such as planer shavings, are to be refined, water can be sprayed upon them in a blender or water can be added in the feeding spout to the refiner. Experience has shown that the 50 to 60% moisture-content level can be appropriate for obtaining a good fiber from such dry material. Fiber length, of course, is determined for the main part in the length of the shavings used. Long fiber, naturally, cannot be made from extremely short particles.

High-density species are usually more difficult to refine because of their nature, and greater amounts of energy may be required. Rocks and large pieces of metal, of course, cause severe problems when passed through a refiner. If such problems are regularly encountered, the installation of a chip washer, or a separator of the air or magnetic types, may be warranted.

To obtain better fibers or, in more correct terms, *fiber bundles*, presteaming of the raw material is preferred and is a common practice in the hardboard industry. It has also been used in the particleboard industry when a fibrous face material has been needed to improve the bending strength. This can be accomplished in the more popular continuous steam digesters as shown in Figure 7.25 or in batch digesters. Figure 7.26 illustrates one of the sizes of the auger which can be as much as 52 in. (1.32 m) in diameter. Grinding hot, steamed raw material, while improving the fiber quality, also requires less energy in the refiner. Steaming pressure ranges from about 10 to 100 psig (68.9–689 kPa). Specific treatment depends upon material size, density, moisture content, and product needs. It might be desirable to also add some water to assist in plasticizing the wood. Heated wood has the lignin (nature's glue holding the cellulose together) softened which enables the subsequent refining to separate the raw material into fibers. Rotary valves, or an equivalent type, are necessary to seal this type of digester and to make it work. The Bauer-Grenco type is a pocket valve (Figure 7.27). One valve is used to deliver the raw material into the digester and another one removes the steamed chips at the other end. Screw-type valves, which form a plug from feed material, force feed a digester while forming a pressure seal. They are extensively used as inlet units.

Feeding refiners must be carefully controlled. If at all possible, the feed material should be of a relatively uniform blend of sizes to keep the loading of the refiner constant and for making a uniform product. Actual feeding should be at a constant feed rate. In practice, the gap between the plates in the refiner should be set for producing the fiber desired. Next, the best approach is to feed as much material as possible into the refiner to build up the motor load to the rated level. The actual governing factor then becomes the electrical load on the motors. Some minor adjustment of plate setting may be required. In other words, the refiner is run by establishing the plate setting and then adjusting the feed rate to load the motors. It should be remembered that there is a limit to the feed quantity for a

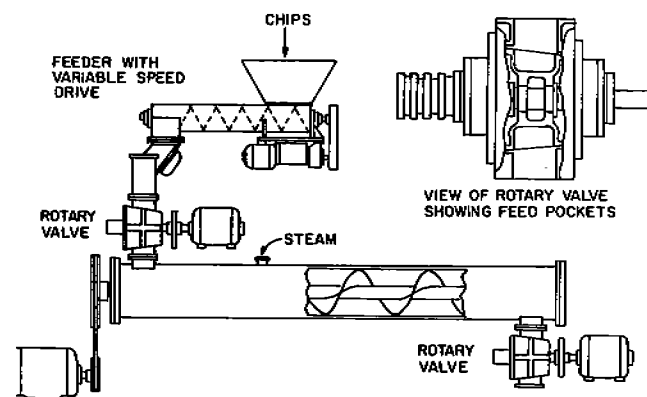


Figure 7.25. A Grenco continuous digester (Textor 1957).

given refiner under required process conditions. It may not be possible to load a large motor and still get the desired product.

A problem can arise when feeding low-bulk-density materials such as waste paper, or raw material as typified by bagasse. These materials are so bulky that a relatively small amount of stock by weight can be ground in a given time. Systems for pelletizing, compressing, or a different refining concept could open the door for greater use of these raw materials in the board industry. Single-revolving-disc refiners can handle the high-bulk-density stock better, as the screw feed can compress the stock while the stock must be fed between the spokes of one of the discs in the double-revolving type. It is important to watch for start-up problems with a cold machine.

Fortunately, disc mills can be readily adjusted to make a variety of particle sizes. As indicated before, feed material, mill speed, plate style, and plate setting are determining factors. Particle size and shape, together with fines content, are important considerations. Surface or overlay stock for particleboard may have a top screen size limit of 12 to 30 or 40 mesh (openings per inch or 25.4 mm). Core stock may have a top limit of 4 mesh. Fibrous furnish is more difficult to measure, as noted, and each plant has established some type of measurement system, most notably bulk density (lbs per ft³), appearance, screen analysis, or drainage rate in a freeness test.

It seems that word or number descriptions of stocks from various raw materials are usually meaningless except for local comparison. By comparison, a description of a flake stock is easy. Most disc mill manufacturers are in a position to demonstrate their equipment and this service should be utilized by any board producer who is considering the use of attrition mills.

Pressurized Refiners

The pressurized refiner is the newest type of refiner used in the board industry. Refiners of this type have been used previously in the wet-process hardboard and

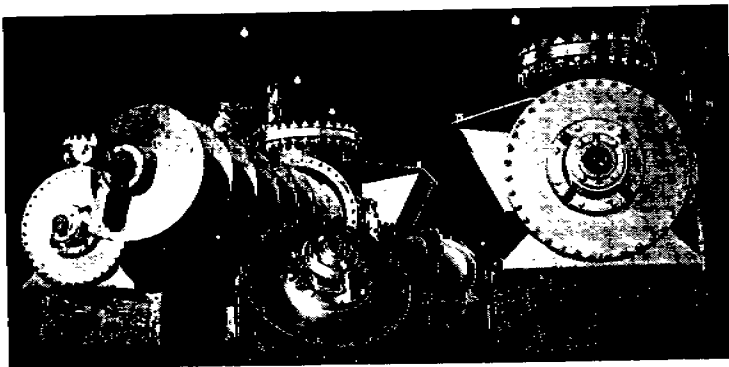


Figure 7.26. Auger for continuous steam digester. (Courtesy C-E Bauer.)

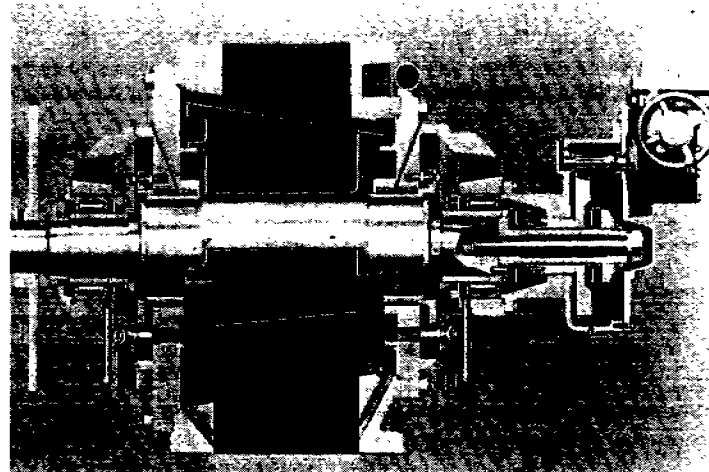


Figure 7.27. Infeed valve to a digester, Bauer-Grenco type, 8 pockets, 10 HP-7.46 kW (Rauch and Cheney 1970).

paper industries. However, in the mid-1960s such units were built for use in medium-density fiberboard plants, and their use has expanded into dry-formed hardboard and particleboard plants.

Pressurized refiners have been a major breakthrough in the wood composition board industry. Hitherto difficult-to-use raw materials, such as dry hardwood residues, dry shavings and plywood trim, can now be refined into acceptable fiber. Greater mixtures of species, particularly those with widely differing specific gravities, appear possible. Dry material can be refined into acceptable fiber, and amazingly, to a number of people, the moisture content of the refined material is not significantly increased. This refiner and more advanced and sophisticated versions are expected to play an important role in the development of the composition board industry.

As a salient point, these refiners are starting to be used heavily in the pulp and paper industry as the quality of their raw material is declining much as it is in the composition board industry. As noted before, composition board is for the most part being forced lower and lower on the scale of raw material. Interestingly, pulp and paper is also moving lower on the scale to secure its raw material. Some of the deterioration of raw material quality has come about by improvements in sawing and planing in sawmills. While they have improved, the resultant residues are of poorer quality for pulp and composition boards.

Pressurized refiners have been promoted by some as a panacea for the problems found when refining low-quality raw materials. They are not a cure-all solution. Significant improvements in particle generation are possible. However, the factors threading their way through all composition board processes—such as

species; raw material type and quality, and moisture content; mixture of species; and interspecies specific gravity variations—must still all be considered.

Two types of pressurized refiners are being used and they shall be differentiated here as the single- and double-revolving disc which is the same classification as used to identify the atmospheric refiner.

The known fact that heat has a plasticizing effect on wood, as mentioned, is used to assist in refining with some of the atmospheric refiners. Wood becomes more plastic with increasing temperature, especially in the presence of moisture. The wood constituents that are the most affected are hemicellulose and lignin. The hemicellulose and lignin components of wood and the microfibrils in the cell wall are softened before the cellulose skeleton of the fiber walls. Since the lignin binds the cellulose fibers together, it is easier to fiberize wood at higher temperatures as contrasted to ambient conditions because the binder (lignin) has been plasticized. This results in horsepower savings because it is easier to grind the fiber, and the quality of the fiber is better when ground under the heated conditions. The pressurized refiners were developed upon the principle not only of grinding steamed wood but grinding while the steam pressure was still applied.

Field results to date indicate that it takes from 0.25 to 1.0 lb (0.11–0.45 kg) of steam to grind 1 lb (0.45 kg) of oven-dry fiber. Interestingly, material fed into such a refiner can have about the same moisture content after refining as before. When using dry raw material, minimum drying after refining is needed for dry forming lines and operating costs are reduced.

Bulk density of pressure-refined fiber ranges from about 1.0 lb/ft³ for the finest fiber to 3.5 lbs (1.59 kg) for coarser fiber. Atmospheric ground fiber will be near the top of the density range although lower density fiber can be ground.

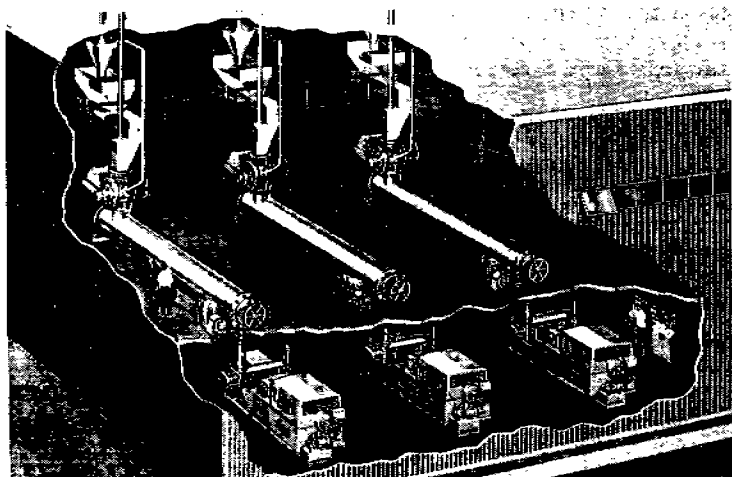
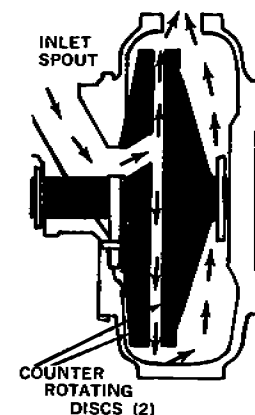


Figure 7.28. General view of refiners in a plant (Runckel 1973).

Figure 7.29. Cutaway view of double-revolving-disc grinding chamber (Runckel 1973).



Double-Revolving-Disc Mills: Raw material for a double-revolving-disc system is fed into a horizontally oriented, continuous steam digester through a rotary valve of the type used on digesters for atmospheric refiners. A typical system is shown in Figure 7.28. Figure 7.29 is a cutaway view of a refiner's double-revolving-disc grinding chamber. Figure 7.30 shows the major operating parts. Pressures in the digester up to 150 psig (1.03 MPa) reportedly have been used. The pressure has to be determined by experimentation for each application. Although more and more knowledge is being gained about this relatively new piece of equipment, each installation has sufficient inherent differences to require some experimentation to establish the operating parameters. After steaming is completed, the raw material enters a transfer feed screw which presents the material to the refiner. After refining, the stock and steam go to the blow cyclone, where the steam and fiber are separated.

In a double-disc mill, feed material must pass between the spokes in one disc into the refining zone. It is necessary to have a seal at this point to prevent infeed material from passing around the back of the disc without going through the refining area. A shive problem would result without a seal. Shives are larger sticklike particles which are undesirable in a fibrous board. Figure 7.31 is a view showing the inside of such a refiner. Note the initial taper between the plates where the raw material is first reduced in size before final fiberizing.

The double-revolving-disc refiner has two motors driving the discs in the opposite directions to each other for the grinding operation and, since the grinding is performed under pressure, the shafts must be sealed to prevent steam loss and wear in the bearings. Stellite sleeves and lantern rings are among the sealing methods used. Some problem was found by some plants at first with seals but, reportedly, research and development have solved these problems.

Single-Revolving-Disc Mills: The other type of pressurized refiner is the single-revolving disc. The general operating principle of refining under pressure is the same as for the double-revolving-disc refiner. However, the techniques of

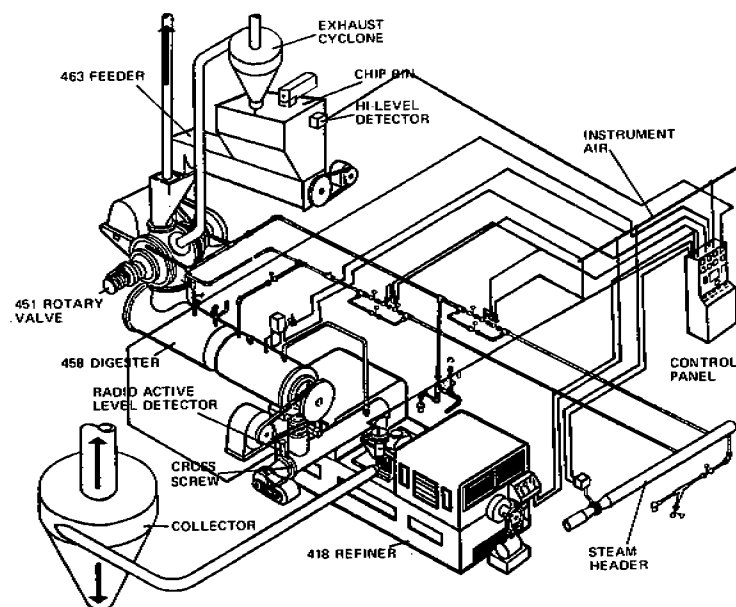


Figure 7.30. Schematic of C-E Bauer 418 refiner system (Johnson 1973).

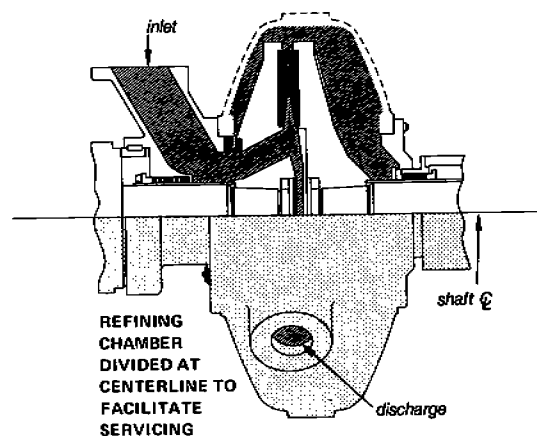


Figure 7.31. Cutaway view of split case (Runckel 1973).

accomplishing refining are different. Figures 7.32 and 7.33 are schematic drawings of a typical installation. The typical installation under discussion has a refiner with 42-in.-diameter (1.07 m) discs. The steaming vessel for this refiner is vertical, contrasted with the horizontal feeder of the previously discussed double-revolving-disc refiner. The discussion here will be generally covering the Defibrator L-42 refiner; however, it should be noted that single-disc pressurized refiners are also made by Sprout Waldron.

The raw material for the refiner, after passing under a magnet and going through a rock separator, goes to a storage bin. From this bin the material is fed by screws to the feed chute which in turn feeds the screw feeder. The screw feeder conveys the wood into the vertical preheater and in so doing must overcome the steam pressure in the preheater. At the same time, it provides a seal which retains the steam in the preheater.

The seal is made by forming a wood plug at the throat of the screw feeder and in the plug pipe, which feeds directly into the preheater. The screw feeder is the most common feeder used to introduce the raw material into the steaming vessel. It is a rugged, dependable unit. The only parts that are subject to wear are the screw and the throat, which are manufactured of special wear-resistant materials. They are easily replaceable and can be rebuilt for further use. Extensive investigation has shown that there is no damage to the fibers caused by the compression in the screw feeder under the conditions of the thermomechanical process. On the other hand,

1. Chip chute
2. Vibrator
3. Screw feeder
4. Chip plug
5. Steam inlet
6. Preheater
7. Gamma-ray level controller
8. Conveyor screw
9. Asplund Defibrator

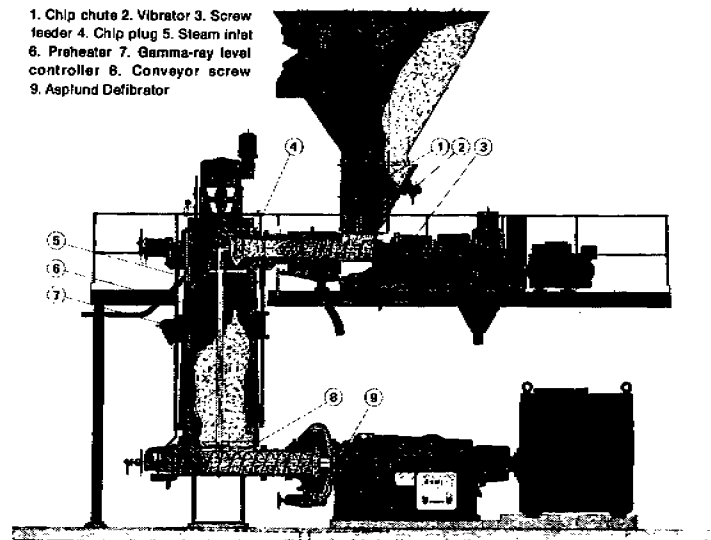
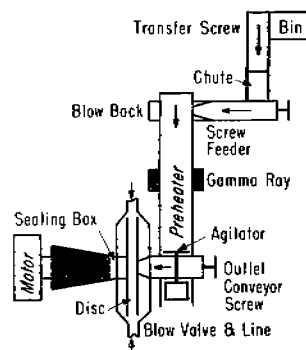


Figure 7.32. Modern Asplund Defibrator pulping system (Gran and Bystedt 1973).

Figure 7.33. Schematic drawing of L-42 Defibrator installation (McVey 1973).



it has been found that when the wood is cooked to pulp yields below approximately 70% in the presence of strong acid or alkaline liquors, the compression may have an adverse effect upon the pulp quality. For these and other applications, where the use of the screw feeder may not be desired, rotary-valve type feeders are available.

The refiner is equipped with a blowback control system which prevents steam from blowing back through the screw feeder when a chip plug is not formed. This is done by an air-activated conical disc which closes off the plug pipe when the plug is lost. This plug of compressed chips emerges from the screw feeder into the pressurized steaming vessel. The steaming causes the plug to fall apart and the chips are quickly heated to the steam temperature. The steam pressure is usually 80 to 150 psig (0.55–1.05 MPa), corresponding to a temperature range of 320° to 365°F (160°–185°C).

The wood is fed by gravity through the preheater into the outlet conveyor screw. The sides of the vertical preheater are tapered, with the diameter being slightly larger at the bottom than at the top. This facilitates the movement of wood through the preheater. A predetermined chip level is automatically maintained in the preheater by the use of a gamma-ray source and detector. At the bottom of the vertical preheater is a slow-moving paddle-type scraper called the *agitator*. The agitator facilitates the movement of wood down into the outlet conveyor screw and helps prevent bridging at the bottom of the preheater. The outlet conveyor screw feeds material through the center of the stationary disc and into the center of the rotating grinding disc. The vertical preheater outlet conveyor screw is driven by a variable-speed DC motor. This screw does not form a plug as the screw feeder does. Instead, a plug of sorts is formed by the fiber between the discs so that a disc housing and preheater steam pressure differential can be maintained.

In the grinding chamber, the steam-softened wood is converted into fiber and thrown out of the discs by the steam pressure differential and centrifugal force. There is a separate steam control for both the disc housing and the preheater. This permits the establishment of either a positive or negative steam pressure differential between the preheater and the housing. Steam is introduced at the top of the

steaming vessel, at the infeed tube of the refiner and at the disc housing. The pressure differential between the inlet and outlet of the refining discs can be controlled in order to obtain the proper flow of steam and fibers. The disc housing is equipped with a drain valve and a product blow valve and line. The product blow valve has an adjustable orifice which controls the rate at which fiber and steam are vented from the housing. The set pressure in the disc housing is maintained automatically by adjusting the steam pressure controls and blow valve opening. At the disc housing end of the main frame bearing bed is located the sealing box for the machine shaft. Water is used to cool and lubricate the packing and to prevent fiber penetration into the packing. Seal water is always maintained at a pressure greater than the working pressure in the disc housing. This means there is continuous discharge of water, internally into the disc housing and externally to the atmosphere. This discharge of water also directly cools the stellite wear sleeve which protects the machine shaft.

Between the front and rear bearings there is an integral hydraulic cylinder for controlling the gap setting between the discs. The piston of this cylinder is fitted to the front bearing housing. When oil is pumped to the rear cylinder chamber, the whole shaft assembly with the rotating disc is moved forwards, i.e., the disc gap is closed. To open the discs, oil is pumped to the other cylinder chamber.

At a set disc gap, the closing and opening hydraulic pressures are automatically controlled to maintain the disc gap with an accuracy of 0.0004 in. (0.01 mm). The hydraulic servo system increases or decreases the disc clearance and, thus, the grinding pressure to balance the grinding loads imposed by the variation of infeed material. Manual disc adjustments can also be made.

The L-42 refiner usually has the rotating disc turning at 1800 rpm and is driven by a 2000 HP (1.5 MW) motor. A constant-speed AC motor can be used to drive the screw feeder or a variable-speed DC drive.

The screw feeder on the Defibrator is run at a constant speed; the amount of wood going to the preheater is controlled by the variable-speed screw feed out of the chip bin. This "starved screw" principle has worked very well in the field. There are some obvious limitations, as for instance if a certain minimum wood feed rate related to the speed of the screw feeder drops too low, there is insufficient wood to form a plug. If a certain maximum wood feed rate related to the speed of the screw feeder is exceeded, the wood will not be carried away fast enough and the incoming wood feed system will plug. The wood feed rate range over which these two extremes will occur is quite wide (3 to 9 tons/hr or 2.72 to 8.2 mt). The wood feed rate range can be changed by varying the size of the screw feeder drive pulley.

The type of wood raw material that is being processed through the refiner makes a big difference in the selection of the feeder screw. For example, the screw for running green material may not work with dry material. A plug must be formed and driven into the preheater as shown in Figure 7.34. In one example, the compression ratio of the screw was not high enough when running dry material to form enough pressure on the grooved walls of the throat or the smooth walls of the plug pipe to prevent the plug from turning. The turning of the plug in the throat and plug pipe prevented it from being extruded into the preheater. This rotating plug would stay in the plug pipe, preventing the passage of additional

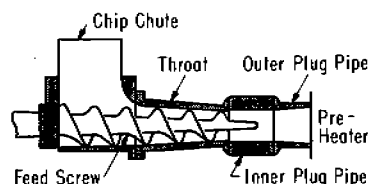


Figure 7.34. Schematic view of plug forming operation (McVey 1973).

material into the preheater. This problem was corrected by replacing the feeder screw with one which had a higher compression ratio and by also replacing the smooth bore plug pipe with one machined with grooves. Such refinements may have to be made in the field once a plant commences operation. These refiners can have steam blowback problems, where steam goes back through the screw feeder and chip chute.

It is possible for small chips or particles to foul the blowback control. Manual operation may correct the problem or it may be necessary to reduce the steam pressure in the preheater to allow the chip plug to form again. A modification by one plant to help minimize the problem of plugging the vertical preheater was to weld a couple of inches on to each end of the agitator blade (Figure 7.35). This prevents an inner shell of wood from forming on the inside of the preheater walls and holding up the pile of chips. It also facilitates the removal of wood from the preheater if it should become plugged. The speed of the agitator is important for uniform feed to the refining discs. One plant uses an agitator rpm from 4 to 8 to achieve this uniformity.

Serious consideration must be given to the location of the discharge from the waste blow line used to exhaust the steam, water, and coarse fiber from the housing when starting a refiner. Each time the machine is started, it must be vented until near normal operating conditions are reached; otherwise serious pipe and dryer build-up will occur from the excessive amounts of water being vented with the fiber. This material presents a potential pollution problem as it is vented to either a drain or to the atmosphere. The best way of handling this material appears to be to mix it back in with the incoming raw material. However, this idea involves handling problems in storage, metering, and blending.

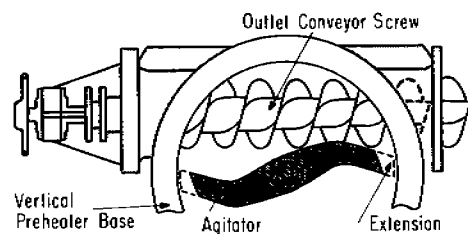


Figure 7.35. View of agitator extension in vertical preheater (McVey 1973).

In small machines, a reciprocating-valve-type discharger is used because it is easier to control the steam consumption with the reciprocating valves. The blow valve is used in larger machines, but it has to be adjusted very carefully because, with a small opening, there is always the hazard of plugging the valve; whereas, a large opening caused excessive steam consumption. At a high production rate, however, where most of the machines run, the opening has to be larger to allow for the increased flow of fibers and steam. The steam consumption per ton of fiber is not increased. Also the larger opening is not so easily clogged. The flow through the blow valve is continuous and less restricted than by a reciprocating valve. Sampling the fiber shortly after it leaves the housing is a problem with pressurized refiners. The product blow line has an above atmospheric pressure which makes sampling somewhat difficult.

Two potential problems, among others, may be present with pressurized refiners. First, the entire machine is hot, and under this condition the proper plate gap setting is more or less fixed. However, if the steam pressure is lost, the entire machine starts to contract which can result in the discs being ground together if the initial gap setting was small. Some type of interlock may be necessary to open the gap, thus preventing the plates from grinding together and causing damage to each other as well as posing a potential fire hazard. The second problem is the necessity for stopping the machine because of malfunctions on the production lines. As noted before, pressure-refined fiber has a relatively low bulk density. Consequently, on a weight basis, a relatively small amount of storage space for freshly refined fiber will be all that can be normally expected. Electrical and mechanical interlocks are therefore necessary to protect the equipment and to make it possible for an orderly shutdown when stops of more than short duration are necessary.

Acidity and Moisture Content

Acidity and moisture content of the raw material can be a problem in grinding good fiber. Under conditions of steaming, pressure, and temperature, various amounts of weak and strong organic acids are produced. The amount and type of acids have been found to vary considerably, depending on species and, to a lesser extent, within a species. It has been observed that the pH of condensate from steamed chips has been on the acid side, and at equilibrium seems to buffer between pH 4 and 5. Research on digestion of various species has shown that great variations may be expected between species at the same oven-dry weight of wood with regard to the amount of acid titratable at a given steam pressure. As pressure increases from 50 to 125 psi (0.34–0.86 MPa) in a species, the total acid produced may be doubled. In digestion and refining, the range of acid content can produce many problems. As the acid content increases, chemical acid hydrolysis of lignin and cellulose increases; and when combined with the already high temperature and pressure in the digester-refiner, the action on the fiber could be either troublesome or desirable.

Investigations of the chemical nature and quantity of acids have shown that different species of wood will be attacked at different rates and when mixtures of wood species are made, one must be careful not to mix highly acidic species with wood species that are subject to acid attack. Some woods, such as gums, produce

small quantities of acids even under severe conditions (150 psi [1.03 MPa] for five minutes) while others, such as red oak, produce four to eight times the titratable acid under the same conditions. Acid attack on gum is vigorous and a 50–50 mixture of gum and oak can lead to a fiber that is short in length, difficult and dangerous to dry, and one that will cause excessive sticking in the press. This type of fiber will possibly require an excessively high resin level in order to produce boards of the desired quality. Water absorption will be high and water soluble material will be higher in these boards than in the corresponding 100% gum or 100% oak boards.

There are other variables that can cause problems, such as treatment of wood, storage, washing and/or drying. When there is a mixture of wood species, control of the mixture of species is necessary or the mixture must be treated for the most troublesome member. Penalties may consequently be imposed by the restrictions on pressure and time. The acidity of digestion conditions has one more effect, which is corrosion. Special alloy plates probably are necessary in the refiner to achieve a reasonably long plate life when using highly acidic woods. Abrasion, plus high acidic conditions, wears plates and drops fiber quality while increasing power requirements for a given fiber.

FLAKERS

Three types of flaking are available at present: drum or cylindrical, ring, and disc. The first two are the most popular throughout the world. Disc flaking produces the highest quality flake and, while used extensively in the early days of particleboard, it has been mostly supplemented by drum and ring flakers because of cost and capacity considerations. A sophisticated flaker is now being developed for cutting flakes from roundwood being cut into timber and lumber products, working much like a chip-and-saw headrig.

All cylindrical-type flakers (Figure 7.36), knife-ring-type flakers (Figure 7.37), and disc flakers use the same cutting principle. Adjustable, sharp knives penetrate the wood and cut flakes of a predetermined thickness. Closer control is usually found with disc and drum flakers. Planers and molders also use the cutting principle; however, the feed direction of the wood is perpendicular to the rotor shaft. Therefore, the planer shavings usually are curled with one end thicker than the other. As a reminder, however, it should be noted that each species planes differently and the many factors involved in planing can result in large flaky particles through tiny cubical ones.

Roundwood and split wood of large dimensions are usually flaked with drum flakers, although the disc flaker is popular in Canada. Wood of small diameter and sawmill waste are usually converted into chips first and, in a second operation, the chips are flaked in a knife-ring-type flaker.

A knife cuts into the wood relatively easily, particularly if the wood moisture content is above fiber saturation. That means the power consumption in kWh/ton is low. A second advantage of the cutting is that the flake thickness can be set to certain tolerances. Cut flakes have a relatively smooth surface which assists with resin bonding. Resin is not lost in rough surfaces. Very green wood, however, can also result in flakes with rough surfaces as the green wood can crush under the

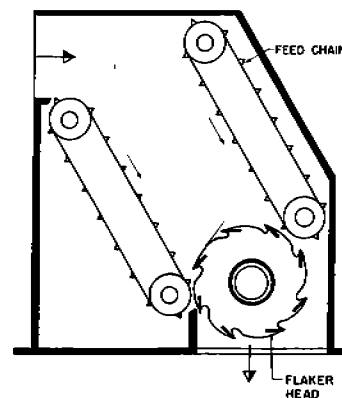


Figure 7.36. A drum-type flaker (Fischer 1972).

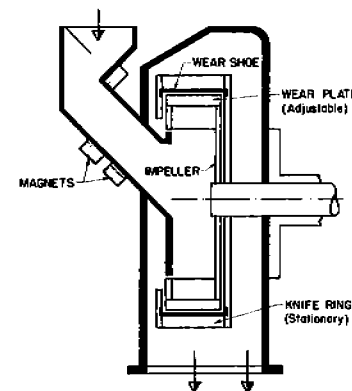


Figure 7.37. A knife-ring-type flaker (Fischer 1972).

flaking pressure. Unfortunately knives become blunt and dull after a short time of operation. Knife changing, knife sharpening, knife setting and the knife itself are expensive items. Flake quality often depends on the maintenance by operators. For the cylindrical-type flaker an operator is needed.

Disc flakers are usually relatively slow operating. Flake quality can be high, however, and for certain types of plants this type of flaker is competitive. Usually the cost of flaking is too expensive for products that can be made with shavings or ring-cut flakes.

Ring Flakers

The most widely used flaker, particularly in North America, is the ring flaker. Previously described in general, the machine is capable of reducing chips, hogged material, and large shavings into acceptable flakelike furnish. The resultant furnish usually has a wide variation in size, as shown in Figures 7.38 and 7.39. However, a certain amount of size variation can be of advantage as particles can intermesh better, usually resulting in boards with better internal bonds.

Two general types of ring flakers have been developed: one which has a stationary knife ring and the other that has a revolving knife ring which is either counter-rotating to the impeller or rotating in the same direction as the impeller.

Figure 7.40 shows the general cutting action of the counter-rotating flaker. Figure 7.41 is a close-up of a section of the knife ring, and Figure 7.42 is a schematic drawing illustrating the cutting action.

Feed material enters through a feed chute into a flaker proper where the fast-rotating impeller catches it and forces it against the counter-rotating knife ring. The flakes are cut off according to the knife projection. Cut flakes are discharged through the gap between the knife and pressure lips.

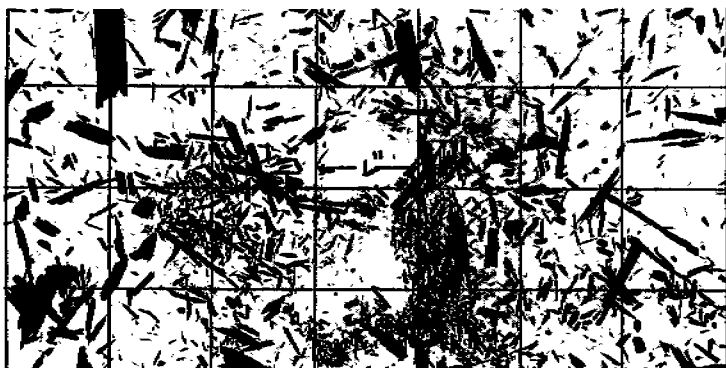


Figure 7.38. Chips ring-flaked at 70% moisture content (Surdyk 1967).

Figure 7.43 shows a sophisticated new model of this machine. The hydraulic release system and spring system are part of a new development which permits extremely fast changing of the knives. Previously, the whole knife ring had to be removed for knife sharpening. Now with the new system, knife changing time has been sharply reduced.

Hundreds of these flakers are in use throughout the world, handling a wide range of wood species of varying densities. They can reduce a variety of sizes and forms of wood into a broad range of flake sizes at a fast rate.

Three important steps are interlocked for successful operation: proper feeding of material into the machine, actual flaking, and proper discharge of the newly cut flakes. Failure in any one of the steps destroys optimum flaking action and flake quality.

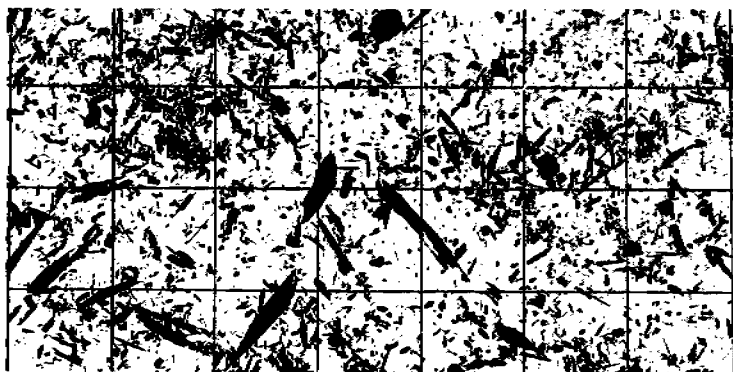


Figure 7.39. Flakes from planer shavings (Surdyk 1967).

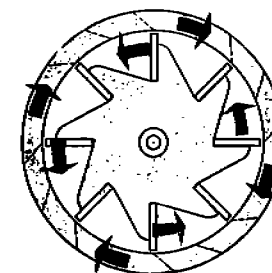


Figure 7.40. Cutting action of a knife-ring flaker with a counter-rotating impeller (Surdyk 1967).

A number of factors affect the performance of any ring flaker and control of these are necessary for achieving optimum performance by the machine. Factors related to the machine are as follows:

1. Sharpness of the knives.
2. Amount of wear on the other interior parts.
3. The gap between knife edge and impeller counterknives.
4. The projection of the knife into the ring.
5. The gap width between the knife edge and leading wear plates (pressure lip).
6. The angles of the knife edges.
7. The angle of the knives in the machine.
8. Impeller rpm and horsepower.
9. Knife-ring rpm and horsepower (if the ring is rotating).

Factors related to the wood are:

1. Amount of metal, stones, and other debris in raw material.
2. Chip shape and size and their range.
3. Moisture content.
4. Chip feed rate and uniformity of feed rate.
5. Species.
6. Chip temperature (whether frozen, warm or steamed).
7. Species density.

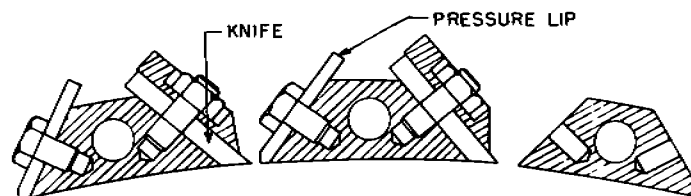


Figure 7.41. A section of the knife ring (Surdyk 1967).

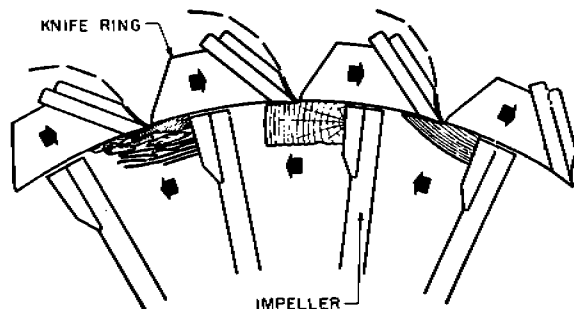


Figure 7.42. A section of the knife ring and impeller showing flaking taking place (Surdyk 1967).

Since there are so many factors, it is a problem to determine the right combination for producing the desired flake. Controlled factors specified by the machine manufacturer are horsepower, impeller and knife-ring rpm, gap between knife edge and leading wear plate, knife angle, and feed rate range. Wood species and density will depend on the plant location. Some experimentation may be needed to find proper angles of the knife edges and the projection of the knives into the ring.

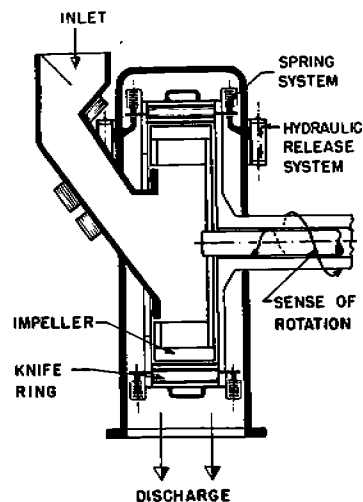


Figure 7.43. New design of a Pallmann ring flaker with fast knife-changing system (Fischer 1974).

Further experimentation can establish limits for knife sharpness, machine wear, moisture content, and range of chip sizes.

There remains the establishment of an adequate quality-control program to insure that the machine is operating within the established limits for producing the desired flakes. One system is to run frequent tests on the flakes, such as thickness measurements and screen analysis, and to watch the impeller-motor ammeter (a high load indicates dull knives). Experience in a given installation will establish the optimum time interval for changing the knives and other wearing parts to maintain flake quality. However, the ammeter on the drive motor must constantly be checked in case the knives are dulled rapidly from foreign material such as rocks or metal.

Eliminating rocks and metal from the material going into the flaker is critical. Metal detection equipment and magnets are absolutely necessary. Suitable rock drops are effective for separating large rocks and heavier metal pieces. A chip-washing unit is especially effective because it will remove sand, small rocks, and metal fragments as well as large rocks and heavy metal objects. The increase in knife life, reduction of interior parts wear, and increased flake quality due to cutting wet material probably will more than offset the added cost of drying a higher-moisture-content furnish.

Depending on plant location in the United States, one could flake wood at temperatures of 60°F (16°C) or more, or frozen wood. Better-quality flakes are cut from the warmer wood especially if the moisture content is above the fiber saturation point. Far more finer particles can be generated from frozen wood. This reaction to frozen wood is particularly true if the rotor counterknife to knife clearance is 0.040 in. (1 mm), or more, or if the knives are dull. With a carefully maintained machine and well-adjusted clearances, good flakes can be produced from frozen wood. Many fines can also be generated from very wet chips (200% moisture content chips), evidently because this very wet material tends to compress and perhaps disintegrate somewhat as it does in an attrition mill.

One of the virtues of this type of machine, however, is its ability to produce acceptable particles from a wide variety of raw material. Figure 7.44 shows a normal distribution of flake thickness from a typical flaker setup. The thicker particles can be reground either in an attrition or an impact mill.

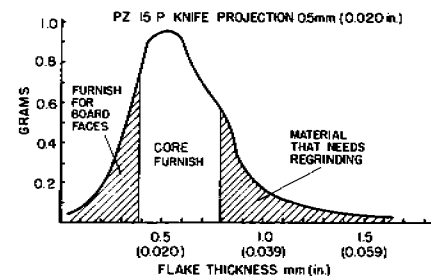


Figure 7.44. A typical distribution of flake sizes (Jager 1975).

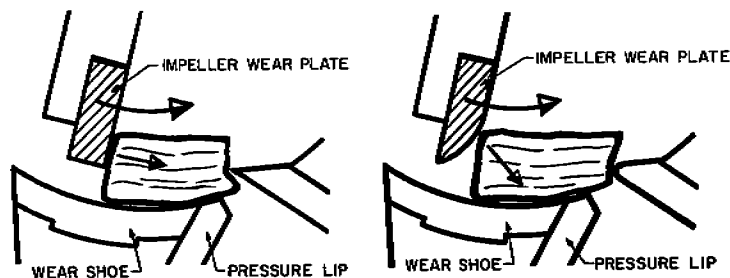


Figure 7.45. Flaking action in a well-maintained machine (Fischer 1974).

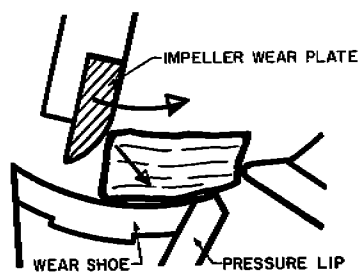


Figure 7.46. Flaking action in a machine with worn knives and impeller wear plates (Fischer 1974).

Naturally the range of chip or other raw material sizes has a great effect on flake size and shape as well as on the range of sizes. Additionally, the knife sharpness and maintenance of the machine are of importance. Figure 7.45 shows the flaking action in a well-maintained machine. The impeller wear plate drives the chip parallel to the inner face of the knife ring. However, this ideal condition changes with time. Blunt knives cut poorly and more power is required for operation. The rounded edge of the impeller wear plate also causes significant problems. Figure 7.46 illustrates what happens as the impeller imparts the driving force into, rather than parallel to, the knife ring. This causes even more wear on the wear shoes and impeller wear plates. The gap between the two widens into a hopper-like shape. Small chips can be squeezed into this gap, causing further wear, and they also function as a brake within the machine thus requiring more power for operation. Flake quality, of course, also diminishes. A similar condition exists when the counterknife to knife clearance becomes excessive.

The other type of ring flaker has a stationary knife ring and both the impeller and knife ring are in the shape of a truncated cone (Figure 7.47).

Figure 7.48 is a schematic diagram of this flaker showing the key parts.

The material to be flaked is fed into the machine through the hopper shown in Figure 7.48. This material is uniformly distributed by the rotor over the length of the flaking knives. Counterknives placed on the ends of the rotor blades then force the material to be flaked across the knives. The rotor blades and the counterknives are set diagonally to the cutting knives to counteract the tendency of the chips to move toward the large diameter of the rotor.

The projection of the flaker knives within the inner surface of the knife ring determines the flake thickness to be cut. However, splinters over minimum thickness, resembling broken match sticks or toothpicks, will occur in increasing percentages as the clearance between the knives and counterknives increases beyond 0.040 in. (1 mm). Flakers with cylindrical knife rings and rotors have a running clearance between the knives and counterknives which varies inversely with the flake thickness for which the knives are set. At a given knife setting, the running clearance is essentially fixed.

With a conical knife ring and rotor, the running clearance can be adjusted independently of flake thickness by moving the rotor axially toward or away from the knife ring. This is done by rotating the adjustment nut (Item 8, Figure 7.48) to move the rotor toward the knife ring until contact is made between the knives and counterknives. The calibrated adjusting nut is then rotated in the opposite direction until the desired running clearance of about 0.010 in. (0.25 mm) is obtained. The adjusting nut is then locked to hold the rotor in the set position. Readjusting the running clearance is not normally required unless the flake thickness or rotor counterknives are changed.

The material is fed through an infeed chute where an adjustable vane splits the material flow into the flaker just above the center of the rotor.

The flaker infeed is designed to accept material either wet or dry having a maximum piece size of 2 3/4 in. (60 mm) in the greatest dimension. Occasional splinters 5 to 6 in. (127–152 mm) long have been found to feed without difficulty.

Permanent magnets are mounted in the infeed hopper and should be cleaned at each knife-ring change. Additional magnets or metal detectors are recommended in the feeder to the flaker. The vertical drop of material going into the flaker should not drop more than 2 ft (610 mm) before entering the infeed hopper. If material is allowed to drop more than 2 ft, tramp metal may attain enough velocity to bypass the magnets and damage the knives. As with all flakers the feed rate to the machine should be as uniform as possible.

Guide plates within the housing divide the infeeding material into two parts. As viewed through the casing door, the material falling down to the right of the shaft is directed towards the door to the small diameter of the rotor. Material to the left of

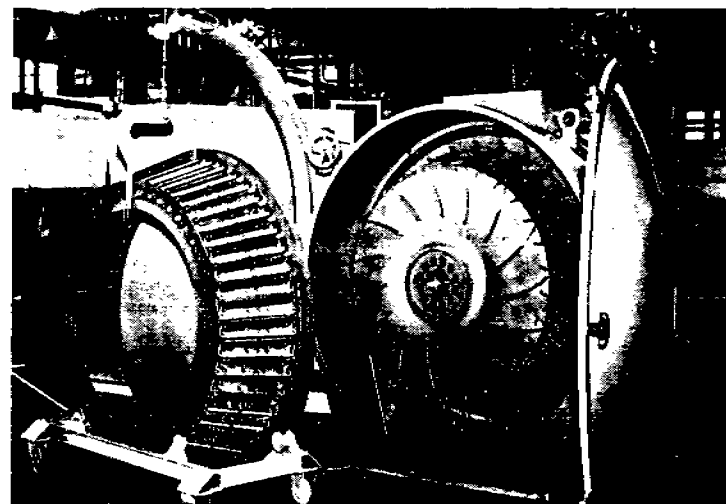
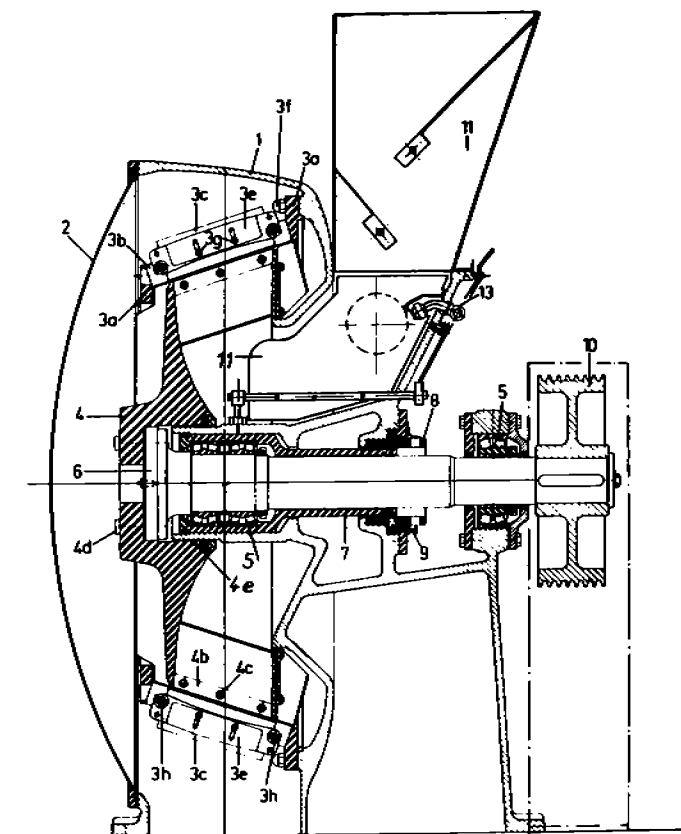


Figure 7.47. A conical flaker with the knife ring removed (Schumann 1970).



- | | |
|---|--------------------------------------|
| 1. Machine housing | 4. Rotor |
| 2. Housing door | 4b. Counterknives |
| 3. Knife ring | 4c. Counterknife bolts |
| 3a. Knife ring flanges | 4d. Bolts for holding rotor to shaft |
| 3b. Knife supports | 4e. Dust seal |
| 3c. Flaking knives | 5. Bearing |
| 3e. Knife holding plates | 6. Rotor shaft end plate |
| 3f. Bolts holding knife ring in flaker | 7. Rotor shaft housing |
| 3g. Bolts securing knife holding plate to knife | 8. Clearance adjusting nut |
| 3h. Bolts holding knife assembly in place in the knife ring | 9. Locking piece |
| | 10. Drive pulley |
| | 11. Material infeed chute |
| | 13. Water spray arrangement |

Figure 7.48. A cross-sectional view of a conical flaker (Schumann 1970).

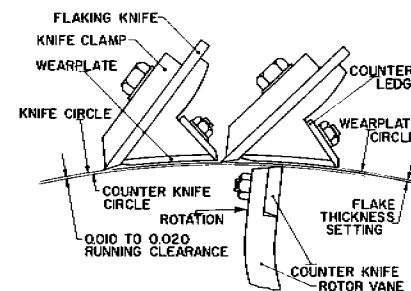


Figure 7.49. The arrangement of knives and rotor counterknives for the cutting of flakes (Schumann 1970).

the shaft falls relatively straight down to the large diameter of the rotor. By this means, the material feeding into the central area of the rotor is distributed uniformly over the full length of the flaking knives.

In Figure 7.48, a counterknife is shown on the tip of one of the rotor vanes, and its exact placement in relation to the knife ring is shown in Figure 7.49. This counterknife is made of abrasion-resistant steel with the leading edges protected by a hard-surface material. Both edges of the counterknife are designed for use; when one edge becomes worn, the knife is inverted and the other edge is used until regrinding is required.

Besides the knives themselves, critical parts of the ring are the knife clamps, the counterledges, and the wear plates. Each knife assembly, consisting of a knife and knife clamp, is bolted with three bolts to the knife support. The knife supports are an integral part of the knife ring. Below each knife support is a wear plate. The wear plates are exposed to heavy abrasive action because of the constant rubbing of wood material and, at times, of foreign material such as sand or small rocks.

The counterledges serve two functions:

1. They provide a renewable wear surface above which the flaking knife projects, establishing the projection of the flaking knife to determine flake thickness.
2. They establish the width of the opening between the counterledge and the leading edge of the flaking knife. The size of this opening has a major effect on the uniformity of the flakes produced.

Figure 7.49 shows schematically the cutting action of the flaker (cross section of knife ring and rotor). The rotor of this flaker functions as a pump impeller that conveys wood material entrained in air. As the rotor revolves within the flaker, flow conditions develop which are similar to a pump, and the rotor distributes the material evenly across the cutting knives. A row of fan blades on the rotor provides air in addition to that generated by the rotor vanes to assure complete scavenging of the cut flakes from the machine.

This flaker has the advantage of two adjustments which control flake thickness. First, a predetermined knife setting is fixed when the knife assembly is put

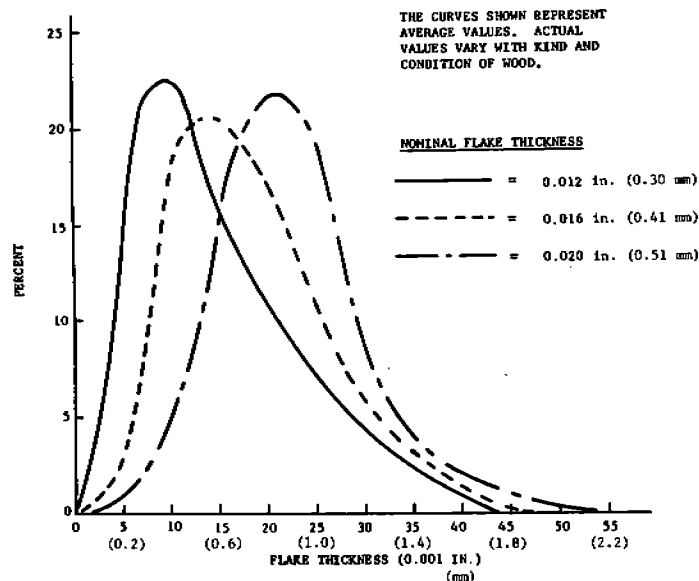


Figure 7.50. Flake thickness distribution when cutting three different nominal thicknesses of flakes (Schumann 1970).

together. Second, the axial adjustment of the rotor within the truncated-cone knife ring allows for precise final control over the flake thickness.

A water spray is available to assist with the flaking of very dry chips and particles (Figure 7.48).

At least two knife rings generally should be provided for each machine. As soon as the flaking knives of one ring become dull, the complete ring can be exchanged for the second one, which normally requires a downtime of 5 to 10 minutes.

After the knife ring is taken out of the machine, it is placed on a ring carrier equipped with rollers. Thereafter, no additional handling of the ring is required for the knife changes. By simple rotation of the knife ring on the carriage, dull knife assemblies can be removed quickly and easily and new sharp ones inserted. Bolt pressure is regulated by using a torque wrench. Any conventional, standard knife grinder can sharpen the flaker knives, and no special tooling is required.

The stationary truncated-cone-shaped knife ring is of simple construction. Problems of unbalanced knife rings due to different knife weights are eliminated because the ring does not rotate. Since only the rotor revolves, there is just one drive motor and belt drive required.

Figure 7.50 presents summarized data on flake thickness distribution in an experiment cutting three different thicknesses of flakes.

Drum or Cylindrical Flakers

The other popular flaker, particularly in Europe and other parts of the world outside of North America, is the drum or cylindrical flaker. Its use, however, is growing in North America. It works particularly well when reducing roundwood into high-quality flakes either for furniture-type panels or structural particleboards. Several designs are available but the basic difference between the two is that one style has to have the stock cut to predetermined lengths while the other style can cut flakes from random-length material. These flakers are in common use where roundwood is used for board. Figure 7.51 shows a typical wood yard when such flakers are used, which is uncommon in the United States. Figure 7.52 illustrates a large drum flaker for pre-cut logs.

For cutting flakes, the long axis of the stock is fed parallel to the flaking drum. The cylindrical flaking drum then slices off the flakes. It is obvious that the rate of feed of the wood into the cutterhead must be regulated in accordance with the rate at which wood is cut away, which in turn is determined by the knife projection. (The cutterhead speed, of course, also affects this, but speed is constant for the machine.) If the wood is fed too rapidly, the cut surface will press against the cylinder, tending to brake the head and overload the cutterhead motor. If the wood is fed too slowly, flakes will be thinner than intended and more variable and uncontrolled in thickness. For each knife projection setting, there is therefore a proper wood feed against the cutterhead. Consequently, the output of the flakers

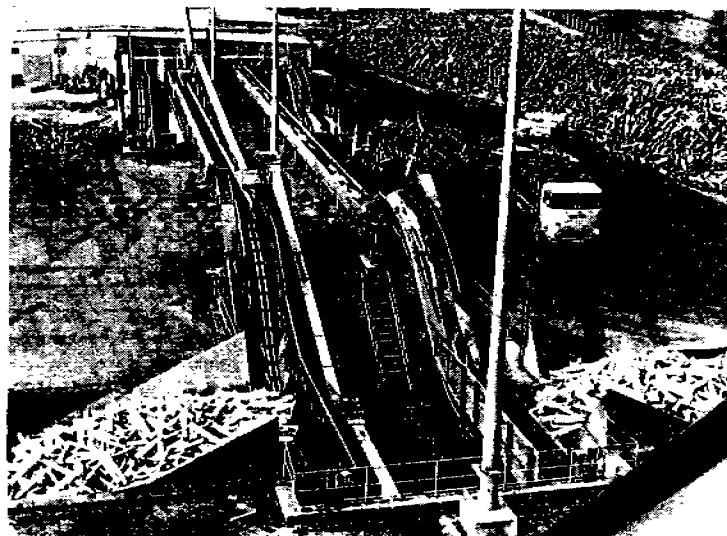


Figure 7.51. Random stacking of 1-m round logs and billets in a round timber loader with following distribution. (Courtesy Hombak GmbH.)

depends on two main factors: (1) the thickness of the flakes being cut and (2) the steadiness with which wood is fed against the cutterhead.

Flake length is established by using scoring knives or by setting the knives in staggered rows, in which case the flakes are torn from the stock leaving ragged ends. The use of scoring knives results in neatly cut ends on the flakes and fewer fines.

Flakers are available to produce flakes from stock lengths ranging from about 3 ft 7 in. to 7 ft 2 in. (1.09–2.18 m). Figure 7.53 shows a schematic drawing of one of these machines and Figure 7.54 shows a cutterhead.

In another smaller-type flaker, shown in Figure 7.55, the wood need not be reduced to a specified length. The wood is fed by gravity in a steeply sloping chute, which in reciprocating up and down alternately feeds the wood against the cutterhead in the up stroke and allows the wood to slide forward into place for the next cut after the down stroke. The reciprocation of the chute is effected by means of a hydraulic cylinder. This type of flaker has been mostly replaced by the larger types.

With the larger types, a horizontal conveyor carries the wood forward to a reciprocating cutterhead. This type also handles wood in any length and therefore eliminates the necessity of precutting to specified lengths. When ready to operate, the stock to be flaked is first clamped to prevent movement during flaking. The cutterhead, in the largest machine which is 4 ft 10 in. long by 3 ft 3 1/2 in. in diameter (1.47x1 m), is then driven by hydraulic cylinders across the stock, reducing it to flakes. The cutterhead then returns to its original position, the stock is unclamped and indexed forward and reclamped ready for the pass by the cutterhead. Flake thickness usually ranges from 0.008 in. (0.2 mm) minimum to a maximum of 0.030 in. (0.76 mm) depending upon the thickness desired.

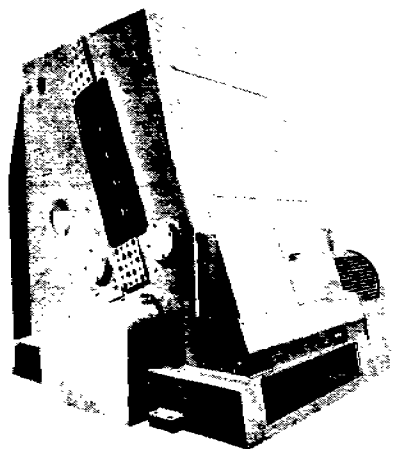


Figure 7.52. Drum flaker. (Courtesy Albert Bezner Maschinenfabrik.)

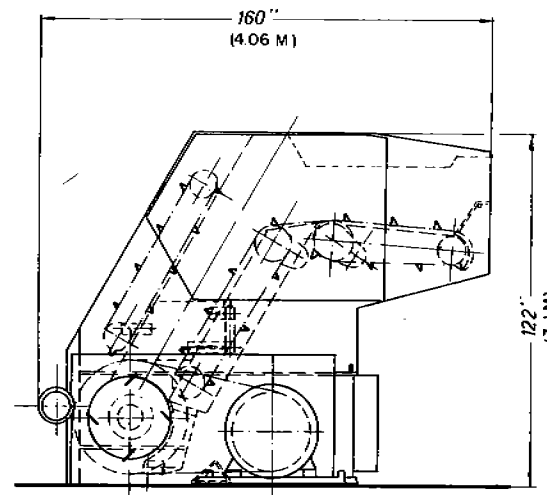


Figure 7.53. Schematic drawing of PRZ Hombak flaker. (Courtesy Hombak GmbH.)

Drum flakers are available which can handle tree-length logs up to 30 in. (762 mm) in diameter. Figure 7.56 shows logs being fed into the plant. The cutterhead and fixed-position backstop for one of these are shown in Figure 7.57.

When tree-length flakers are used, operations such as cutting, splitting, transporting, and feeding pre-cut logs are eliminated. In addition, the tree-length logs lose less moisture in short-time storage than short logs, which makes it easier to maintain flake quality.

In addition to their use on tree-length roundwood, these drum flakers have been used successfully to flake green slabs and edgings which are fed into the machine in bundles.

Skidding logs in the woods results in having large quantities of dirt and stones adhering to the bark. These impurities will cause severe knife damage if the logs are not debarked or cleaned; thus it is recommended that logs be cleaned before flaking. By bouncing the logs several times on a heavy steel-beam structure before they are put into the feeding unit of the flaker, a large amount of sand, stones, and loose bark particles can be removed, and much longer duty cycles of the knives can be achieved. It should be noted that in many cases logs are flaked in Europe without debarking.

A commonly used method of fastening the knives in the cutterhead is shown in Figure 7.58. The knife (A) is fastened onto a knife carrier (B) by means of screws. The knife and knife carrier are held in place by a spring-loaded gib (C).

When the knives need resharpener, the cutterhead is turned to bring the gib of the first knife to be removed directly under a lever mounted on the cutterhead

housing. The gib is forced down by means of this lever, compressing the spring (*E*), and as a consequence the wedging force of the gib against the knife carrier and knife is removed. The knife and carrier are slid out of the slot, and a fresh knife and carrier are slid back in place. The cutterhead is then moved to bring the next knife slot into position. The process is repeated until all of the knives have been changed.

The dull knives are sharpened by conventional means and then repositioned on the knife carriers by means of a jig. The knife is positioned on the carrier with the assistance of a micrometer dial indicator mounted on the jig.

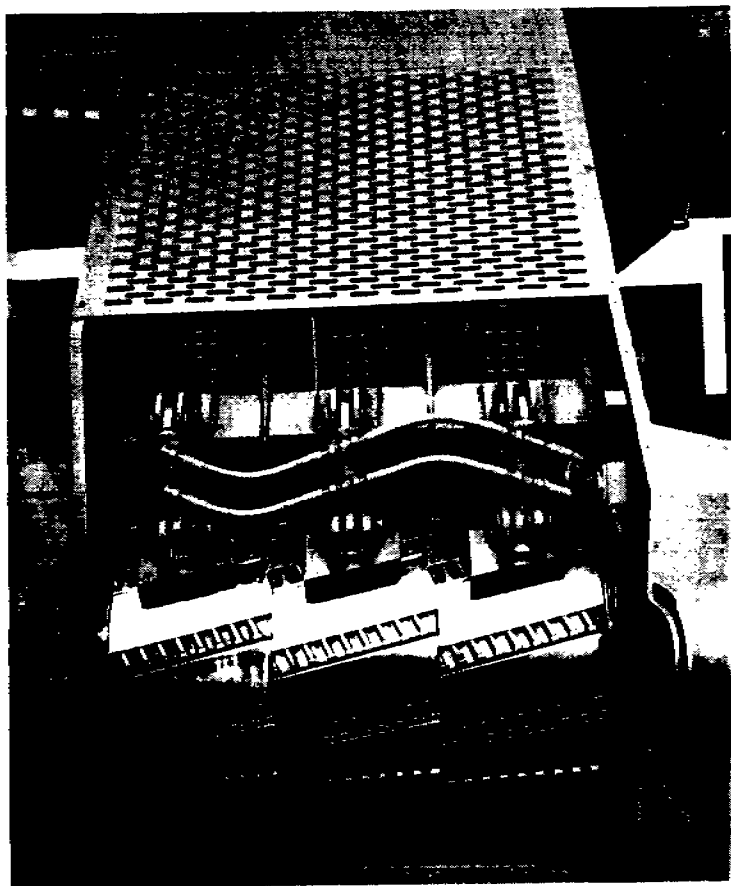


Figure 7.54. Hombak drum flaker, Type Z. (Courtesy Hombak GmbH.)

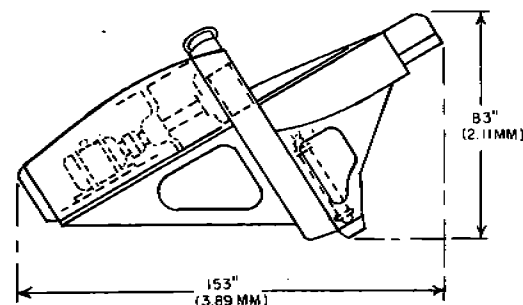


Figure 7.55. Schematic drawing of the Type PRZ Hombak flaker (Mottet 1967).

The position of the knives on the carriers determines their projection beyond the surface of the cylinder which in turn determines the thickness of the flakes cut. It can be seen in the diagram that the position of the knife carrier in the cutterhead always remains the same because of a tongue-and-groove arrangement (*D*) for positioning the knife carrier in the cutterhead.

This knife-changing arrangement provides for a very rapid method of changing knives. With a 10-knife cutterhead, the knives can be changed in as little as three to four minutes. On very large machines, knife-changing time is only 20 to 30 minutes. The ease and speed of knife changing encourages operating with sharper



Figure 7.56. Logs being fed into plant for drum flaking. (Courtesy Hombak GmbH.)

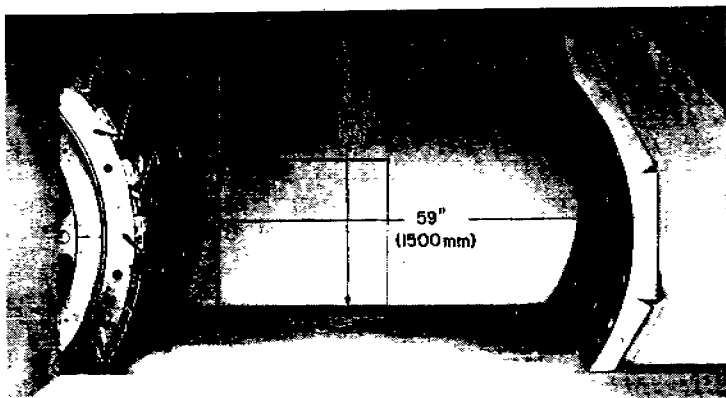


Figure 7.57. Cutting area in a large drum flaker. (Courtesy Hombak GmbH.)

knives on the average and therefore contributes to the quality of flakes. Interestingly, an even faster system of changing knives is being developed and should be available soon.

A wide range of quality flakes can be generated with drum flakers. Outputs can be from about 2600 lbs (1182 kg) per hour with a small unit to 30,000 lbs (13,636 kg) per hour with the largest units available. It should be noted that a greater production of thicker flakes is possible as compared to thinner flakes. When cutting 0.020-in.-thick (0.51 mm) flakes, for example, only half as many cuts are required as would be needed if 0.010-in.-thick (0.25 mm) flakes were being cut. With the rapidly developing structural particleboard product, greater use of the large flakers is expected.

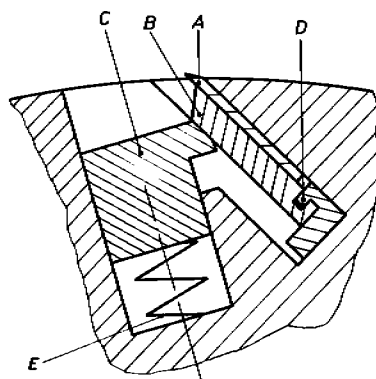


Figure 7.58. A method of assembling knives in the cutterhead. (Courtesy Hombak GmbH.)

Disc Flakers

Disc flakers can provide the highest quality flakes because of the precision with which stock is presented to the knives and the way the knives can be oriented to perform the cutting. Such precision, however, is not economical for most of the industry and some quality must be sacrificed for speed. It is interesting to note, however, that in some cases, thin and large flakes, particularly wide ones, can cause problems in board. These flakes when used as surface material can block the venting of vapor through the board faces during hot pressing, which can lead to blows. Such is the case especially with species that contain volatile extractives as for instance cedars and redwood. In these cases, it may be necessary to use a hammermill without a screen, wing-beater mill, or some flailing device to break the wide flakes lengthwise, thereby providing more surface vents.

Material to be flaked is fed edgewise against the cutting disc, whereas the same material would be fed endwise into a disc chipper for the cutting of chips. Otherwise, both types of machines operate on the same general principles.

Disc flakers can operate with the stock being fed against a horizontal, angled, or vertical disc. The most popular in North America uses a vertical disc. The flaker shown in Figure 7.59 is a 93-in.-diameter (2.36 m) disc oriented vertically. The wood length fed to the flaker is 24 to 24 1/4 in. (610–616 mm). Minimum and maximum log diameters are 4 and 20 in. (102 and 508 mm) respectively. Flake thicknesses can be adjusted between 0.010 and 0.060 in. (0.025–1.52 mm). The disc requires about a 200-HP (149 kW) motor and the disc revolves at about 500 rpm. Twenty knives are mounted in the disc. A sophisticated feeding system consisting of two sets of spiked chains on each side is needed to hold the stock in place until it is completely flaked as the last small piece of a log. Unless the stock is held



Figure 7.59. A large disc flaker. (Courtesy CAE Machinery Ltd.)

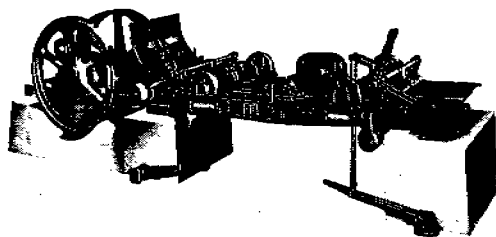


Figure 7.60. A machine for producing wood wool. (Courtesy Maschinenfabrik Rehau.)

properly, large chunks or highly irregular flakes may be generated. This flaker is popular in the rapidly expanding Canadian waferboard industry although drum flakers are also used. Most flakes being generated are about 1 1/2 in. to 2 1/8 in. (38.1–54 mm) long with a great variation in widths since the material being flaked is roundwood and it is impossible to predetermine widths with roundwood. For establishing flake length, scoring knives are set in the disc face. They cut tiny grooves across the face of the stock prior to the slicing off of the flakes by the flaker knives. If boards are being flaked, the basic flake width is determined by the board thickness.

In the waferboard industry, to improve the flaking operation, logs are placed in hot water ponds (temperature about 195°F [90°C]) for periods up to about four hours before flaking. Shorter conditioning times are used in the warmer summer months. This type of conditioning is used with both drum and disc flakers.

EXCELSIOR OR WOOD WOOL PREPARATION

Excelsior or wood wool products are relatively minor at present. Shortages of synthetic resins, which encourage the use of Portland cement as a binding agent (the normal for wood wool products), and the fire resistance of such products may lead to a significant expansion of this part of the industry. It should be mentioned, however, that resin can be used for wood wool panels. Figure 7.60 shows a typical machine for producing wood wool. In most machines, the log is held parallel to a reciprocating slide on which are mounted alternate slicing and scoring knives set for the desired thickness and width of excelsior. The log is fed downward against the reciprocating slide during the cutting operation.

MATERIAL HANDLING AND STORING

Conveyors and bins are used throughout the process. For convenience, they are being discussed here.

Storing and handling chips and particles, as with any part of the composition board process, result in a number of interactions between the various particles and their characteristics and the conveyor or bin configuration. For example, there are

differences between wet and dry material. Flakes, being small wedges, tend to accumulate and jam into some pieces of conveying equipment, and this has to be taken into account in the design. Fiber, because of its low bulk density, can cause all kinds of problems in conveying and handling. All factors must be considered before choosing the final equipment. Many pitfalls are waiting to trap the unwary if they rush this part of the design phase of a new plant. There is no universal conveyor or bin that works equally well on all types of particles.

Conveyors

A number of different types of conveyors can be used, including screws or augers, belts, chains, vibration, and air or pneumatic systems. Air systems now have the problem of pollution to contend with as air exhausted to atmosphere must be cleaned of small particulate matter.

Simple belt-type conveyors are popular in the industry for fast movement of material such as shavings, chips, and blended furnish (Figure 7.61). Screw or auger conveyors are used for more precise operations such as feeding attrition mills where they can also serve as metering devices. Screws can be set in either the horizontal, inclined, or vertical position. In the vertical position, the simultaneous lifting-turning motion conveys granular material uphill along the helical trough.

Chain conveyors (Figure 7.62) can serve as a simple conveyor in many variations or as a metering conveyor as shown in Figure 7.63. Such a conveyor also can act as an elevator (Figure 7.64) in either the vertical or inclined mode.

Vibrating conveyors can move fragile particles without damage. If desired, other processing steps could be employed, such as screening, drying, and scalping. However, these are uncommon in the industry at present. Vibration can also be used effectively on material feeders for granular material, but they cannot be used too effectively with fiber.

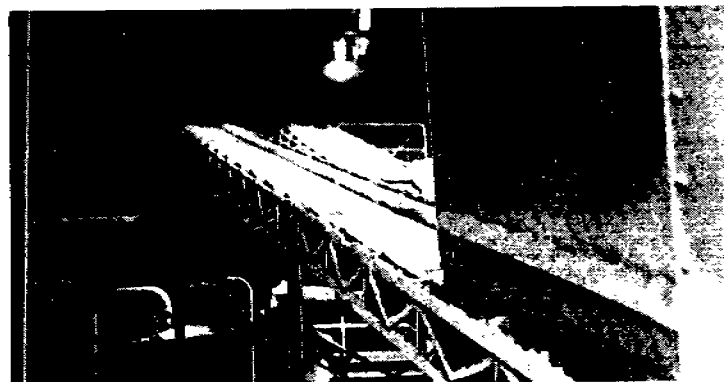


Figure 7.61. Belt conveyors carrying furnish from face and core blenders to the former. (Courtesy Washington State Univ.)

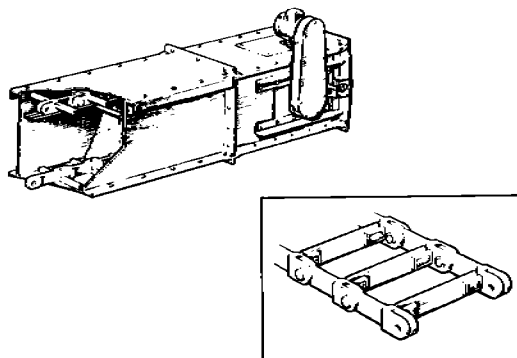
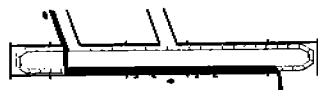


Figure 7.62. Two types of conveyor chains. (Courtesy Redler Conveyors, Ltd.)

Basic Conveyor

Horizontal or inclined – controlled or flood feed – multiple inlets and outlets.



Basic Conveyor with Hoppered inlet

For materials which must be fed directly into the conveying run – controlled or flood feed.



Split-leg Conveyor with Hoppered inlet

Multiple inlets feeding directly into the conveying run – controlled or flood feed.



Two-way Conveyor

Conveying in both directions at the same time – multiple inlets and outlets – controlled or flood feed.



Metering Conveyor

Discharges from a flood feed at a rate determined by an integral metering control gate. Can also be fitted with variable speed drive for variable rate feeding, or with totalising counter for batch measurement.



Figure 7.63. Typical conveyor arrangements. (Courtesy Redler Conveyors, Ltd.)

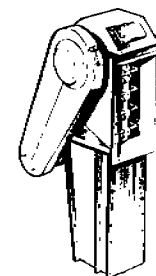
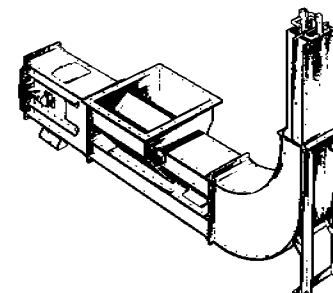


Figure 7.64. A chain elevator. (Courtesy Redler Conveyors, Ltd.)



Bins

To eliminate binning problems with the raw material as received, in many U.S. plants the particles are stored outside, as shown in Figure 7.65, or in large storage sheds. Material usually comes in by truck and is dumped (Figure 7.66) and then blown by air conveyors to the storage area. Conveyor belts mounted overhead deposit the particles in the desired pile (Figure 7.67). The dump operator controls the conveyor belt or belts, which can be adjusted over the length of the storage building. The operator can check on the storage area by using a television setup. Thus the large building becomes a large "bin." Usually such material must be stored in a building rather than outside as the finer particles can be blown about, causing air pollution. Front-end loaders (one shown in Figure 7.65) are used to meter the raw material into the plant by the scoopful.

Characteristics which affect bin design and operation are: particle size, moisture content, bulk density, angle of repose, angle of slide, coefficient of friction, abrasiveness, corrosiveness, compressibility, fibrosity or bulk density, fluidity, and the tendency to arch or bridge. It would be desirable never to stop furnish once it starts through a plant. This is very difficult to achieve as plants have failures in operating. Most of these are minor, but provisions must be built in to accumulate material and hold it so that the overall production can proceed as continuously as possible. Thus surge bins are necessary. They serve as a buffer in the flow of material between the particle-generation equipment and the dryers and



Figure 7.65. A raw material storage yard and a front-end loader. (Courtesy Washington State Univ.)

between the dryers and the blenders. Consequently, they are multifunctional as they store, meter, and proportionately deliver material.

Ideally, they are built low and long so that material cannot pack into them to a great degree. However, such bins take up large areas and so bins that are more compact—that is to say, tall and relatively small in area—are used in many cases. These types have more trouble with packing and bridging because of their configuration. All types of bins or silos should operate on the “first in—first out” principle so that no material is left unused for long periods of time.

Bins are built as silos or with a rectangular-shaped configuration. Some would define silos as *round storage structures*, and bins as the *rectangular shaped structures*. Bins are also known as *bunkers*. Wood particles, as is well known, tend to arch or bridge when confined in a bin. A number of approaches are taken to overcome this tendency of the particles to arch or bridge, ranging from live bottom screws to arch breakers. Size of the bin is also important, particularly if material is allowed to sit in them for several days. For example, particles left to sit in a full, large bin can become so well packed that extreme measures are necessary for breaking them loose.

The particle geometry is also quite important when considering storage. Pulp chips are relatively easy to handle, followed by sawdust, shavings, flakes, wafers, and fiber.

Silos: Silos for large bulk storage use several methods for unloading, including a rotating screw revolving on the horizontal axis, a screw operating on a V pattern, a single rotating shaft or arch breaker set on an inclined angle up into the bin operating in conjunction with a plate feeder, by using chains of sweep buckets, and a hydraulic rotor.

Figure 7.68 shows the first type. The single-rotating-screw unloader operates on the bottom of a suspended, circular storage bin. Screw unloaders of this type are particularly effective with wet material. The screw rotates about its own axis forcing the binned material out through an opening in the centrally located rotating thimble. The whole mechanism travels in a circular path about the vertical binned axis. A conveyor carries the discharged material away. The carriage travel speed and screw speed are adjustable. The pitch volume of the screw flights from end to end is varied so that the same amount of material is picked up along the entire length of the screw. As the screw moves forward, all material in its pathway on the bottom of the bin is moved out. The cavity left behind is filled by the material above it breaking and falling of its own weight. The agitation of the screw helps

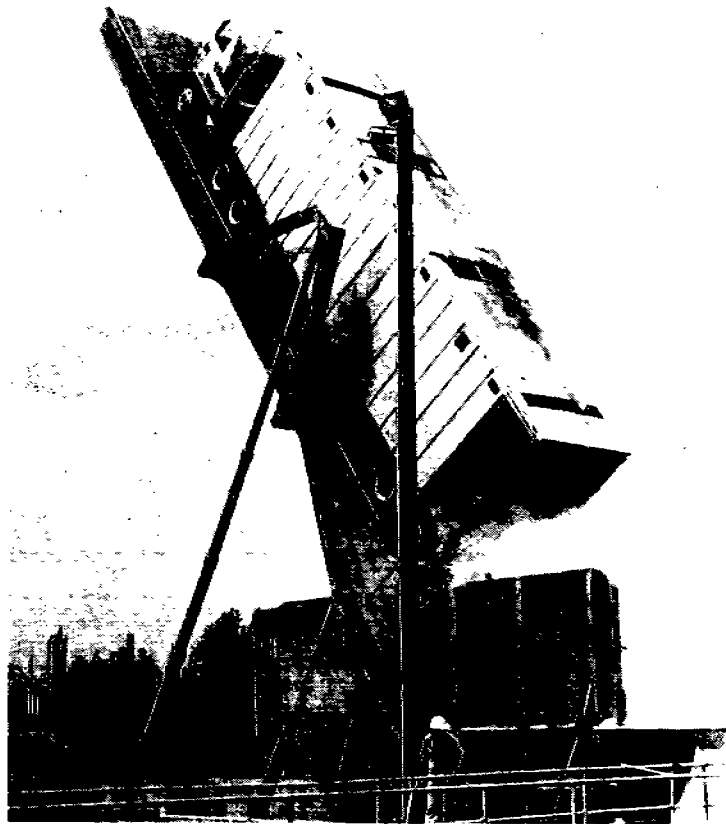


Figure 7.66. A truckload of wood raw material being dumped (Johnson 1973).

with this filling action. Picker bars welded onto the screw flighting can help this filling action.

The V unloader is shown in Figure 7.69. It was designed as an inexpensive positive-discharge unloader adaptable to a wide variety of bin sizes and types of construction. It consists of a single operating screw at the bottom of a suspended circular storage bin. However, the screw does not rotate around its own axis, as with the previous type, but traverses back and forth in an arc. The discharge end is mounted on a pivot outside of the bin. The free end of the screw traverses an arc of about 64 degrees.

The type of discharge shown in Figure 7.70 is a combination of an arch breaker and circular bin discharger of a plate design. The arch breaker rotates inside the bin preventing bridging and allowing the rotary plate feeder to provide a positive discharge of the particles. Variable-speed drives can be used to control the discharge rate. A similar machine developed by Ehram has worked well in the United States.

The system using chains of sweep buckets is illustrated in Figure 7.71. This system can work either with bins or with open storage. From three to six sweep chains are used, depending on bin diameter and volume of flow required. Each sweep chain is fixed at one end to a powered rotating "pull ring" encircling the storage area. The other end is free or trailing. As the pull ring rotates around the periphery of the bin, the sweep chains automatically trail towards the center. The sweep buckets contact the stored material outside of the pile and as the pull ring continues to rotate, the buckets fill and the material is swept through the openings between "grizzly" bars into an outfeed conveyor recessed in the floor.



Figure 7.67. Overhead conveyor in storage building. (Courtesy Washington State Univ.)

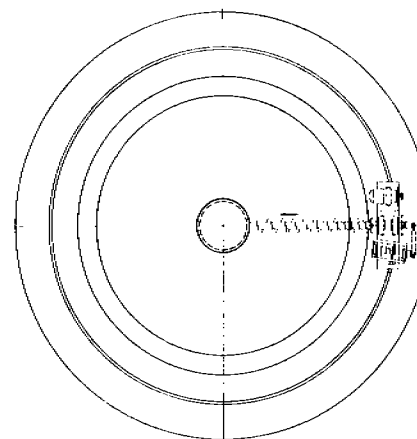


Figure 7.68. Plan view of a Roto-Centric unloader. (Courtesy Miller Hoff, Inc.)

The buckets feed from the outside of the pile under all conditions. Bridging of compacted materials thus does not interfere with the discharging process.

The outfeed is uniform and has been found as an effective surge and feeding system in volumes as small as 300 ft³ (8.4 m³). Very large installations have been made with this system.

In many parts of the world, large storage silos are in use that have a hydraulic rotor at the bottom for removing particles from the silo. As far as is known, all particles except fiber can be successfully handled by this system. Standard sizes range up to 600 m³ (875 yd³) in capacity.

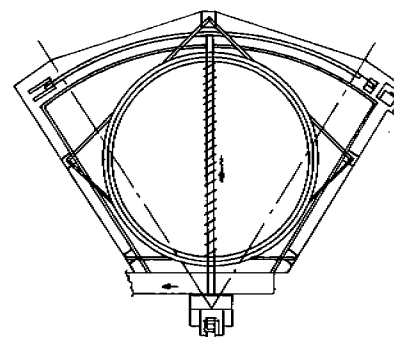
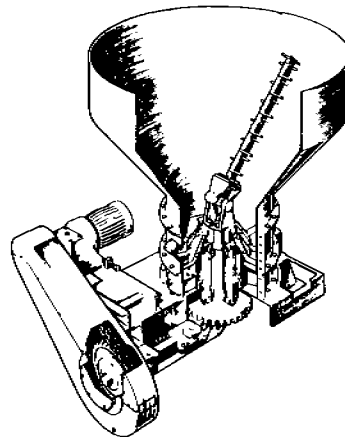


Figure 7.69. Typical plan view of a type V unloader with suspended tank. (Courtesy Miller Hoff, Inc.)

Single Stage

For free discharge of materials tending to arch. Output is dependant on the flow or breakaway rate of the material and the speed of the Circular Bin Discharger. Capacities of up to 200 tonnes/hour are being achieved.



Two Stage

The inclusion of a second stage brings the material flow rate under control and volumetric measurement with a high degree of accuracy is possible with many materials.

Figure 7.70. An arch breaker system. (Courtesy Redler Conveyors, Ltd.)

Figure 7.72 illustrates the rotor system which is mounted on the bottom of the silo. Material is fed into the silo and leveled by means of a distributing rotor. The hydraulic rotor system then removes the material at a predetermined rate by raking the material over openings in the silo floor. Both arms are mounted under the rotor, or one can be mounted above the rotor so that any bridging of the material is broken up. The set working pressure of the hydraulic cylinder is adjustable from the outside. (Another company's design uses spring-loaded arms, Figure 7.73.) The rotor arms are very rigid and work with full force right up to the silo wall, which helps prevent bridging. If a high resistance is met, however, the

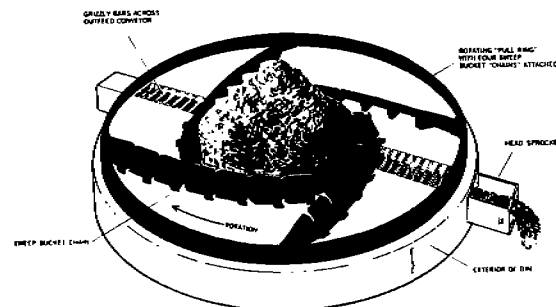


Figure 7.71. System using chains of sweep buckets. (Courtesy Atlas Systems Corp.)

1. Oil container.
2. Oil level inspection points.
3. Pump with motor.
4. Manometer.
5. Oil filling cap.
6. Return flow filter.
7. Pressure limit valve.
8. Connection for the hydraulic oil flow.
9. angular gear.
10. Rotor arm.
12. Rotor arm shaft.
13. Pulling chain.
14. Hydraulic cylinder.
15. Oil reservoir for reverse side of piston.

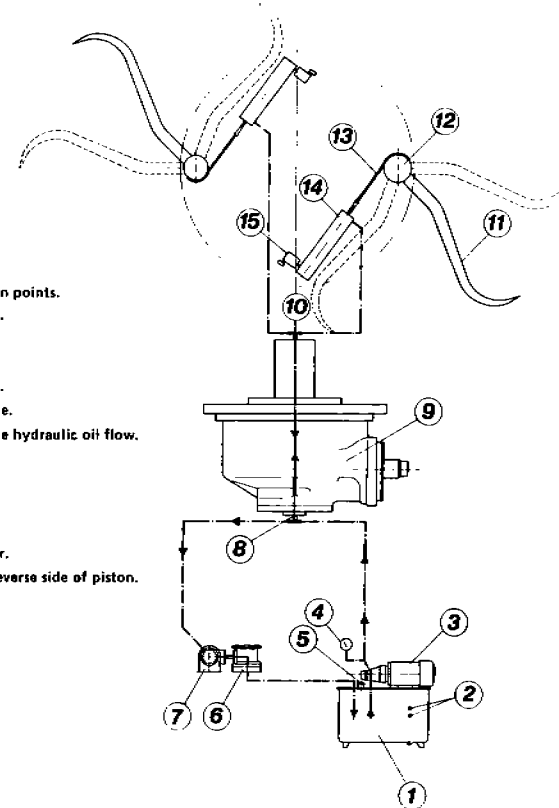
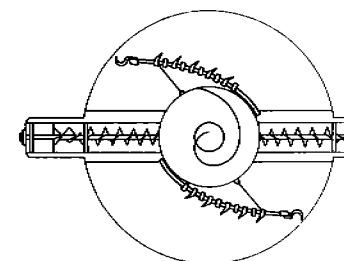


Figure 7.72. Plan view of rotor discharging system. (Courtesy Saxlund A/S.)

Figure 7.73. Silo using spring-loaded rotor (Ryman 1976).



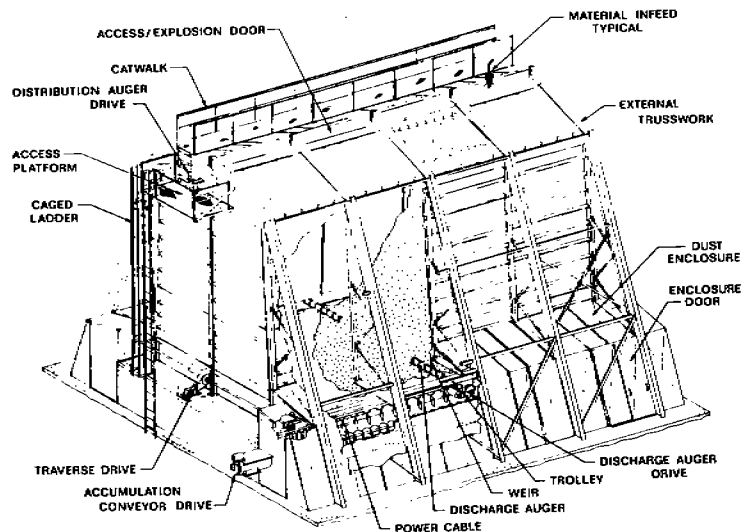


Figure 7.74. A traversing screw unloader. (Courtesy Clarke's Sheet Metal, Inc.)



Figure 7.75. Discharge end of a traversing screw unloader. (Courtesy Miller Hoff, Inc.)

rotor arms give way (shown in Figure 7.72) as a pressure limit valve is included as part of the hydraulic package.

Material is carried away by screw conveyors or bucket conveyors mounted beneath the silo in various ways. These conveyors can be installed to help randomize and blend the material.

Traversing Screw Unloaders: This type of unloader operates beneath a suspended wall rectangular bin, a below grade-level pit or an A-frame-type structure. The bin sides are normally inward sloping to help prevent bridging of the material. This is an all-purpose unloader operating with single or twin counter-rotating feed screws as shown in Figure 7.74. The screws traverse back and forth along the entire length of the bin discharging particles. Figure 7.75 shows one in operation.

Live Bottom Bins: Live bottom bins in use utilize screws, drum-rolls, chains, and belts as the active bottom of the bin. They are rectangularly shaped and normally have inward sloping sides so that there is a larger area at the bottom to minimize bridging or arching.

Figure 7.76 shows a typical bin configuration under which screws or drum-rolls are mounted. Constant- or variable-speed drives can be used. The screws drive the material across to one side of the bin to the discharge end. Screws are excellent with chips, shavings, and sawdust. The drum-roll-feeder type has a high discharge rate and passes the material between the rolls as shown in Figure 7.77. The surfaces of the rolls are interspersed with welded lengths of bar stock or other similar material for a positive feeding action.

Belt bottom feeders are low-volume, high-discharge metering bins effective with low-bulk-density materials. The material is advanced ahead by the belt bottom while being scalped across the top to keep a constant head. The material is raked off the front and deposited into a conveyor, as shown in Figure 7.78. This type of bin works well with flakes and wafers.

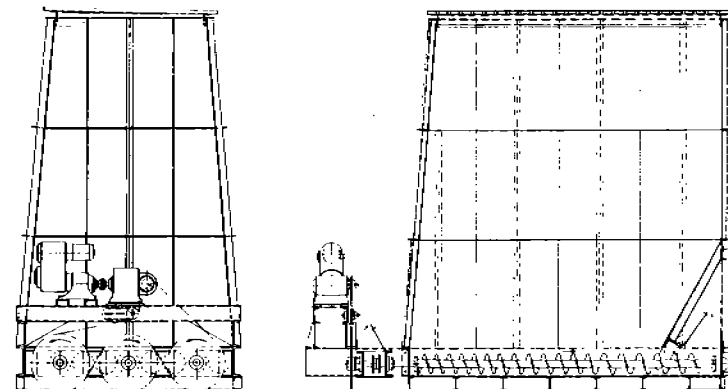


Figure 7.76. Typical arrangement of a live bottom bin. (Courtesy Miller Hoff, Inc.)



Figure 7.77. Drum rolls turning, showing positive, controlled feeding action. (Courtesy Miller Hofft, Inc.)

Chains are effective means of discharging fine, dry material such as sander dust. They also serve as the live bottom of the fiber bin that has performed excellently in the field (Figure 7.79). Wing-type drag chains pull the fiber into "doffing" rolls (Figures 7.80 and 7.81). The fiber is metered between these doffing rolls (14 in. or 356 mm in diameter turning at about 175 rpm) where it is aerated so that it can be handled by air systems or belt conveyors without any clumping.

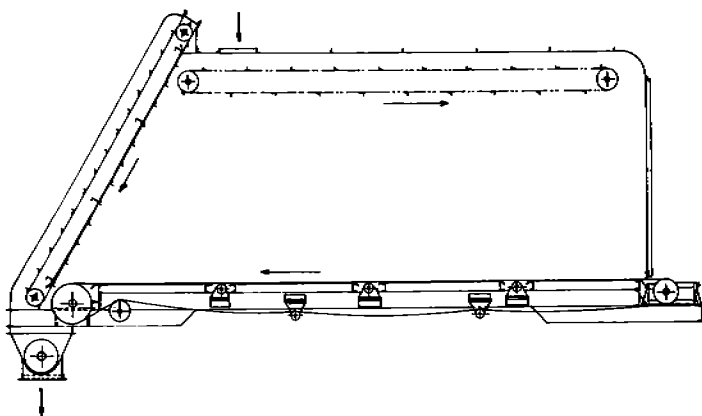


Figure 7.78. A belt bottom feeder. Arrows indicate material flow. (Courtesy Miller Hofft, Inc.)

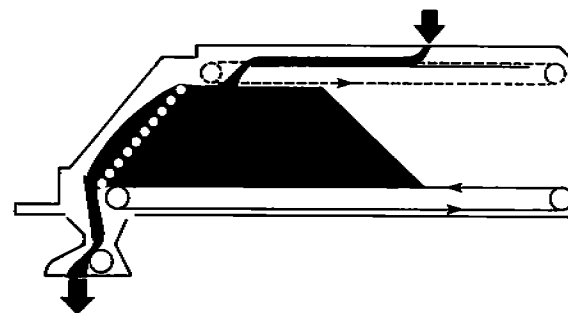


Figure 7.79. Live bottom bin with doffing rolls (Ryman 1976).

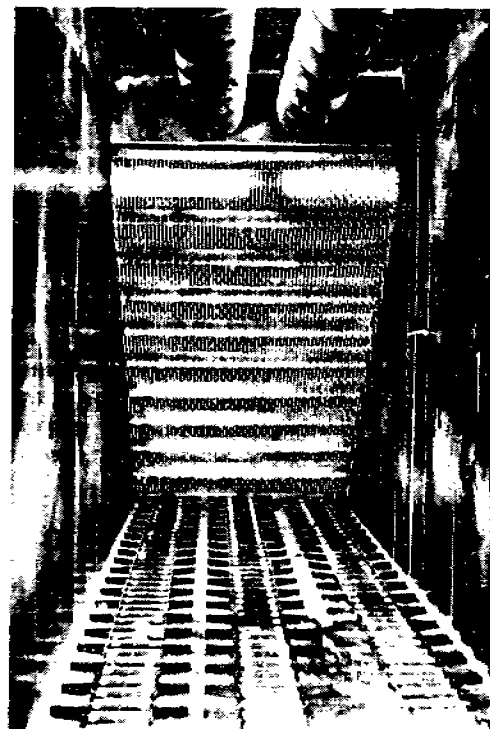


Figure 7.80. Inside of doffing roll bin, showing drag chains on bottom, doffing rolls at the far end, and the overhead leveling screws (Patten 1976).

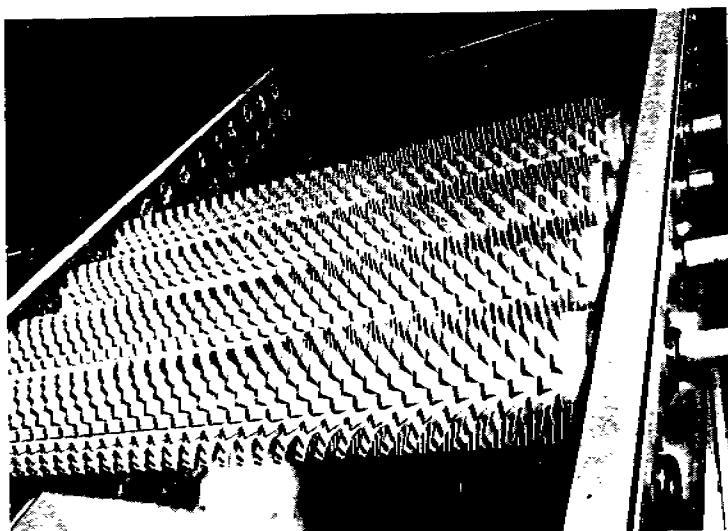


Figure 7.81. Close-up of doffing rolls (Patten 1976).

Overhead screws serve to level the incoming material and move it to the rear of the bin, keeping a constant head of material in the front of the bin near the doffing rolls. The fiber should be fed into the bin immediately behind the doffing rolls to maintain a full bin in the metering area.

Explosions are always a problem with fiber. From field reports, it is advised that at least 1 ft² of venting to each 35 ft³ (0.99 m³) of capacity be used. Covers on explosion vent doors should be solidly chained to the bin to prevent injury to operating personnel. Venting should be directed away from the operators. The door at the end of the bin can be opened and the material dumped by reversing the chains on the bin bottom in case of fire. This has been a particularly effective system when using pressure-refined fiber.

When dealing with fiber, only those bins absolutely necessary should be used to avoid the plugging and variable-feed type of problems associated with fiber.

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8.

DRYING PRINCIPLES AND PRACTICES

Drying is a critical step in the processing of composition board. Rarely does the furnish arrive at the plant low enough in moisture content for immediate use. Exceptions to this rule will be found in the few plants using powdered phenolic resin and dry shavings or flakes generated from kiln-dried lumber. In these cases drying may be omitted. But these plants produce a minute amount of the total production. Furnish can range from about 10% in moisture content to over 200%. For use with liquid resin, the major binder in use, the furnish must be reduced to about 2 to 7% in moisture content depending upon process parameters.

Composition board furnish is done in a much different way than conventional wood drying. In a dry kiln, close attention is paid to wet-bulb and dry-bulb temperatures, and sophisticated drying schedules have been developed. If done improperly, the lumber is severely damaged. Drying can take days. In contrast, drying composition board furnish takes place in minutes, or seconds at relatively high temperatures.

Research on particle drying has not been as extensive as on other parts of the process. Some work has been done, as in 1958 when experimental boards were made comparing flash drying with more severe oven drying, where the material reaches much higher temperatures. There was a definite indication of significant differences in the modulus of rupture values for these boards—ones made from oven-dried furnish were lower. Similar differences might be assumed for the modulus of elasticity. Factors that contribute to the drop in strength values might be case-hardening, a problem that occurs to some extent in any lumber or veneer drying operation; changing of the chemical environment on the particle surfaces causing problems with resin bonding; or a flow of natural wood resins and chemicals to the surface if the material temperature becomes too high, which could cause further resin bonding problems. An example of the wood-resin problem is the buildup on the surfaces and ends of lumber that has been dried in a kiln. Such an accumulation could easily interfere with the adhesive bonding properties that are so crucial in board production. These are just some examples of problems faced when drying composition board furnish.

Research is now taking place on particle drying and the application of fundamental knowledge gained should help improve practices and equipment. For now, however, present principles and practices are those to be discussed. Much of the drying equipment used is modified from the agricultural industry, where dryers are used extensively with alfalfa, sugar, corn, etc.

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(4) final moisture content; (5) size and shape of furnish; (6) efficiency in the use of the heating medium (which depends on all the previous factors plus equipment design); and (7) ability of the operating personnel to get maximum heat from a given fuel (this depends on good control of inlet versus outlet dryer temperatures).

A number of operating factors are associated with drying, such as initial moisture content of the furnish and its variations, particle geometry of the furnish, variable ambient conditions, the feeding system to the dryer, contamination and discoloration, and last but not least, fire and explosion problems. Each of these will be dealt with in general before discussing individual dryer designs.

INITIAL MOISTURE CONTENT OF FURNISH

Source of Raw Material

The initial moisture content of the furnish entering the dryer varies considerably depending primarily on the type of raw material being used. If the raw material originates from green wood, the initial moisture content will be much higher than in a raw material from residue materials which have already been partially or completely dried.

Examples of green material are:

1. Green planer shavings which result from surfacing of green lumber.
2. Green residue material (normally chips) from a plywood plant, which result from the roundup of veneer bolts and veneer clippings.
3. Green residue materials (normally chips) from sawmill slabs, edgings, and trimmings.
4. Green roundwood which has been processed into furnish.
5. Green sawdust.

Examples of dry raw material are:

1. Planer shavings from surfacing kiln-dried lumber of any species.
2. Residues from plywood plants (mostly plywood trim).
3. Mill ends from kiln-dried boards from lumber, and millwork plants.
4. Sawdust.
5. Sander dust.

Mixtures of relatively dry and green material, particularly if uncontrolled, can be disastrous. Dry material can be overdried and ignite. It may also be difficult to glue this material. Green material will be too wet and probably will cause blows in the press.

Species

The species of wood being used has a very significant effect on the green moisture content. For example, in the coniferous softwoods, the pines in general have much higher green moisture content (80 to 200%, oven-dried basis) in

comparison with Do content among hard in the order of two t differences between the pine group; but heartwood material standpoint. However, segregate raw mate

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comparison with Douglas fir (about 40%). Even though the range in green moisture content among hardwood species is not so great, there are significant differences in the order of two to one among the common species being used. There are major differences between the sapwood and heartwood of a given species, particularly in the pine group; but since there are no practical means of segregating sapwood and heartwood materials, this usually is not an important factor from an operating standpoint. However, such problems may be handled to a degree if it is possible to segregate raw material by large and small trees and top versus butts.

Average Level of Moisture Content

The average initial moisture content is very important. The amount of moisture in the raw material affects the economics of drying since, regardless of type of equipment, it requires somewhere between 1400 and 2000 Btus (1.48 and 2.11 megajoules) to evaporate a pound of water. The range may be even wider in some plants, depending on the efficiency of the dryer operations. If the initial moisture content is high relative to outlet moisture content (i.e., if the evaporation rate is high), comparatively large drying equipment both in terms of the burner or combustion chamber, drying drum, and conveyor will be required to produce a given quantity of dry furnish. Three basic cost factors are involved: (1) the initial capital investment of the drying equipment; (2) the cost of the fuel to generate the drying medium; and (3) the efficiency of the drying equipment (included in the cost of fuel), which is also influenced by the average moisture content, with higher efficiency expected as the initial moisture content increases.

Variation in Initial Moisture Content

The variation in the initial moisture content of the raw material is more important in determining the final range in moisture content than is the average level of the moisture content. If a wide range exists in the material entering the dryer, the drying equipment must make rapid responses in the burning of the fuel to adjust for the changing heat requirements. Two examples will illustrate this more effectively. Assume in working with green planer shavings that the average moisture content is 60% (oven-dry basis). Also, assume that after the drying equipment has reached an equilibrium temperature state (meaning a fairly stable inlet temperature) and therefore fuel level burning rate has been achieved, the average moisture content of the green shavings suddenly drops to 40%. The types of drying equipment used in many cases will immediately respond to this change by reducing the fuel consumption rate. For a comparatively short period of time, even after the fuel rate has been reduced to correspond to the lower drying load, there will be a tendency to over-dry the furnish because of the residual heat which is contained in the drying drum, resulting from operating at the previous higher inlet temperature level. On the other hand, if the initial moisture content should suddenly increase to a level of 100%, the dryer would immediately respond by increasing the inlet temperature resulting from the higher fuel consumption rate to handle the added drying load. In this particular case, part of this added fuel will be used to increase the equilibrium-state-temperature of the drying drum rather than

for drying the furnish. For a short time there will be a tendency for furnish to be discharged at a higher than desired moisture-content level.

Some of the drying equipment makes adjustments in retention time in the dryer rather than by adjusting fuel consumption rate. Regardless of the method used to correct for the sudden change in initial moisture content, the effect on uniformity in final moisture content will be the same. If the initial moisture content changes gradually from high to low or low to high, the effect on the final moisture variation will be indiscernible. Therefore, if it is possible to have prior knowledge of the variation in the moisture content of the incoming material and if it is practical to uniformly mix high- and low-moisture-content material, the problems previously described will not be serious. The most important factor in drying furnish to a uniform moisture content is to have furnish with a relatively uniform moisture content entering the dryer.

PARTICLE GEOMETRY

The size and shape of the individual particles in the furnish also are significant factors affecting the drying operation. Variation in size and shape during the drying operation can be extremely troublesome.

Size and Shape

Assuming the objective is to supply the plant with furnish at a given moisture content, increasing the size of a particle of a given shape will tend to increase the cost of drying. The larger-size particle will require more heat to remove a given percentage of moisture because of the exposure of less surface area per unit of volume and time.

Unfortunately, it is difficult, and often undesirable, in most of the raw material processing operations to achieve uniformity in particle configuration. For example, less variance in particle size would be expected in starting with roundwood that is reduced to flakes by a disc or drum flaker, since the thickness and the length of the flakes are more closely controlled as compared with raw material such as planer shavings, hogged fuel, or furniture millblocks that are hammermilled. If the range in size is large, there will be a tendency to over-dry the small-size and under-dry the large-size material. The over-dried small particles may present a fire and explosion hazard. From a practical operating standpoint, as far as over-dried small particles are concerned, this may not be a serious problem if the dried material is allowed to remain in an in-process storage bin for a sufficient length of time to allow some equalization of moisture content, namely, a transfer of moisture from the large- to the small-sized particles. However, fire and explosion problems in the dryer still exist.

VARIABLE AMBIENT CONDITIONS

Changing ambient temperature and humidity conditions often make adjustments in the dryer inlet temperature necessary in order to maintain a constant desired final moisture content. For example, if the relative humidity increases

significantly, dry furnish up one or two percent and pressing operation can be a serious problem where hourly or daily

In the winter months many days of subfreezing temperatures are required for three reasons: the need for evaporation of the fuel and as temperature level. This hourly savings, however, to the experience of d.

The method of introducing moisture uniformly in moisture step, uniform feeding systems use a volumetric conveyor operating at a rate that would also be true if a directly from the tailspindle by a screw or

The major problem influence of changing bulk density (weight) such as species (where of flaking knives over time resulting from variation in moisture content. As the bulk density changes, the moisture content has to change. For example, a level of 10 lbs/ft³ (161 kg/m³) factors being equal, the change in drying load because dryer controls

Practical operating conditions that comparative material load coming in first type of feed system conveyed by a belt to comparatively high speed rather than delivering

Feeding pressure-reducing Tube-type dryers are c

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significantly, dry furnish from the discharge of the dryer can be expected to pick up one or two percent in moisture content as it is conveyed through the forming and pressing operations. The opposite is true if relative humidity decreases. This can be a serious problem in a plant, particularly in the southeastern United States, where hourly or daily fluctuations in relative humidity are common.

In the winter months in the northern states, the climatic conditions involve many days of subfreezing weather which affects the capacity of the drying equipment for three reasons. First, if the wood material is frozen, additional heat is required for evaporating the water or ice. Second, the air used to support combustion of the fuel and as the drying medium must be heated from a much lower temperature level. Third, the furnish itself must also be heated more. Daily and hourly savings, however, are much more important than seasonal ones according to the experience of dryer manufacturers.

FEED SYSTEM TO THE DRYER

The method of introducing the furnish to the dryer inlet can also affect the uniformity in moisture content of the dried furnish. In virtually every process step, uniform feeding is extremely important. By far the majority of the feeding systems use a volumetric rather than a weight principle. For example, a screw conveyor operating at a given speed will deliver a given volume of material. This would also be true if a belt conveyor were used and even if the dryer is being fed directly from the tailspout of a cyclone, assuming the material is being fed to the cyclone by a screw or belt conveying system.

The major problem with the volumetric approach in the feeding system is the influence of changing bulk density in the furnish and short-term volume changes. The bulk density (weight per unit volume) is influenced by uncontrollable factors such as species (where more than one species is being used), change in sharpness of flaking knives over the life of the knives, or influence of particle configuration resulting from variation in moisture content entering the initial processing equipment. As the bulk density of the furnish changes, and even assuming the initial moisture content has remained fairly constant, the drying load on the dryer will change. For example, if the bulk density of the incoming material has been at a level of 10 lbs/ft³ (161 kg/m³) and gradually changes to 15 lbs/ft³ (241 kg/m³), other factors being equal, the evaporable load on the dryer has increased by 50%. If this change in drying load is slow and gradual, no particular problem will result because dryer controls can respond.

Practical operating experience with different types of feeding equipment indicates that comparatively small-diameter, high-speed screw conveyors are preferred over large-diameter slow-speed screw conveyors. Minimum variations in the material load coming to the screw conveyors can be leveled out better with the first type of feed system. This same principle applies if the material is being conveyed by a belt to the dryer inlet. It is much better to operate the belt at a comparatively high speed, delivering a small quantity of material to the belt, rather than delivering a comparatively large quantity on a slow-moving belt.

Feeding pressure-refined fiber into a dryer presents a different set of problems. Tube-type dryers are commonly used with fiber. One method exhausts fiber and

steam from the refiner directly to the dryer inlet. At the dryer outlet, the cyclone separates the fiber from the air and steam. The cyclone is equipped with a rotary valve for discharging the fiber. The rotary valve keeps the steam and conveying air from passing with the fiber to a storage bin. Another method has a cyclone before the dryer for separating the steam from the fiber. The fiber is fed through a rotary valve into a tube dryer. Slugs of excessively wet material can cause problems in this arrangement as it is too heavy to be conveyed by air. Thus, it cakes in the dryer entrance and eventually dries out and ignites. A solution to this problem is to use a drop box after the rotary valve cyclone discharge. The heavy material thus drops out because it cannot be conveyed by the airstream and is not introduced into the dryer.

Fiber from atmospheric refiners can also be fed to the dryer by means of a cyclone discharge through a rotary valve.

CONTAMINATION AND DISCOLORATION

Contamination

A problem with certain types of fuel, particularly oil, is the possible contamination of the furnish. The importance of getting complete combustion of the fuel must be emphasized. Complete combustion is more difficult to achieve with oil than natural gas. If complete combustion is not achieved, contamination can be expected in the form of unburned fuel particles which, in the most critical state, could affect bonding in the final pressing operation by interference with the resins that have been added as bonding agents. This condition is not likely to happen if reasonable control of fuel combustion is exercised.

Discoloration

Another problem encountered in high-temperature dryers is the discoloration of the furnish resulting from using excessively high inlet temperatures. In many products this is not critical unless actual charring of the finely divided particles takes place, which again could affect the particle-to-particle resin bond. On the other hand, some manufacturers have found that it is important to maintain color uniformity in the furnish, since it affects the appearance of the finished products. It is possible at high-inlet-temperature levels to scorch the finely divided particles and thus give a grayish cast to the final product.

FIRE PROBLEMS

Instrumentation

A few points on fire problems will be mentioned here, with more details in Chapter 11. With high-temperature dryers, regardless of the particular type of equipment, one must expect to have occasional fires. All of the major manufacturers of this type of drying equipment incorporate in their control systems good

instrumentation to indicate when systems are also built with temperature control preset level. There are a few "out" in the combustion this type of drying process changes in the infed condition of the material as partially plug feed to the dryer.

Fuel

The type of fuel also is more difficult to accept can also be expected residual wood material; major problems in the combustion and minimum end of the combustion a certain inlet temperature fire.

Control Methods

Certainly the char used between the con furnish to open flame and economical manufacturing.

Most operating problems gases from a burner impossible to eliminate oxygen level in the dryer shown in Figure dryer inlet. Some of oxygen content in the emission to atmosphere going into the dryer from gas, hot gas from the atmosphere.

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Instrumentation to indicate either the presence or probability of fires; suppression systems are also built into the dryers. In all cases there is some sort of high-limit-temperature control which automatically keeps the outlet temperature below a preset level. There are also provisions in the equipment to take care of "flame-out" in the combustion chambers. Despite these precautions, the very nature of this type of drying presents fire and danger, particularly when there are sudden changes in the infed of material to the dryer. This can result from change in the condition of the material, discussed previously, or from such unexpected conditions as partially plugged cyclones, screw conveyors, etc., that affect the regular feed to the dryer.

Fuel

The type of fuel also affects the probability of a fire. Experience indicates that it is more difficult to achieve complete combustion of oil than gas. More problems can also be expected when a combination of fuels involving oil and/or gas and residual wood materials such as sander dust are used in combination. One of the major problems in the use of the lower grades of oil is achieving complete combustion and minimizing the chances of an oil-film buildup near the discharge end of the combustion chamber. When this condition reaches a certain point, after a certain inlet temperature level has been reached, the oil will ignite and cause a fire.

Control Methods

Certainly the chances of having a fire are greatly reduced if a heat exchanger is used between the combustion chamber and the dryer, because the exposure of the furnish to open flame is eliminated. On the other hand, this is not the most efficient and economical method of drying the materials normally used in board manufacturing.

Most operating plants use the high-temperature drying principle mixing hot gases from a burner with the furnish. Thus, they accept the fact that it is virtually impossible to eliminate fires completely. Newer developments are lowering the oxygen level in the dryers, thus reducing the risk of fire. One system on a tube dryer shown in Figure 8.1 recycles part of the dryer discharge gas directly to the dryer inlet. Some of the discharge gas also goes to the incinerator. Thus, the oxygen content in the dryer is reduced, heat is also conserved, and the particulate emission to atmosphere is either reduced or eliminated. Three gas flows are mixed going into the dryer furnace, depending on the desired conditions: dryer discharge gas, hot gas from the solid wood incinerator or burner, and makeup air from atmosphere.

The main concern is extinguishing the fire once it starts and, in particular, keeping the burned material from getting into storage bins and other confined areas where the danger of explosion is high. In some systems, it is desirable to keep the fans running for cooling and to remove the material from the dryer. Two methods are popular for handling a fire. One is to contain the fire in the drum and to suppress it. The other is to get the burning material out of the drum and to dump

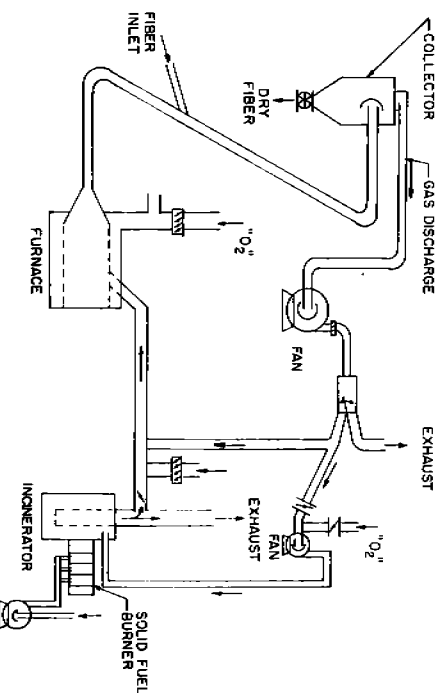


Figure 8.1. A discharge-gas recycle system for a dryer. (Courtesy M-E-C Co.)

it before it reaches the storage bin. With the first method, it is not easy to contain the material in the dryer drum because most of the furnish is usually being conveyed by air. Even if the fan systems are interlocked with the fire control instrumentation, there are still several seconds before the fans can be completely stopped. Due to the high velocity of air (perhaps 4000 to 6000 ft/minute or 1220 to 1830 m/minute) in these air-conveying systems, it is almost impossible to keep some burning material from getting into the storage bins. One of the more practical methods of hedging against this problem is to discharge from the dryer onto an open conveying system, such as a screw of belt conveyor, which can be reversed or stopped quickly when the proper signal is received. Beyond this approach, there remains only to provide adequate suppression equipment, and the discharge conveying systems, including cyclone and conveyor belts and screws.

In the system using a fire dump, the fans keep running to cool the dryer and to remove the burning material. The infed of material is stopped when a fire occurs, as it is with the previously discussed system. The fire dump can be anywhere between the dryer discharge and the conveyor belt leading to the storage bin. An extinguishing system is still required in the dryer in case the fire cannot be handled by the fire dump approach. With bins storing dried fiber, which usually have belt bottoms, the belt direction can be reversed to dump the stored fiber in case the fire reaches the bin.

A development pioneered by the industry itself in certain dryers has been to increase the distance between the combustion chamber and the feed entrance for the furnish. Small sparks thus have more time to extinguish before reaching the furnish. Another approach has been to mount the combustion chamber at 90 or 180 degrees to the dryer itself to provide more time for any sparks to extinguish before they reach the furnish.

Often fires exist in the furnish before it is fed into the dryer. A case in point would be when rocks or metal get into a flaker or refiner, spark, and set a fire in the furnish.

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Three-Pass Dryer

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OTHER PROBLEM AREAS

Greater sophistication in manufacturing procedures, all designed to produce a broader range of products and/or more versatile products have resulted in other drying problems. For example, in systems producing multi-layer or graduated boards, it has been found desirable in many cases not only to vary the type of furnish with respect to particle size and configuration in each layer, but also to vary the moisture content in the different layers. It is generally desirable to have a higher moisture content in the surface layers than in the core layers. The reasons for high moisture in the surface layers is discussed later under "pressing." Usually, however, different dryers are needed for face and core furnish when the moisture contents are different.

In a few of the manufacturing processes it is desirable to introduce the synthetic resins ahead of the drying operation. This occurs, for example, with the blending of resin with fiber as it is being ground in an attrition mill. At the present time, the choice of the resins (usually phenolic) which can stand the heat treatment involved in the high-temperature dryers is limited. Recently, however, several plants have been adding the urea part of urea-formaldehyde resin in the blow line leading to the dryer or raw material being ground into fiber in the attrition mill.

ROTARY DRYERS

Rotary dryers can be broken down into three types: three-pass, double-pass, and single-pass. A number of designs of this third type have been popular in the past but their use has been superseded by the three-pass and the fixed horizontal dryer. It appears, however, that this trend is reversing with more single-pass dryers going into use.

Three-Pass Dryers

Three-pass dryers have been built for over 40 years for use in the agricultural industry, commonly for drying alfalfa. In addition to drying many different forms of wood products such as paper pulp, flakes, fibers and particles, these highly efficient, high-temperature dryers have also been used successfully in the processing of various by-products, industrial wastes, and chemical residues. A representative sample of these other products includes antibiotic residues, beet pulp, canning company by-products, kelp, peat, cattle manure, citrus waste, cooked blood, crab scrap, feathers, fish meal, and packing house by-products. Figure 8.2 shows a bank of these dryers. Figure 8.3 is a schematic drawing showing the operation of such a dryer. Figure 8.4 is a cutaway view of a typical three-pass installation. Several companies supply this type of dryer. These dryers can range in size to over 100 ft (30.48 m) in length and over 14 ft (4.27 m) in diameter.

The three-pass dryer can best be described as a concurrent, multiple-cylinder rotary-drum, direct-fired-type dryer which utilizes heated air as the drying medium. The product to be dried is transported through the system in a pneumatic fashion by means of an induced-draft fan on the discharge side of the drum, with a retention time commensurate with particle size, geometry, and moisture content.

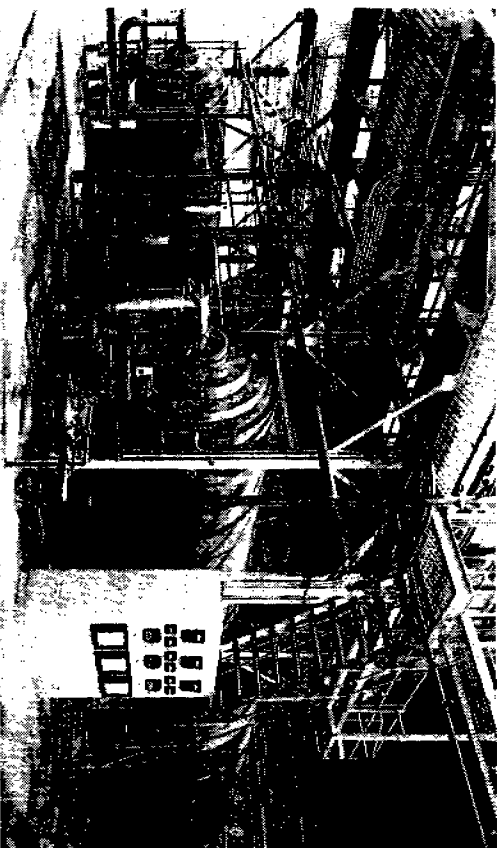


Figure 8.2. A bank of three-pass dryers. (Courtesy The Heil Co.)

The major components of the three-pass dryer are illustrated in Figure 8.4. The first is the combustion chamber which is designed to be in complete balance with the attached drying drum and air-conveying equipment to permit efficient and economical drying for a given drying load. The burner of the combustion chamber can be designed to permit the burning of natural gas, propane, fuel oil, sander dust or combinations of fuels. The second major component is the rotating drying cylindrical drum, which basically consists of three concentric cylinders tied together as illustrated in Figure 8.5. The third major component, known as the exhaust unit, consists usually of one or two fans. The air system can be either positive or negative as shown in Figure 8.6. With a positive air system, the fan is located between the dryer and the cyclone. With the negative air system, the fan is located beyond the cyclone. This system has the advantages of less wear on the fan impeller and no generation of fines by passing the furnish through the fan.

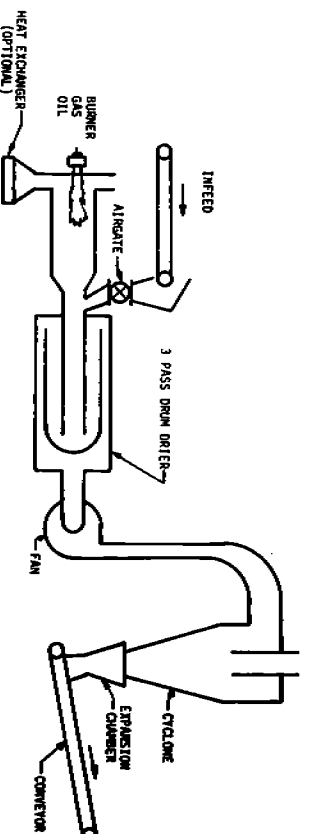


Figure 8.3. A conventional three-pass drum dryer (Bulkat 1971).

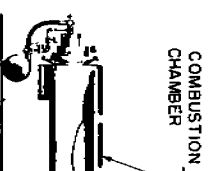


Figure 8.4. Majic 1967).

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Figure 8.5. Cura dryer (Stillinger

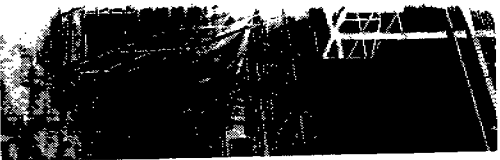
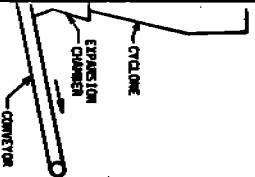


Figure 8.4. The cyclone separator is a simple device that is efficient and compact. It is used in the drying chamber to separate the dust from the air. The fan is used to draw the air through the fan.



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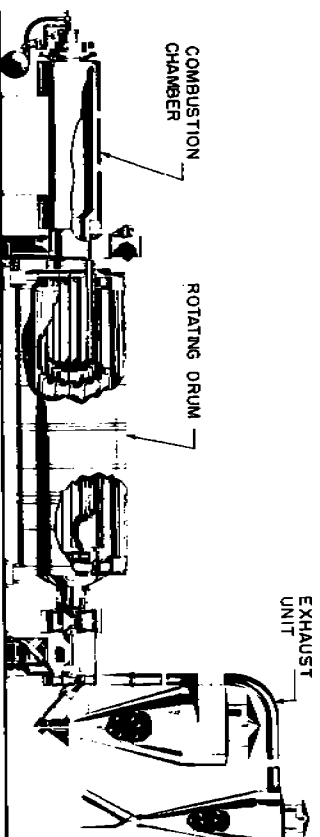


Figure 8.4. Major components in a typical three-pass dryer installation (Stillinger 1967).

One cyclone is used if the material load is relatively light. A second cyclone is used with heavier loads. The first one takes out the heavy particles and the second one, the fine particles. The use of two cyclones also makes it easier to control particulate emissions.

The major components of the electrical control system can involve a temperature controller with thermocouple located between the drum and fan, a high limit indicating pyrometer with thermocouple located between the furnace and the drum. The temperature controller with thermocouple measures the temperature of the gases at the outlet end of the dryer drum and is the primary control instrument. A given outlet temperature corresponds to a specified outlet moisture content for a given size and configuration of furnish. The high limit system

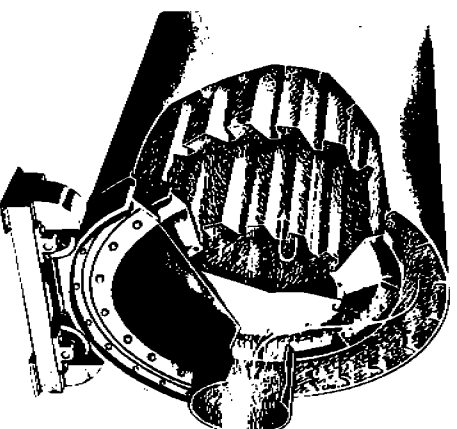


Figure 8.5. Cutaway section illustrating the "showering action" in a three-pass dryer (Stillinger 1967).

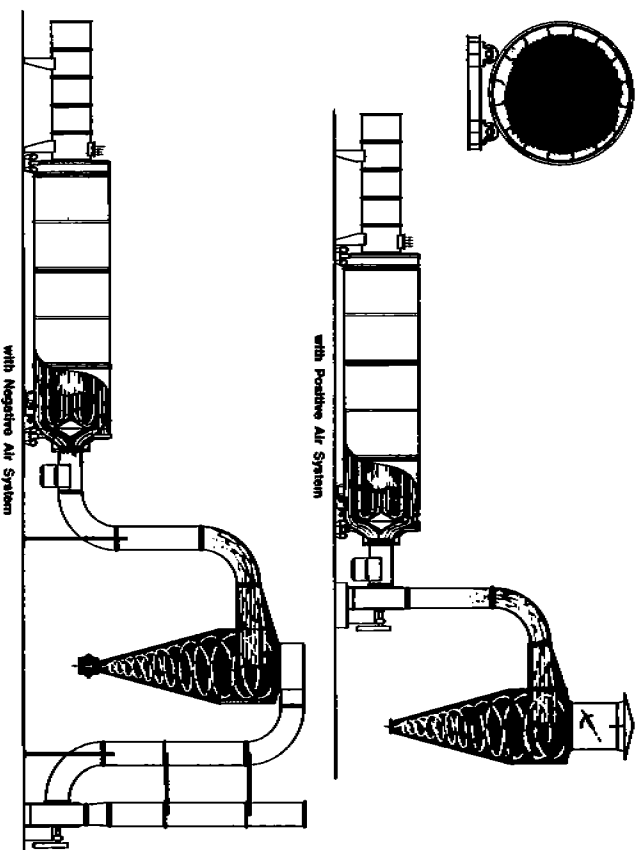


Figure 8.6. Positive and negative air systems for three-pass dryers. (Courtesy M-E-C Co.)

automatically stops the entire drying operation when the outlet temperature exceeds a certain preset level. Inlet temperature can range as high as 1500° to 1600°F (816°-871°C) with wet furnish. This is far above the burning point of wood (about 450°F or 232°C). The "blue haze" problem with dryers occurs at temperatures above 750°F (399°C). However, the drying taking place keeps the wood cool and as long as moisture is present in the wood, its temperature stays below the combustion level. Once all the moisture is removed, fires can be started in a matter of seconds. For drying relatively dry furnish such as kiln-dried planer shavings, inlet temperatures are reduced to about 500 to 600°F (260°-316°C) or lower.

The drying load for a given-size dryer is dependent upon the initial moisture content, inlet and outlet temperatures, outlet moisture content, ambient conditions, air velocity, speed of the drum rotation, etc., and the geometric configuration of the material being dried. For example, the higher the initial moisture content, the higher inlet temperature to which the material can be exposed; and, therefore, a greater quantity of water can be evaporated per unit of time. The configuration of the material being dried influences the evaporable load from two standpoints: in some materials there is a definite upper limit in inlet temperature which the material can stand without burning or discoloration; and, in a furnish consisting of various-sized particles, the evaporable load will normally be controlled by the smaller-size material because it will be the first to dry, although it passes through the dryer faster.

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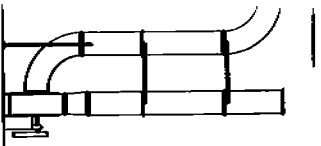


Fig. 15. (Courtesy

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The concept of three-pass drying is as follows. When heat and air turbulence are applied to the furnish, surface moisture evaporates (being absorbed by the heated air), during the constant-rate-evaporation period. This takes place predominantly in the first cylinder where the highest air temperature and velocity can be employed. As the vapor pressure increases within the particle, moisture diffuses to the surface. The larger particles are allowed to slow up in the intermediate cylinders where they can warm up in a moderate temperature zone; thus, the absorbed moisture is removed during the diminishing-rate-evaporation period in the second and third cylinders.

The three-pass cylindrical drum uses comparatively higher air velocities and heat in the center cylinder (first pass) because of its smaller diameter where the products are the heaviest and the wettest. Lower velocities and heats are used in the intermediate drum, and even lower velocities and heats are used in the outer drum. The actual velocity of the heated air varies with temperature and drum diameter as it moves through the three drums. With green planer shavings being dried in any of the larger size dryers and assuming a maximum inlet temperature of 1200 to 1400°F (649°-760°C), the entrance velocities for each drum would be in the order of 1600, 640, and 320 ft (498, 195, and 98 m) per minute. Fine dust emerges in seconds while large particles may take more than five minutes to travel through the drying drum. The three-pass drum provides gentle handling of the particles as they fall a few inches from flight to flight. This is particularly true in the intermediate and outer drums, although there are more "bounces" of flights as compared to single-pass dryers.

Heat is transferred to the product primarily by convection air currents and secondarily by radiation and conduction. The latter plays an almost negligible part when processing refined wood particles. To obtain maximum and intimate contact of the heated air with the product, the interior and exterior of the various cylinders are equipped with properly designated lifting flights which provide the so-called showering action. Air turbulence surrounding each particle must be sufficiently high to prevent or destroy the cool film of vapor enveloping each particle which otherwise would tend to insulate against further evaporation. It follows that if a good differential between air and particle velocity can be achieved, a maximum evaporation rate can be achieved. Care has been exercised in designing and proportioning the drum cylinders, so that velocity of combustion gases and heated air is not sufficiently great to adversely influence the movement of the product through the drying drum.

Electronic temperature control systems usually installed have a built-in anticipating device which minimizes over and under shooting of the desired temperature control point, resulting in accurate control of the product moisture content. Sensitive electrical controls adjust to changes in moisture and changes in product volume while holding the outlet air temperature within close tolerance. Accurate temperature control is further assisted from the nominal amount of refractory used in the combustion chamber; therefore, only a nominal amount of heat is stored. The development of quick and accurate instrumentation for determining moisture content nowadays makes it possible to operate the controls based on the moisture content of the furnish as it enters and leaves the dryer. Naturally, wild swings in incoming moisture levels will make it almost impossible for the controls

to work properly, even if their measurements are precise. The temperature within the dryer just cannot be adjusted quickly. Therefore, as mentioned, reasonably even feed of furnish within predetermined moisture content limits is still of paramount importance even with the sophisticated new moisture measuring and controlling instrumentation.

Two-Pass Dryers

Two-pass dryers have also been developed but their use has not caught on in the United States. The drying action is the same as in the three-pass dryers. An advantage reported is easier access to the interior for maintenance because of more room between the concentric shells.

Single-Pass Dryers

Figure 8.7 shows a parallel-flow direct-heat single-pass dryer used for years successfully in the USA. It is 10 ft (3.05 m) in diameter by 100 ft (30.4 m) long. The rotation is 3 rpm. The gases and dry flakes are pulled from the dryer by two fans turning at a calculated rate of 720 rpm through an opening that splits into a Y configuration. Hot combustion gases are mixed with diluent gases and fed into the dryer drum. Exposure of the wet furnish to the hot gases is accomplished by means of peripheral lifters on the drum wall.

Single-pass dryers, as mentioned, are being used more, although their use is not widespread yet. Hard data comparing these two types are hard to find. Some differences found with the single-pass dryer apparently are less initial expense for



Figure 8.7. Feed-end view of single-pass particle dryer. A conveyor belt feeds the wet flakes to the dryer through the circular chute shown at top center (Surdyk 1971).



Figure 8.8. F M-E-C Co.)

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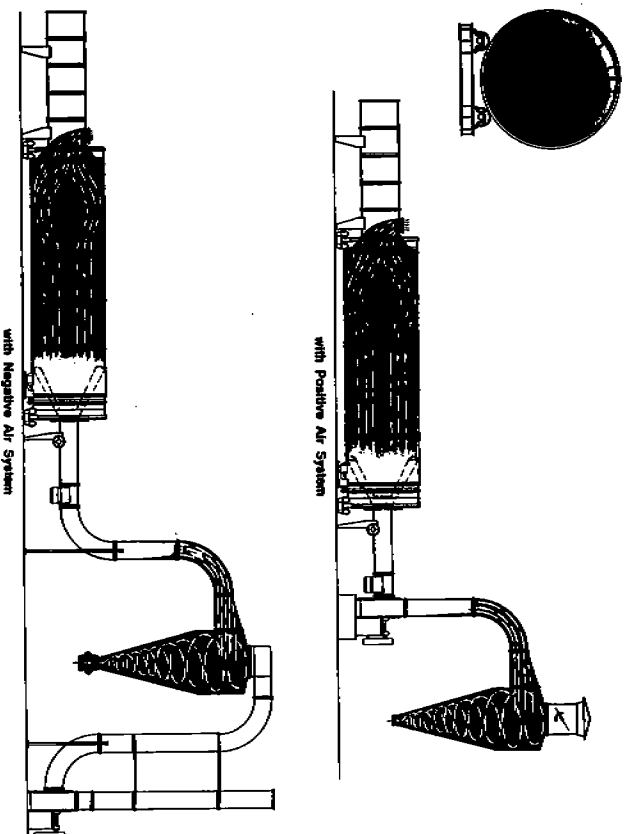


Figure 8.8. Positive and negative air systems for single-pass dryer. (Courtesy M-E-C Co.)

the same capacity, less maintenance because of simpler construction, a requirement for a slightly higher-outlet temperature, and slightly more attention to operation (automatic moisture controls alleviate this problem). The single-pass type takes up more space than the three-pass. The air drawn through the dryer moves the fines through rapidly, preventing over-drying. Controls are the same as with the three-pass dryers.

Figure 8.8 shows this type of dryer with positive and negative air systems. A "target" is shown about one-fourth the way down the dryer. This is simply a metal disc which causes turbulence in the airstream. This turbulence provides for better use of the hot air in the dryer.

Another design from Europe has been used extensively there and has found applications in Canada. This dryer works on a different principle than the dryers described so far, where hot air is mixed with the furnish to be dried at extremely high temperatures. It must be recalled that wood particles at temperatures over 400°F (204°C) will burn before 500°F (260°C) is reached. With dryers operating at inlet temperatures that may reach 1600°F (871°C), particles must pass through the dryer quickly before their temperatures are raised to the charring or burning point.

In this single-pass dryer, also known as a *bundle-tube* dryer, the wet furnish is tumbled in a rotary drum over steam, hot water, or oil-heated tubes similar to the tubes in a boiler. Figure 8.9 is a schematic drawing showing the general arrangement of such a dryer. Figure 8.10 is a photograph of the heated tubes.

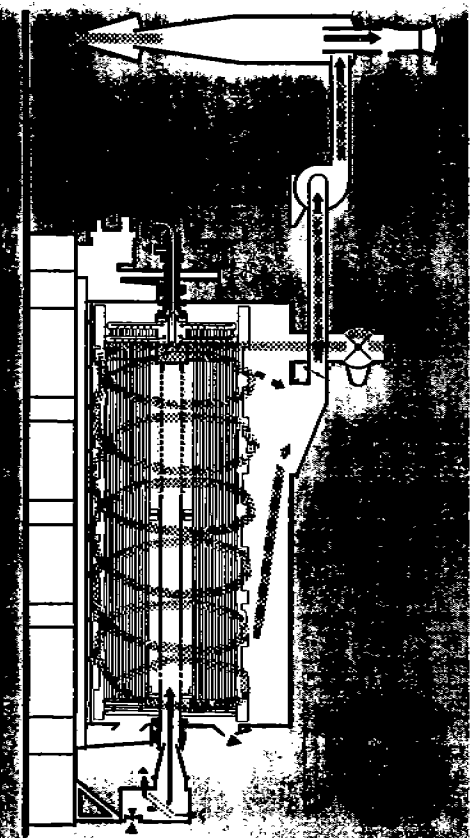


Figure 8.9. Schematic drawing of a typical dryer equipped with heated tubes.
(Courtesy Ponderof Maschinenfabrik KG.)

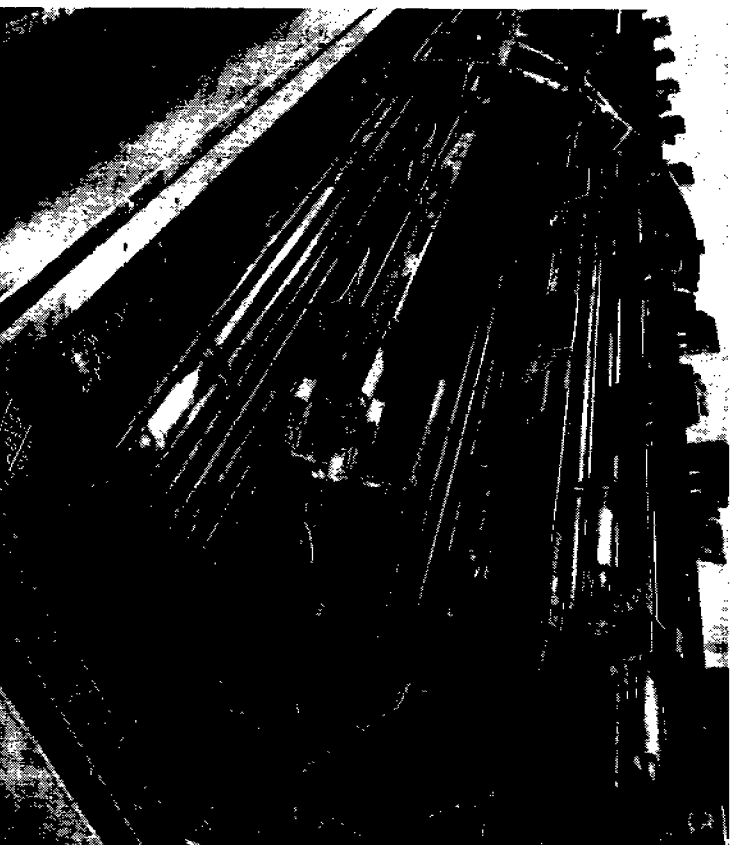


Figure 8.10. Photograph of the heated tubes (Young 1967).

The amount of water or steam in the dryer. Because the temperature in the dryer is high, the moisture content of the material being dried is found in the three to four percent range.

Uniformity of moisture content is important in the three to four percent range. Efficiency is maintained by the use of fans to help control the temperature.

Efficiency is maintained by the use of fans to help control the temperature. Fans are required to carry the air through the dryer.

This dryer is a continuous type. The dryers are supplied with steam when the dryer is in operation. This is a catch fire. This is a safety feature. This is a safety feature. This is a safety feature.

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Jet Dryers

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red tubes.

The amount of evaporation which takes place is controlled by the temperature of the water or steam and by the speed at which the furnish is passed through the dryer. Because of the direct contact of the furnish with the hot tubes, the temperature in the tubes is normally held below 400°F (204°C).

Uniformity of feed into the dryer and uniformity of the incoming furnish moisture content is extremely important. An air-classification such as the one found in the three-pass dryer is not taking place. A preheating drum has been used to help control the incoming moisture content.

Efficiency is rated as high and the electrical energy required is low because no fans are required for moving large volumes of air. Some air must be exhausted, of course, to carry the evaporated water out of the dryer.

This dryer is relatively safe from fires and explosions but they have happened. The dryers are supplied with automatic sprinkler systems. A dangerous time for fire is when the dryer is shut down. Furnish then sits on top of the hot tubes and can catch fire. This is a particular problem when power failures occur, but safeguards are built in to cool the dryer and the automatic sprinkler system is available in the event fires do start.

HORIZONTAL FIXED DRYERS

Two types of horizontal fixed dryer have been developed, one commonly known as a *jet dryer* and the other as a *tube dryer*. The jet dryer was first manufactured about 20 years ago. Tube dryers are of relatively recent origin in the industry as they are specifically used in the plants using fiber for the furnish. Some of the drying tubes are in S shapes but the burners are horizontally oriented.

Jet Dryers

The jet dryer was developed in the Federal Republic of Germany and many have been used throughout the world, although only a few are in use in the United States. Its use has been mostly in the particleboard industry, but some installations have recently been made in fiberboard plants. One of these dryers is shown in Figure 8.11.

The jet dryer operates basically on the fluidized-bed principle. The wet furnish is fed into one end of a stationary drum and heated air is blown into the drum through a slot at the bottom of the drum extending its entire length. The heated air blows through the bed of material; the fluffing and forward movement of the bed is assisted by rotating rake arms or paddles. Figure 8.12 diagrams the general arrangement of the jet dryer. The four major parts are: the heating unit, the jet dryer drum, the circulating fan, and the cyclone collector.

The wet material forms a bed along the length of the drum one-fourth to one-third of its depth. The fan forces the heating medium around the dryer circuit, from the heating unit, through the drum and cyclone collector, and back through the heating unit. The air-lock system is very efficient as heat for drying is mostly kept within the drying unit.

The slot through which the heated drying medium enters the drum is arranged so that the medium enters tangentially and thus causes a rotation or spinning of the

material in the bed as it moves forward through the drum (Figures 8.13 and 8.14). The dried material is drawn out of the dryer drum, through the circulating fan, and is discharged from the drying system through a rotary air lock at the bottom of the cyclone collector.

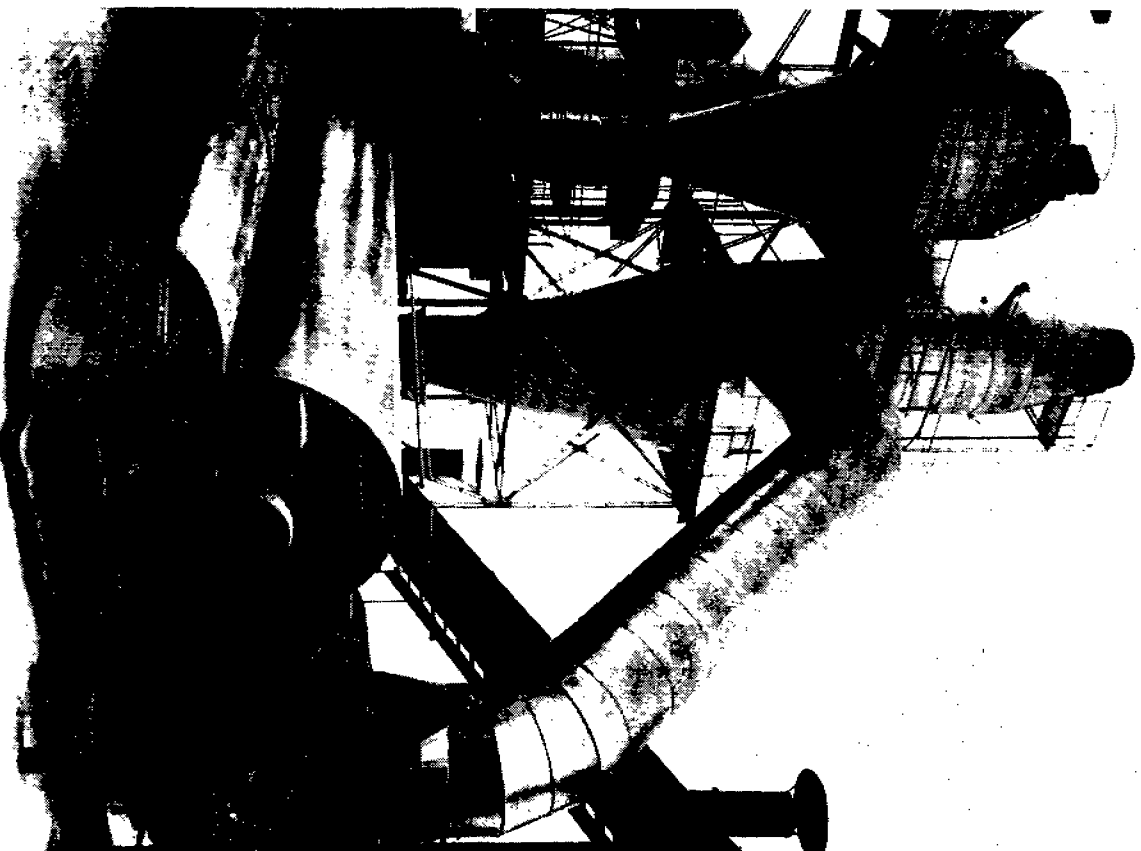


Figure 8.11. A jet dryer. (Courtesy Bütner-Schlde-Haas AG.)

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Part of the spent heating unit. For n equal the volume o tion gases from the to meet pollution s

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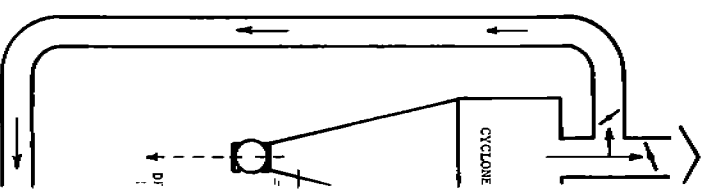


Figure 8.12. Schen

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Part of the spent air is exhausted and the remainder is recirculated through the heating unit. For maximum heat economy only enough spent air is exhausted to equal the volume of moisture evaporated plus the volume of makeup hot combustion gases from the heating unit. Offgas will probably have to be utilized or cleaned to meet pollution standards in many countries.

Of paramount importance in the control of the dryer operation is the series of vanes situated in the air intake slot along the bottom of the drum. These determine the angle of spin of the heating medium in the drum and the speed of forward movement of the furnish, and, through this, the dwell time of the material in the drum. It is to be noted in the diagram that the vanes in the first third of the drum are disposed to hasten the movement through that zone, in the second third to be neutral toward forward movement, and in the last third to tend to hold back the forward flow.

It is characteristic of this system of moving furnish for the finer particles, which need less drying time, to move faster through the drum and for the coarser material, which needs longer drying time, to move more slowly and thus have a longer dwell time. The adjustment of the vanes therefore affords not only control

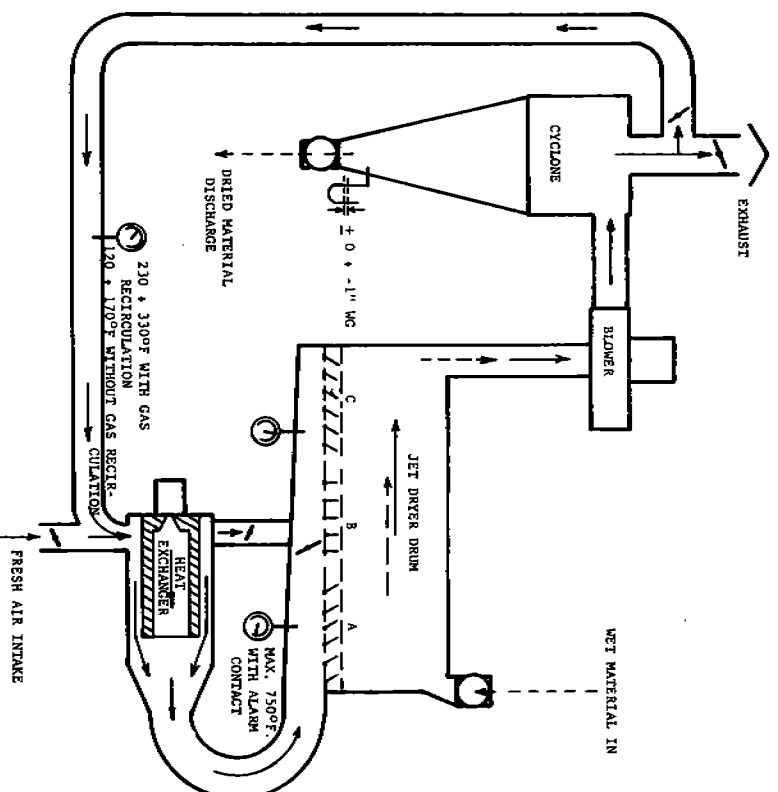


Figure 8.12. Schematic drawing of a jet dryer (Mottet 1967).

of the average dwell time of the material in the drum but also the relative dwell times for fines and coarse material. Thus, the material moves through the dryer at times corresponding to particle size even though the drum is stationary.

If the feed rate, furnish moisture content, and drying characteristics of the furnish are known, the factors under control in the jet dryer are: (1) outlet drying medium temperature—via thermostatic control of the firing rate of the heating unit, (2) material dwell time in jet drum—via jet vane control, and (3) amount of recirculation of heating medium and fresh air makeup.

The jet dryer shown in Figure 8.13 is a direct-heated type which constitutes the majority of installations, employing either gas or oil fuel, which can be supplemented with sander dust fuel from the board sanders. The other type (Figure 8.14) involves indirect heating by means of steam, hot water, or thermal oil. In this type the spent air cannot be recirculated.

The direct-heated dryers operate with inlet temperatures up to 700° F (371°-399° C) while the indirectly heated types, operating usually with the heating medium in the range of 360° to 400° F (182°-204° C), have dryer inlet temperatures of 320° to 370° F (160°-188° C).

Due to the fact that the direct-fired jet dryer operates predominantly with recirculated air comprised mainly of inert gases—nitrogen, carbon dioxide, and water vapor—fire danger is minimized. However, because a combustible material (wood) is dried in a system employing heating medium temperatures above the ignition point of wood, fire danger remains.

Some recent improvements on the jet dryer have been offered, all concerned with maximizing fire safety. First, speed governors for fan, rake shaft, and discharge rotary air lock so that, if one of these fails, both the material supply and furnace will be shut down. Second, automatic cleanout of the dryer cylinder. If the feed material contains large chunks of wood, these tend to accumulate in the dryer

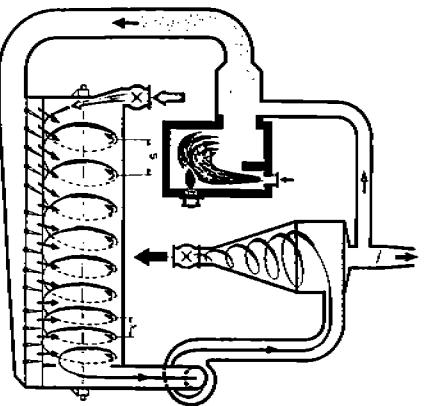


Figure 8.13. Direct-fired dryer showing movement of furnish (Mottet 1967). This type is generally used.

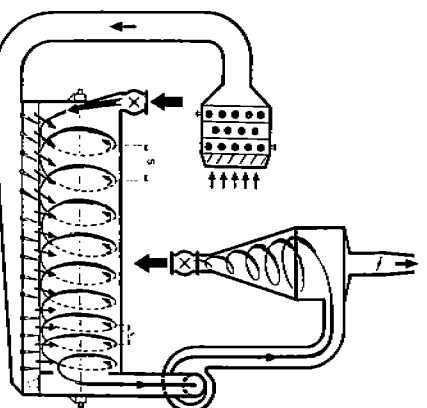


Figure 8.14. This dryer is indirectly fired through means of a heat exchanger (Mottet 1967).

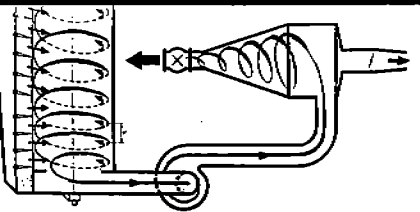
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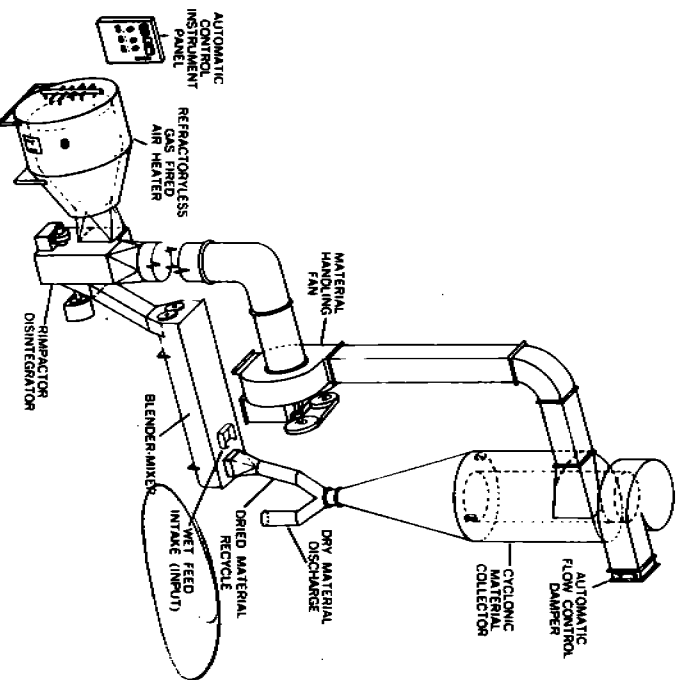


Figure 8.15. A single-tube dryer. (Courtesy Edw. Renneburg & Sons Co.)

drum, particularly if the control vanes are set for long dwell times. With automatic cleanout, the vanes are automatically switched to fast travel briefly to move out the heavy chunks. Third, a nylon thread connected to a limit switch so that, if the thread overheats, it melts and both material supply and furnace are switched off. Fourth, automatic water sprays in the dryer and in the cyclone collector if a specific temperature limit is exceeded. Fifth, hot gas damper control. When the dryer and furnace are shut off, an automatic damper discharges the air from the furnace to an outlet stack instead of into the dryer, where some remaining material may be overheated by the heat stored in the furnace brickwork, shell, etc. The aforementioned new moisture measuring and control systems are also being used to precisely control this dryer.

Tube-Type Dryers

The tube dryers (single-stage or double-stage) are shown in Figures 8.15 and 8.16 and are used mostly for drying pressure-refined fiber. The single-stage tube dryer consists of one long tube of about 225 ft (69 m) or longer with a pneumatic pull-through system (Figure 8.15). A tube dryer installed is shown in Figure 8.17. This particular dryer has tubes about 54 in. (1.37 m) in diameter. When using pressure-refined fiber, the heat can be generated from gas, oil, sander dust, or combinations of these, or a heat exchanger. The double-stage dryer (Figure 8.16)

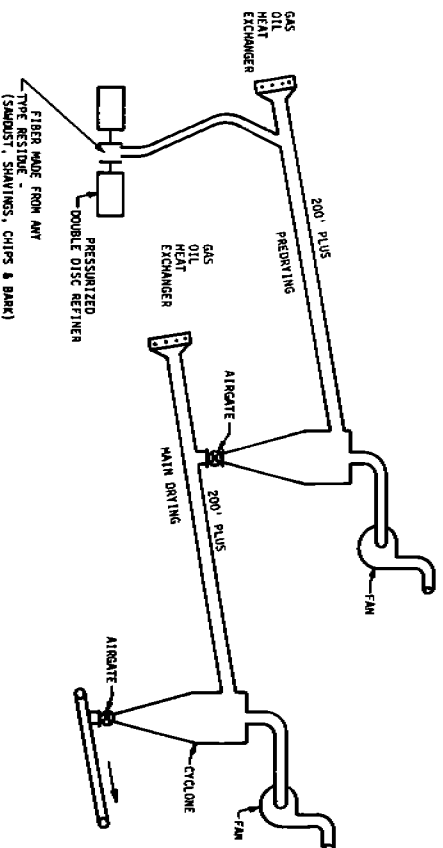


Figure 8.16. A double-stage tube dryer (Buikat 1971).

Maloney (1977)

does the drying in two steps in a total tube length that can be ± 400 ft (122 m) in length. In the first stage of drying, more heat is used, at about a range of 400° to 600°F (200° to 316°C). Temperatures in the second stage are 100° to 180°F (38° to 82°C). In both stages, the moisture is discharged through a pneumatic pull-through system. Moisture control is effected by controlling temperature and, of course, the amount of material entering the dryer. The drying is accomplished in a matter of seconds.

Dry fiber is extremely sensitive to fire and explosion and great care is exercised in handling these problems. One of the most important features is to feed the refined fiber evenly into the dryer, thus preventing a plastering of wet fiber onto the hot tube. If such plastering occurs, the fiber mat, when dried, catches fire and sends sparks through the dryer. In the extreme case, sparks could carry on through the cyclone and into dry fiber storage; should this occur, the sparks would cause wholesale fires and explosions.



Figure 8.17. M-E-C flash tube dryer system. (Courtesy M-E-C Co.)

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MODERN & PARTICLEBOARD DRY-PROCESS FIBERBOARD MANUFACTURING

Thomas M. Maloney



An open conveyor can be used to insure that the drying-type inks are dry before sealing. Nondrying inks must pass through a dryer. The sealer or topcoat is then applied by roller coater, precision coater, or curtain coater. A sealer is used to protect the print of panels for furniture manufacture, where additional finishing steps are to be applied. Sealers are usually nitrocellulose- or vinyl-based. If the completed composition board panel is used as is, generally a heavier coating of a more abrasion- and stain-resistant topcoat is applied as the last step. Alkyd-ureas are most frequently used, combining high build and abrasion resistance, rapid cure response, good chemical resistance, and low cost. Nitrocellulose, catalyzed nitrocellulose, vinyl, and cellulose acetate butyrate (CAB) are also used.

Fairly recently, UV-curable polyesters and acrylics have been introduced, utilizing similar technology and curing systems to the UV-curable fillers. Another recent addition is the water-reducible topcoats based on acrylic or polyester resins, cross-linked with urea- or melamine-formaldehyde resins. Both UV-curable and water-reducible topcoats will see increased use in the future as the industry moves to improve its environmental impact.

Laminating

(to particle board & fiberboard)

When it comes to laminates for overlaying board substrates, there are two types: self-bonding and adhesive-bonded. Adhesive-bonded laminates include wood veneer, the familiar high-pressure plastic laminate used for many years, paper with precondensed amino and phenolic resins, film underlays with phenolic resin or amino resin impregnation and coatings, vulcanized fiber with amino resin coatings, and thermal plastic films such as polyvinyl chloride. The self-bonding laminates are newer and include melamine and polyester resin-impregnated paper. Diethyl-phthalate (DAP) impregnated paper is another but is not used in the United States.

For successful laminating with thin films, it is important to have very fine particles on the faces of the board panel. Very fine material, previously thought to be a resin hog in board manufacture, is being used more and more for achieving smooth surfaces. The smooth surfaces, as mentioned, are needed for preventing show-through of irregularities through the thin surface in papers. It appears that more attention must also be paid to the particle size and geometry in the board core to insure a high-quality end product. If a high gloss on a film is used, irregularities are highlighted. However, most of the thin films are matte, satin or "furniture" finished, which tends to diminish this problem. Particleboard with large particles on the faces needs some type of "barrier," "cushion," or underlayment sheet underneath the film surfaces, such as phenolic- or polyester-impregnated paper (Kraft). The use of panels without faces of fine particles is highly unusual in the United States.

A very low moisture content of the board can cause difficulties when the board and surface film are combined. Too high a moisture content causes stains due to the increased vaporization and also runs the risk of a poorly closed surface. Moreover, such a condition can cause overlay "blisters" and an undue shrinkage in thickness. The optimum moisture content for good bonding ranges between 6 and 7.5%.

Dense panel faces can give problems with adhesion to the films. Poorly cured adhesive joints can let go because of high tensile and shearing forces developed in the laminate. Because most particleboard has a low surface density on the outermost faces, problems can occur because of the lower strength associated with lower density. It has been found that 0.8 to 0.9 sp gr on the panel surface appears satisfactory. Thus, low-density faces must be sanded off, particularly if this has not been accomplished on the regular production line. These faces were mentioned in the discussion of density profile. The density of board for conventional laminating normally exceeds 45 lbs/ft³ (0.72 sp gr). Boards of lower densities have reportedly been used in short-cycle laminating but this is unusual in the United States.

Variations in specific gravity with thin boards are superimposed upon stresses generated by the laminating pressure. These stresses can become of such magnitude as the board shrinks and swells, due to changes in humidity, that stress cracks form in the laminates. Thin boards surfaced with melamine-resin overlays, ultraviolet-cured polyester underlays, and hard urea resin coatings are particularly susceptible.

It is also possible to laminate some overlays onto particleboard during the actual pressing of the particleboard. This is becoming of more importance with the thinner boards that are now being produced, particularly the continuous type where surface layers can be rolled upon the formed mat as it enters the hot press. In this case, almost perfect forming of the mat is necessary to keep a uniform density over the entire area of the final board. Let us now turn to the major types of overlays and their applications.

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Dense panel faces can give problems with adhesion to the films. Poorly cured adhesive joints can let go because of high tensile and shearing forces developed in the laminate. Because most particleboard has a low surface density on the outer-most faces, problems can occur because of the lower strength associated with lower density. It has been found that 0.8 to 0.9 sp gr on the panel surface appears satisfactory. Thus, low-density faces must be sanded off, particularly if this has not been accomplished on the regular production line. These faces were mentioned in the discussion of density profile. The density of board for conventional laminating normally exceeds 45 lbs/ft³ (0.72 sp gr). Boards of lower densities have reportedly been used in short-cycle laminating but this is unusual in the United States.

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High-Pressure Decorative Laminates: High-pressure decorative laminates have been around for many years. They consist of printed papers which have been saturated with thermosetting resin, generally of the melamine-formaldehyde type and bonded to multiple layers of phenolic-impregnated kraft paper under high heat and pressure. This is a high-cost product with excellent impact and abrasion resistance, good chemical resistance, and durability. It should be used where the

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high-performance properties can be best utilized. These uses include tabletops and countertops and other horizontal surfaces on furniture, kitchen cabinets, and on bathroom walls.

The pattern sheet of the composite is a high-quality pigmented alpha-cellulose paper, which is printed generally in up to four additional colors for optimum appearance quality. The sheet is impregnated with melamine resin and a water-alcohol solution and then dried. A clean alpha-cellulose tissue highly impregnated with melamine is assembled over the dried patterned sheet, and these in turn are placed over several sheets of phenolic-impregnated kraft paper. The assembly is then bonded and cured in a press operating between about 250° and 280°F (120°–138°C). Pressing pressure ranges between 1100 and 1400 psi (7.58–9.65 MPa) for periods varying from 45 to 60 minutes and longer, depending on the type of material being made. These laminates must be cooled in the press and the cooling time may be as long as the heating period. The resultant high-pressure laminate is in turn bonded to the wood substrate using contact-type adhesives, polyvinyl acetate (white glues), hot melts, urea-formaldehyde adhesives, casein, etc., for interior or protected applications and resorcinol or similar waterproof adhesives for exterior use. Where high laminating pressures under heat are required, phenolic-bonded high-density board is normally used.

For interior-type applications, the contact-type adhesives offer an advantage which the others do not in that they are suitable for on-site installation and do not require clamping or platen pressing. They provide the most versatile means of installing decorative laminates and have been one of the major reasons for the use of laminates. These adhesives have also been the cause of many problems when they have been used improperly.

Polyvinyl Chloride: One of the best-known overlay materials is polyvinyl chloride (PVC) film. There are two types: plasticized film and rigid. When applied in a plant, the film is usually in a pure form and is bonded to the substrate with an adhesive in a roll-laminating process. This film can be printed and embossed. Prints on the outside of the film can wear away in areas receiving severe abrasion. This has been overcome by printing the pattern on the reverse side of the film, which is placed next to the substrate. The back print is then covered with a ground coat or color coat which masks the substrate and adhesive. With wood grain printed pattern, the back printing technique has a degree of realism very difficult to attain otherwise. It is also possible to put a clear protective film over any of the films where face printing is desired, and this is a common practice.

It is reported that polyvinyl fluoride overlaid PVC film is nearly equal to ceramic tile in stain-resistance and cleanliness. This two-sheet laminated overlay is valuable for the manufacturer of vinyl-clad panels which are folded for cabinet or furniture parts. This system is used for making finished products of square, rectangular, or polyhedral shape. The first step consists of lamination of the board with the flexible plastic sheet. Then accurate miter-grooves are cut through the substrate in the desired locations. Adhesive is then metered into the grooves and the panel is folded into the desired shape, using the flexible plastic sheet as hinges. Figure 18.39 shows some typical configurations that are possible. When back-printed film is used, cutting into the film results in an undesirable and distinct white line. But, by using face-printed film (usually with a protective film on top),

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overcutting to a considerable depth is possible before it is visible from the face.

The back- or reverse-printed film is normally about 3 mils (0.08 mm) thick. The volume market for the face-printed film, which has a clear film laminated to the top, calls for 6-mil (0.15 mm) material (commonly 4-mil [0.10 mm] film for printing with a 2-mil [0.05 mm] overlay or a 3-mil [0.08 mm] film for printing with a 3-mil overlay).

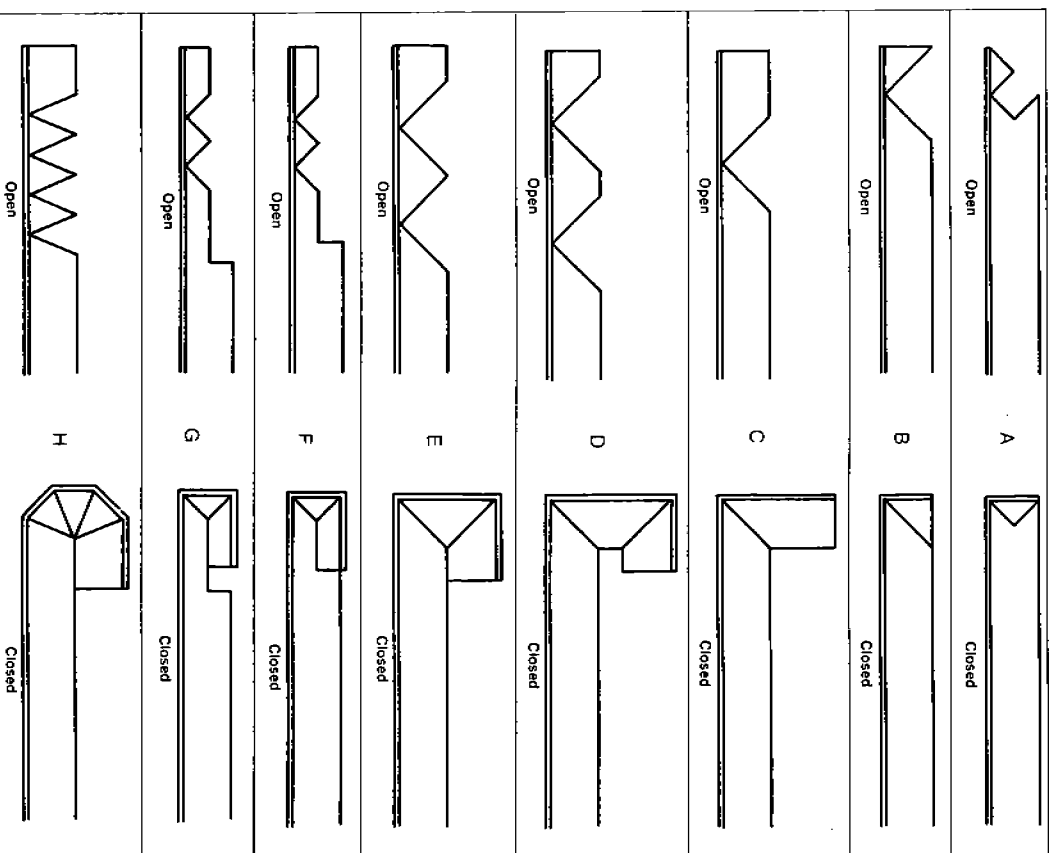


Figure 18.39. V-grooving process permits many simple as well as complex forms to be accomplished in uncomplicated grooving, folding, and gluing procedures (NPA Bulletin 13).

Adhesives are necessary for bonding vinyl film to wood-based panels and generally are of two classes: water-based (polyvinyl acetate) and solvent (polyester or polyurethane) which are applied to the substrate. Epoxy is being used more and more and has the advantage of being 100% solids, thus, there is not any solvent to evaporate. The solvent-based systems are two-part materials and are considered to produce the maximum overlay bond strength. The water systems are usually thermoplastic and are the types most commonly used. Whichever system is used, the adhesive must be resistant to the plasticizers that can migrate from the PVC film. The bond of the film to the panel should be sufficiently strong to resist film creep or shrinking away from the panel edges.

Application equipment for this system can be relatively simple (Figure 18.40). The essential parts consist of rolls to tension the vinyl sheet, a heating unit to soften the film and make it easier to handle, an adhesive applicator roll to apply the adhesive to the film, a heater to flash off the water and also soften the film, and nip or pressure rolls to provide intimate contact between the film and the panel substrate. In some cases, the adhesives may be applied to the panel substrate rather than to the film. Folding and tucking rolls may be used for the edge wrapping of the panel, as pointed out earlier. An embossing roll is normally used to emboss a realistic wood grain effect. Figure 18.41 shows a laminated panel leaving the press.

Vinyl films can also be applied to wood substrates, particularly those with three-dimensional characteristics, by vacuum lamination. The substrate material should be between 6 and 10% in moisture content. It is first shaped for profile to desired contours. The curves and corners are rounded, avoiding 90-degree angles.

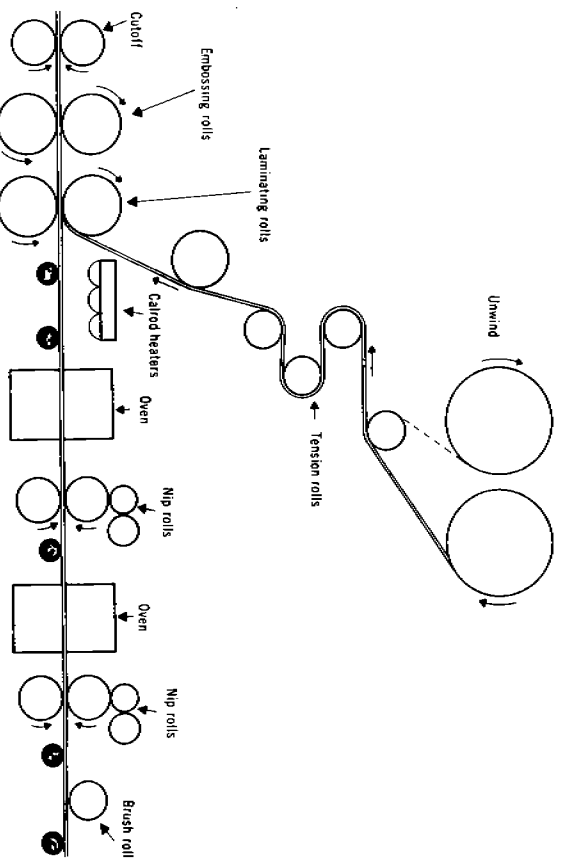


Figure 18.40. A typical direct-roll coating system for application of vinyl film to particleboard (Using Particleboard 1972).

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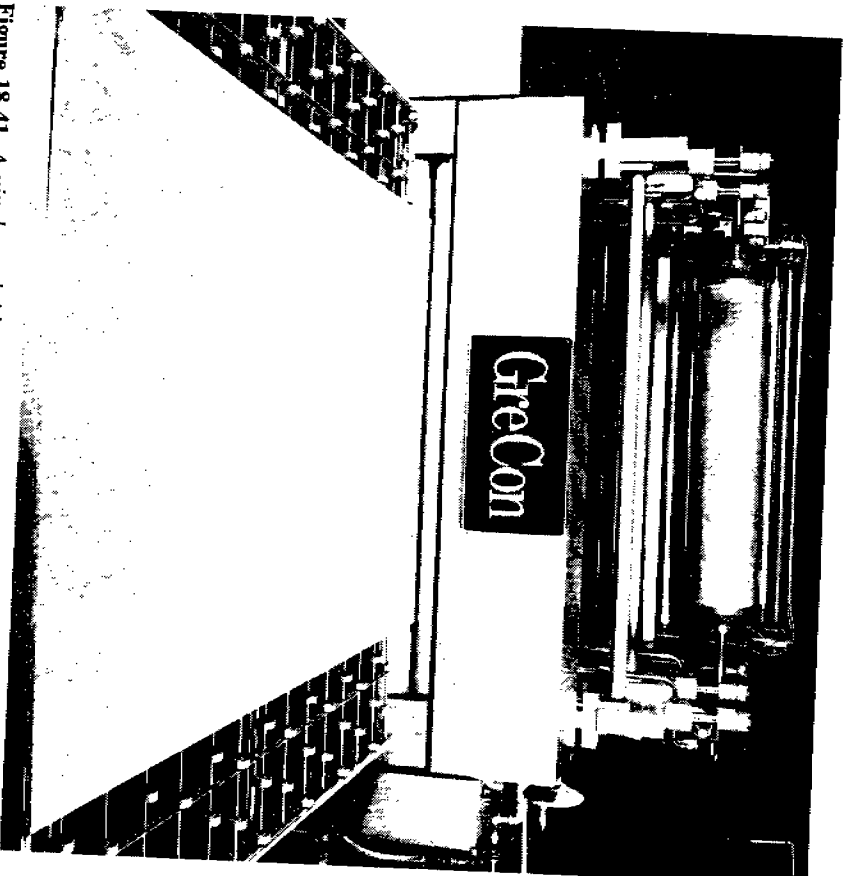


Figure 18.41. A vinyl overlaid panel leaving the press (Wenworth 1972).



Next, the part is spray-coated with a thermosetting resin. Only one coat of adhesive is necessary on dense substrate surfaces, whereas two coats may be placed on the platen of a vacuum-forming machine. A part or a number of parts are then placed on the platen of a vacuum-forming machine. This platen is perforated with holes. Next, the vinyl film is placed in position above the workpiece and clamped into position. The film is then heated from above, while air is forced up from below, relaxing the film. The air trapped under the film is then evacuated to a reserve tank below the assembly, creating a vacuum below the film. Next, the film is drawn down to cover the part's surface and edges. More heat is then applied to the film until the glue line is activated. The heat is then removed and the part cooled while still under vacuum. Cycle times for this system are about four to five minutes in duration. The plasticized PVC film used on wood substrates is restricted to interior applications such as for wall paneling and furniture. Fabric-backed or supported vinyl film, which is used in field applications, can be used for special cases in a plant because the greater thickness lends itself to deep embossing. Textured wood pattern is one example.

Unplasticized polyvinyl chloride film (rigid PVC) is formulated without a plasticizer and is normally thinner than the plasticized material. Thicknesses of 10 mils (0.25 mm) or more are known; however, 1.7- to 1.8-mil (0.04-0.05 mm) film is the volume market. The material is roll-laminated to board substrates. It is reported that a great market potential for this material is in residential siding products, where the chemical resistance, color durability, and low maintenance qualities of the exterior weatherable PVC can be utilized.

Low-Pressure Decorative Overlays: Of great importance in the industry today are the low-pressure decorative overlays. The first was diallyl phthalate (DAP) which was first developed (in the United States) about 1960. By 1964, an overlay material had been developed in straight polyester or melamine systems or combinations of the two.

Polyesters were most popular through the 1960s. Later on, European melamine-resin manufacturers came out with hot press and treating equipment packages for producing melamine-faced board panels in short cycles. A single-opening, fast-cycle system for 5x18-ft (1.52x5.49 m) panels was introduced in the United States around 1970, and several of these plants are operating or about to start operations. One will produce 8x24-ft (2.44x7.32 m) overlaid particleboards in one minute or less. These overlays can contain a decorative pattern or they can serve as a paint substrate.

Before pressing, polyester overlays are flexible and virtually tack free. Melamines are also quite tack free but are more brittle and may fracture if not handled carefully. Polyesters have a longer shelf life and can be successfully stored for six months or more at 65° to 70°F (18°-21°C). Melamines, however, slowly become more brittle and should be used within 30 to 60 days provided they are kept at 65° to 70°F (18°-21°C). Less advanced resins can be used in melamines to prolong their storage life in cases such as overseas shipments. Longer press times, however, are required.

The polyester-type overlay is alpha-cellulose paper treated with polyester resins ranging in resin content from about 52 to 62%. Most of the pressing at present is done in multi-opening presses at specific pressures of about 150 to 250 psi (1.03-1.72 MPa) and temperatures between 270° and 350°F (132°-177°C) at the board surface. In overlaying with both polyesters and melamines, press pads can be used between the press platens and pressing plates which are in contact with the overlays. West Coast U.S. plants, however, are mostly operating without press pads. Press or cushion pads tend to distribute the pressure uniformly over the panel being laminated and are particularly useful with panels of uneven dimension. Release papers are normally used to prevent sticking to the press platens and to provide the type of finish desired (smooth or textured). Pressing time in these presses is about one to two minutes for single-opening presses and five to eight minutes for multi-opening presses. This is time under pressure and does not include loading, unloading, press opening, and closing. The overlaid panels are hot when pulled from the press.

These polyester overlays are nonshrinking while curing and are consequently stress-free and nonwarping if cooled flat. Polyester is tougher and more resilient than melamine. In addition, polyester overlays exhibit less checking, greater impact resistance, and superior machinability.

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The production of the overlays based on melamine-resin-saturated alpha-cellulose paper is rapidly growing in importance. The melamine-formaldehyde resin used has modifiers added to it to enhance the elasticity of the hardened melamine resins. Other materials are added to the resin solution, which later on improves the impregnation of the paper and helps prevent films from sticking to the platens.

The base papers for the decorative films are alpha-cellulose papers, which are used almost exclusively. For impregnation, these papers must have a high wet strength and the right porosity to accept the proper amount of resin. The board laminate consists of one to three papers: an overlay sheet, a decorative sheet and a barrier (or base) sheet. Barrier sheets are not known to be used in the United States. Most U.S. board has very smooth surfaces, eliminating the need for such sheets, which are used to cover porous surfaces. It should be mentioned that balancing papers are also normally used on the back of the board so that, after it is laminated, warping will not occur. In some cases, the same type of melamine overlay is used on both sides of the panel. In this way, if some minor defect happens to occur on one side, the other side is still perfectly acceptable for a top-grade face, and warping problems are minimized with identical papers on both sides.

The melamine-saturated papers usually contain 50 to 55% resin. The overlay or cap paper is an unfilled alpha-cellulose paper which, upon pressing, becomes transparent and protects the decorative paper lying underneath, particularly against wear and tear. The use of a cap sheet is popular in the United States on the wear side of panels. To improve abrasion resistance such cap sheets can also be used on polyesters. It has already been mentioned that the decorative papers are either pigmented solid colors or pigmented sheets with a wood grain or random design in one color or multi-color prints. It should be mentioned that these colors must be fade-resistant and compatible with polyester resins and solvents used in polyester and melamine resins.

Not much melamine overlay is applied in multi-opening presses in the United States. Special handling is necessary to prevent precure of the resin when loading this type of press. In the instances where such laminating is done, press times between two and eight minutes are reported at temperatures ranging from 280° to 330°F (138°-166°C). Pressures are higher than used for polyester, being about 350 psi (2.41 MPa). Release papers can be used to give smooth or textured surfaces. Melamines shrink slightly during curing; consequently, they must be handled carefully if laminated to thin substrates below 1/2 in. (12.7 mm) in thickness. Warp problems, which will be covered later, must be handled. In comparison to polyesters, the melamine surfaces have better scratch resistance at the same resin level.

Formerly, relatively long times were always necessary for applying these types of decorative surface laminates. However, there has been a clear move to high temperatures at relatively short pressing times, made possible by the development of better resin systems.

A great step forward in this type of laminating is the previously mentioned short-cycle process with single-opening presses where lamination is accomplished in about one minute. High-gloss finishes so far have not been possible with this type of finishing. For most applications in the United States, high-gloss finishes are not desirable because any slight imperfection in the overlay or substrate is shown up. Resins with very short cure times (from 20 to 30 seconds or

less) are now available; thus, very fast press times are possible. These fast-curing resins require, however, that the time between initial contact of the film with a hot heating platen or plate to the time it takes to reach a specific pressure of approximately 120 psi (0.83 MPa) must not exceed a value of 15 to 20% of the condensation time. This means that in the case of a condensation time of 30 seconds, loading of the press, closing of the press, and generating of sufficient pressure must not exceed a time of about 6 seconds. Therefore, once the board and overlays are inserted into the press, maximum pressure must be applied quickly or the fast-curing resin in the overlays will polymerize before good bonding to the substrate takes place (referred to as *preure*).

Polyester laminating is accomplished in about 1 minute (40 seconds for resin cure and 20 seconds for unloading and loading in the press). Pressures range from about 175 to 220 psi (1.21–1.52 MPa). Release papers are usually necessary.

Melamine laminating takes about 80 seconds (60 seconds for resin cure and 20 seconds for press unloading and loading). Pressing pressures range as high as 350 psi (2.41 MPa), and resin curing temperatures range from 310° to 350°F (154° to 177°C). Release papers may or may not be used. The use of polished chrome-plated pressing plates and melamine containing a release agent often eliminates the need for release papers.

It must be kept in mind that there are many variations of the low-pressure laminates available and that the figures given here are intended as guidelines. Plants equipped to overlay with melamine can usually operate with polyesters, but the reverse may not be true because of the higher pressing pressures required.

One system in use loads the press by means of a tray-belt on which the composition board with top and bottom overlay is aligned, as shown in Figure 18.42. Unloading is done by a traveling vacuum lift, which travels into the open press and carries out the finished board; or the bottom caul travels out of the press and a vacuum lift behind the press carries the board via an intermediate storage station to the finished board stack. The press plates and press pads (if used) usually remain in the press. In case a vacuum lift is used for unloading a press, the bottom heating platen is usually controlled differently than the top heating platen with regard to temperature. This is necessary to avoid differential curing rates between the top and bottom overlays, as the bottom overlay is in contact with the heated platen longer than the top overlay.

Another type of short-cycle laminating which has been developed is a vertical laminator as illustrated in Figures 18.43 and 18.44. The substrate is cleaned and transferred to the vertical position by a special vacuum lift. The overlay papers are placed in positions and "tacked" there by means of a gluing process. The sandwich is then fed into the vertical press, and heat and pressure are applied simultaneously to both faces of the panel. In both systems the finished panel is then edge trimmed with conventional equipment.

Vulcanized Fiber: Vulcanized fiber has been successfully bonded to wood panel products for many years. It possesses some properties such as toughness not matched by the more common resin-treated fiber overlays, but it has not been able to compete economically with the medium-density overlay products. A paperlike sheet is made from chemically converted cotton cellulose generally treated with zinc chloride and is felted into a multi-layer product of whatever

thickness is desired. It is very tough and dense and has excellent electrical properties. Many of its properties, such as dimensional stability, are quite similar to those of wood. Modified polyvinyl acetate and resorcinol adhesives provide durable exterior quality bond on wood-based panel products. An important use for vulcanized fiber has been as crossbanding in the furniture industry under fine hardwood face veneers applied to plywood, particleboard, or lumber core panels. The sheet provides a stabilizing influence on the thin hardwood overlay and resists telegraphing from the core panel.

Resin-Treated Fiber Overlays: Resin-treated fiber overlays are another important surfacing for wood-based panel products. They consist of cellulose sheets or papers which may be plain, bleached, dyed, or printed, saturated with a resin such as phenol formaldehyde or polyester, and then hot-press-bonded to the wood substrate by heat and pressure. Some systems contain sufficient resin to be self-bonding, while others require secondary adhesive.

High-density overlays are described as a surfacing that is hard, smooth, and of such a character that further finishing by paint or varnish is not necessary. These overlays consist of a cellulose-fiber sheet or sheets containing not less than 45% resin solids based on a volatile-free weight of fiber and resin, with the resin being a thermal-setting phenol or melamine type.

Medium-density overlay is a resin-treated facing that presents a smooth, uniform surface intended for high-quality paint finishes. It consists of a cellulose fiber sheet containing not less than 17% resin solids for a beater-loaded sheet, or 22% for an impregnated sheet, both values based on the volatile free weight of resin and fiber exclusive of glue line. The resin can be a thermosetting phenol type, or a combination of polymers that will pass performance standards of U.S. Product Standard PS 1-74 for Construction and Industrial Plywood. Commercial production is usually hot press laminating, but roll laminating has been done.

A light-weight, medium-density type overlay is manufactured particularly for use with particleboard and insulation board. This phenolic resin-treated paper weighs approximately 33 pounds per thousand square feet without the glue line. When bonded with phenolic adhesives and finished with conventional paints, it performs very well on products for which it is designed. Considerable production of a fiberboard siding product overlaid with this type of material and preprimed and/or prefinished at the factory has been performing well for several years.

Polyvinyl Fluoride: Polyvinyl fluoride overlay is supplied in a variety of thicknesses, up to about 2 mils (0.051 mm). It is commonly roll laminated onto products such as hardboard, utilizing a modified epoxy adhesive. The adhesive is applied to the board, the solvent flashed off, and the film nip rolled to the substrate. The overlay possesses excellent color retention, good chemical resistance, and has good abrasion resistance. However, it is expensive, which limits its use. It has been used on some residential house siding (particularly plywood), where its weathering properties are excellent.

Specialized Overlays: Specialized overlays, such as fiber glass, reinforced plastic, and metal, have not found widespread use in the composition board industry as yet. However, their success with certain plywood products fore-shadows the possibility of more use of these types of products taking place in the future.



positioned over the substrate. (3) The assembly is then clamped prior to being loaded into the press. (4) Finished board is ready for unloading. (Courtesy Siempelkamp Corp.)

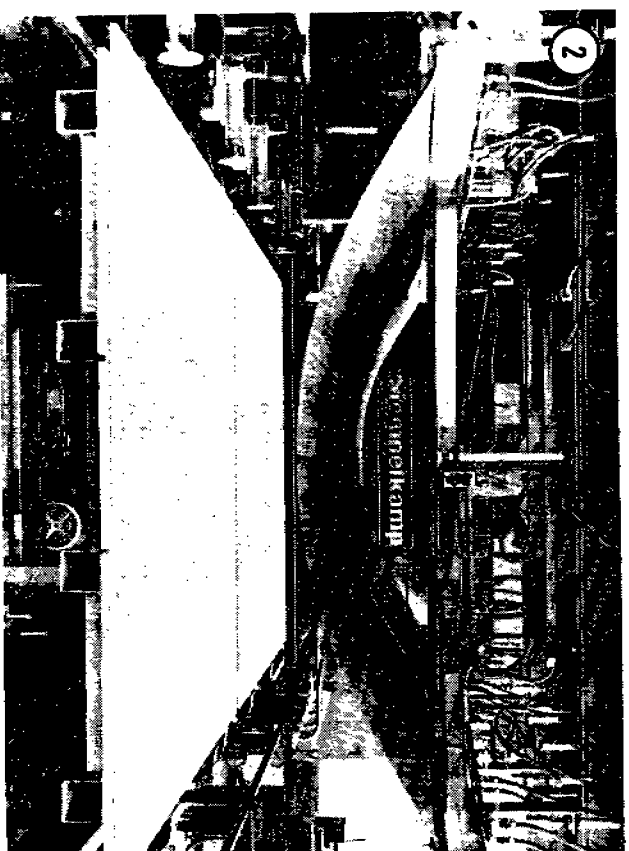
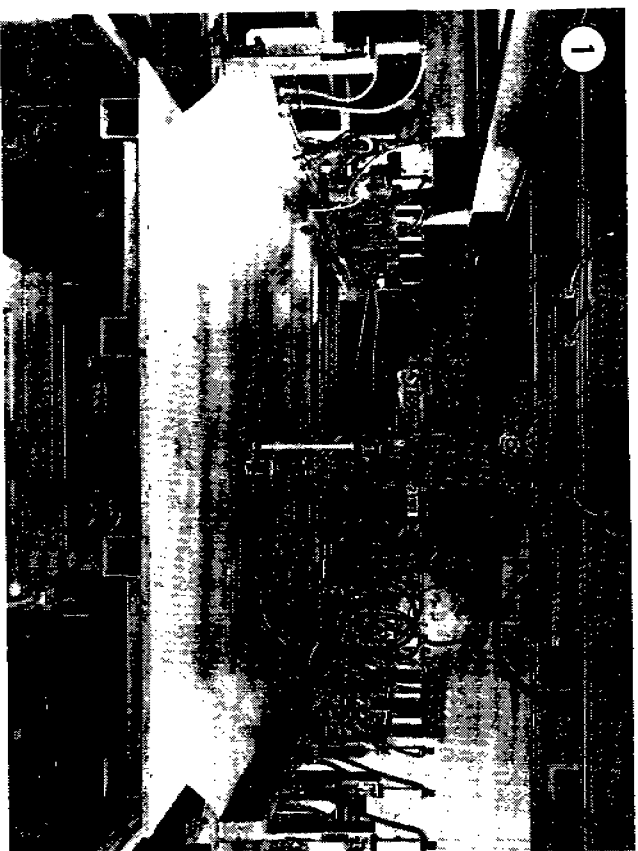


Figure 18.42. A short-cycle press line for overlaying. The four photos show assembly of resin-treated papers with board substrates and press loading. (1) Laydown and positioning of bottom surface papers. (2) The top papers are

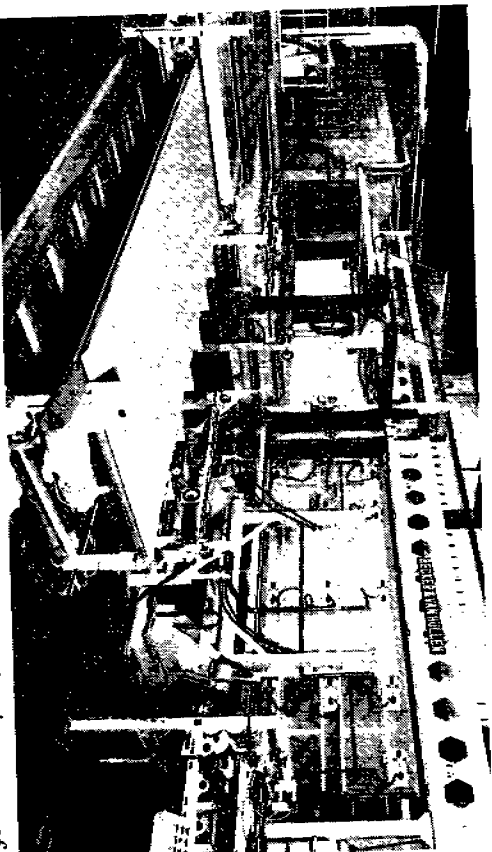


Figure 18.43. The panel in front is raised into vertical position by means of a movable vacuum table shown in rear. Resin-impregnated papers are then fixed to the panel. (Courtesy Becker & van Hillen.)

Warp

Composition boards must stay flat in service conditions, particularly when they are unsupported in modes such as cabinet doors. Wood products have tendencies to warp because of unbalanced construction either from natural causes, such as differential shrinking and swelling between summerwood and springwood, or from man-made causes in panels, such as particleboard where a skewed density profile is developed. Nothing can be done about the natural causes of warping found in lumber and, to some extent, in plywood. If the composition board is produced properly, however, such sources of warp should not exist. However, the man-made causes of warp must be considered and handled. A secondary manufacturer is at the mercy of the board manufacturer in that he has no control over the way the board was produced. However, a secondary manufacturer can induce problems such as a skewed density profile in the panels by sanding only one side of a board he receives, which can result in warp problems.

The type of unbalanced construction developed by sanding can be handled by proper care. Such a panel should not warp when subjected to the forces induced by moisture changes. However, upon applying decorative plastic laminates and backing sheets, differentials in response to the changes in moisture content can cause an imbalance within the panel. These stresses caused by the differential movement are a major cause of warpage in the field. Much of the warpage is created because of different stresses within the materials which are originally bonded together into the laminated composition board final product. There can also be an unequal stress as exerted by the laminate material on opposite sides of the board. This can be caused by having unequal thicknesses of the sheets of material or by having different types of material.

Temporary laminates and backing sheets are found to attain rates in about or such moisture characteristics (direction to the characteristics (ing if conclusion on too short an

It is important conditions before about 40 to 45% but local conditions offset the longit order to prevent moisture change core as does if laminate on both exposed from more expensive used, running the backing sheet.

It should also machine direct response to changes across the machine direction. This prior to final laminate as rubber-based to the substrate



Figure 18.44.

Maloney (1977)

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10.

PARTICLE SEPARATION: PRINCIPLES AND EQUIPMENT

Almost every particleboard preparation system requires the separation of particles. Some fiberboard operations also require separation, but it is not as common as in particleboard. The requirements vary, but fall generally into the categories of separation in terms of particle size by screening, separation in terms of particle surface-to-weight ratio by air-classification, and a third method which is a combination of screening and air-classifying. Input materials can range from dustlike material to chunks of wood. Smaller particles are often directly usable in the process, and their removal means less material needs to be run through particle-generating equipment.

The screens commonly used are vibrating and gyratory. Capacity and efficiency are the two principal criteria for judging screens. Capacity represents the quantity of material a screen will satisfactorily handle under a given set of circumstances. Efficiency describes the quality of the particle separation and can be expressed as a percentage by dividing the amount of a certain size material removed by the amount of such material in the particle mix.

Air-classifiers pass the wood particles through a moving airstream for stratification of the particles. Unlike screening, where size is the only variable which affects the separation, air-classification is affected by both particle weight and surface area. Part of the material air-classified can then be screened if desired. Also, some air-classifiers use screening simultaneously with air separation.

Probably no two board plants in existence have the same screening and classifying requirements. This relates to differences in raw materials, differences in end product, and differences in the plant design. Decisions about particle separation also come from within the process itself. These decisions also must consider the methods and equipment available. This discussion reviews the general principles involved and offers several examples of machines developed for particle separation or classification. Some have high capacities and some that operate more precisely have relatively low capacities. A number of companies produce such equipment using the approaches presented.

SCREENING

By definition, screening is accomplished by passing material over a surface with sized openings through which the undersized particles will pass. The differ-

ences between the various types of screens relate to the means of transporting and agitating the material bed.

The choice of the type of screen best suited to any given separation is not always easy. Screening is an empirical field lacking in precise mathematical theory. The best practical approach is to select the screen type or types that appear best suited to the desired separation and have laboratory tests performed to forecast the actual commercial screening operation.

A number of factors affect screen performance, such as material bulk density, particle shape, and moisture content as well as feed rate to the screen, retention time on the screen, and screen motion. Before discussing these factors, however, it will be well to consider how various screens function. None of them can economically perform as well as the various laboratory classifiers such as the Ro-Tap sieve shaker (Figure 10.1). Particles are retained long enough in these classifiers to completely and precisely separate the particles. The quality of particle separation required in an industrial screening operation can be evaluated by using a sieve analyzer.

The Ro-Tap testing sieve shaker or any other similar analyzer, such as Syntron, Sweco, or Williams, is a valuable piece of equipment for determining the ultimate screening that can be achieved. For economical reasons, such precise screening cannot be done in the plant, but a correlation can be worked out for the plant screens that are used.

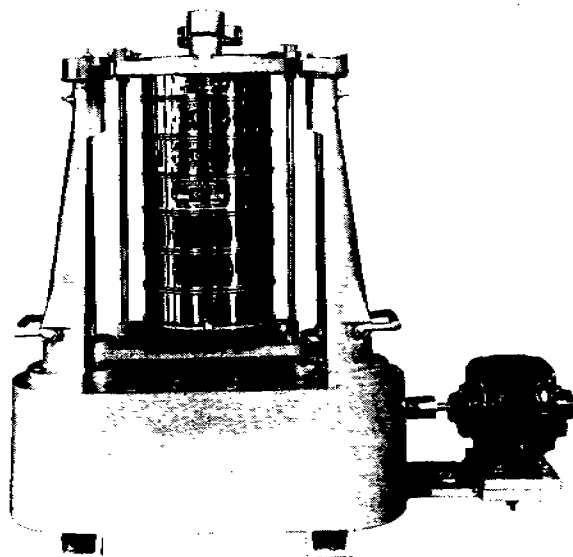


Figure 10.1. Ro-Tap testing sieve shaker. (Courtesy C-E Tyler.)

The testing sieves have woven wire screens with standardized openings. In the United States, Tyler Series and U.S.A. Sieve Series are used, and which is used should be noted as the sizes differ. For this discussion the Tyler Series will be considered.

In rough terms, the sieves are known as having so many openings per inch, e.g., a Number 4 sieve has 4 openings per inch (25.4 mm). However, care must be exercised in such a description, particularly with industrial screens, as the diameter of the wire can be different than the standard and thus change the screen opening. Consequently, it is desirable to specify the screens by both the size of the opening and the openings per inch or by the size of the openings and the wire diameter. In doing so, a closer correlation between the industrial screen and the Tyler Sieve can be made.

To run the tests, a set of sieves is nested together and placed in the shaker. For particle testing, a typical set of sieves could be 6, 9, 14, 20, 32, and 42 mesh. The bottom of the assembly is a pan. The assembly has the largest screen at the top and the smallest at the bottom. A 100-gram sample (usually dry) is randomly selected, making sure a representative sample is chosen. The sample is placed in the top sieve and the shaker is then turned on. A typical shaking time is five minutes. Afterwards the amount of material retained in each screen is weighed and reported as a percentage of the total. The normal way of reporting this information would be the percentages for +6, -6+9, -9+14, -14+20, -20+32, -32+42, and -42 (using the screens described in the above example). These sieve designations mean the material passed through the sieve shown as minus and was retained on the sieve shown as plus. For accuracy, at least three tests should be made, and the average reported.

Since severe shaking takes place, some long, slender particles will be upended and they will drop through the screen opening according to the width and thickness of the particle. Such particles passing over an industrial screen, however, will tend to slide over the small openings since they probably will not be upended as frequently because of less agitation in the short period of time they are traversing the screen. There are also fewer opportunities for these particles to be screened out. Additionally, the bed depth of the particles possibly will restrain such upending. With flake-type particles, therefore, it may be advisable to perform some type of air-classifying to better determine the sizes of the flaked particles. Laboratory devices for doing such a test are available, but no commercial ones are known.

Industrial screens can be regarded as falling into two basic categories: vibrating screens (high frequency, small amplitude) and shaking or gyrating screens (low speed, large amplitude). The latter type is the most popular in the industry.

Inclined Vibrating Screens

Inclined vibrating screens, with the exception of a few specialized magnetic or pneumatically vibrated units, are driven by a rotor whose axis lies parallel to the screen plane which develops a circular motion in the plane at right angles to the screen plane. Because this circular motion has little or no conveying property, the screen plane must be inclined in order that the material will move from feed to discharge (Figure 10.2).

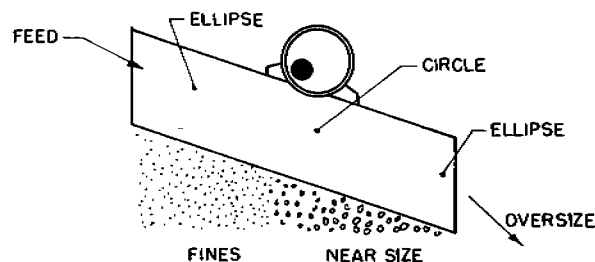


Figure 10.2. The inclined vibrating screen (Ryan 1967).

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In the most common two-bearing design, an unbalanced rotor is mounted in the vibrating body, or *screen box*, which is supported on elastic mounts of low stiffness. The resulting motion is circular if the rotor is coaxial with the center of gravity of the vibrating body. If the rotor is displaced from the center of gravity, a rocking action around the center of gravity results in elliptical motion at the extremities of the screen as illustrated in Figure 10.2.

Vibration transmitted to the supports is determined by the stiffness of the springs, and is normally limited to 2% of the exciting or driving force. In addition to its extreme simplicity and low vibration transmission characteristics, the inclined vibrating screen has the important advantage of easy amplitude adjustment.

Horizontal Vibrating Screens

Horizontal vibrating screens operate with a reciprocating motion inclined at an angle to the horizontal. Material is conveyed across the screen in a series of hops, with virtually no friction with the screen surface (Figure 10.3). The direct-connected eccentric drive, commonly used with slow-speed shaking screens, is not used in the high-speed designs because the large inertia forces developed by the high-speed motion are very difficult to harness in any economical manner. Inertia drives and natural frequency drive systems are used instead.

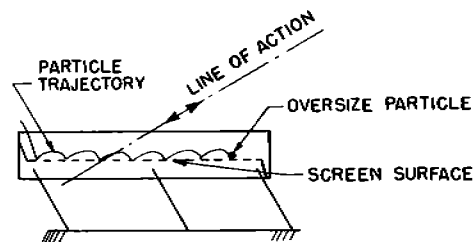


Figure 10.3. Schematic diagram of material travel on the horizontal vibrating screen (Ryan 1967).

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Circular and Gyratory Screens

Under the category of circular and gyratory types falls a wide variety of screens which are distinguished from the inclined and horizontal vibrating screens in that some component of the motion is circular or elliptical in the plane of the screening surface. The screening surface may be horizontal or inclined, the latter relying at least partially on gravity to move the material from feed to discharge. The following descriptions of popular screen types within this category illustrate the operating principles of this type of screen.

A circular screen popular outside the United States is shown in Figure 10.4. This screen has a three-dimensional movement which combines horizontal and vertical screening actions, thereby achieving a tumbling effect as illustrated in Figure 10.5. The material is fed into the screen from above. As it spreads over the screen, the finer material falls through the screen and the oversize passes out through the spout on the side of the machine. Three screen panels are stacked in the machine shown in Figure 10.5. The entire unit is supported on soft springs which isolate vibration from the support structure. Air can also be used with these screens to assist with the particle separation. These screens are fully enclosed, thus reducing dust pollution.

A popular inclined rectangular screen is illustrated in Figure 10.6. The screen box is driven at the feed end by a vertical eccentric unit which imparts circular motion in the plane of the screening surface. The discharge end of the screen box

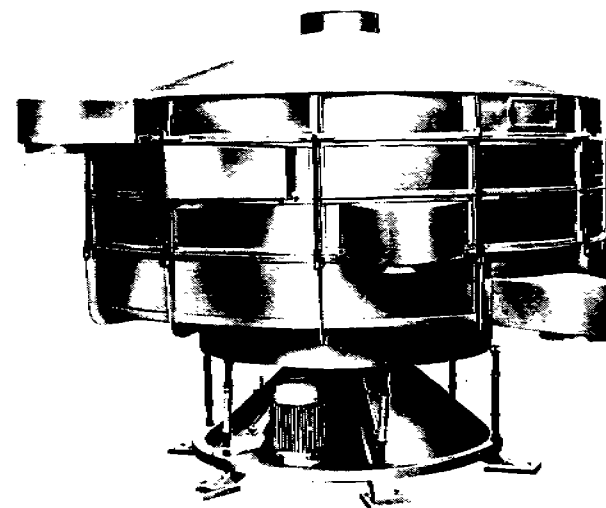


Figure 10.4. A circular screen for separating four fractions. (Courtesy Allgaier-Werke GmbH.)



Figure 10.5. Three-dimensional movement of material on the screen surface. (Courtesy Allgaier-Werke GmbH.)

rests on slide blocks which restrain the box so as to create linear motion. The motion at other points on the deck is elliptical, with the minor axis of the ellipse becoming smaller as the discharge end is approached. The manufacturer feels that this motion gives higher efficiency in the heavily loaded feed zone and greater conveyance in the more lightly loaded area of the deck.

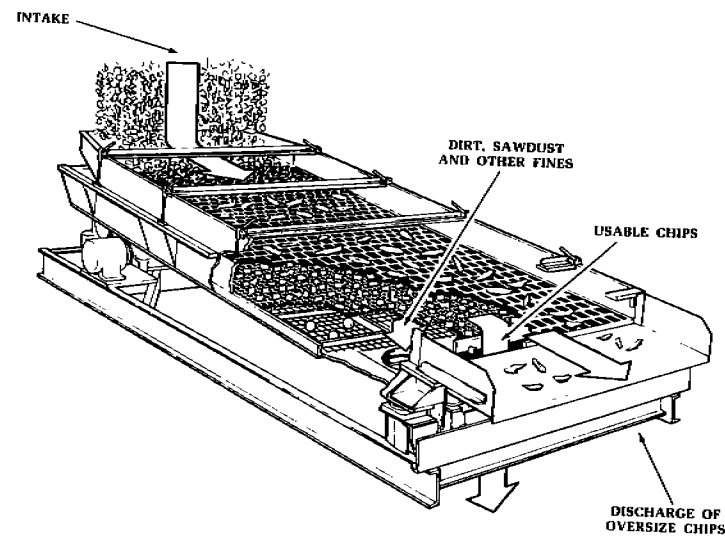


Figure 10.6. A Rotex screen working with chips. (Courtesy Rotex Inc.)

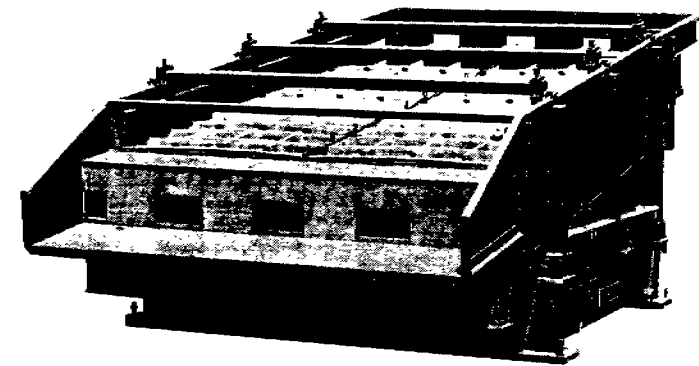


Figure 10.7. A full rotary particle screen. (Courtesy Black-Clawson, Inc.)

Another popular type of gyratory screen is shown in Figure 10.7. It is an inclined rectangular screen with a full circular motion, the plane of which is horizontal. This type of design allows a practically complete dynamic balance of the inertia forces. It is a versatile design concept adaptable to two-, three-, or four-sort screening operations and features the *bouncing balls* when screen blinding is a problem, as does the previous type of screen. These balls continually tap the bottom side of the screen, thus preventing screen blinding (Figure 10.8).

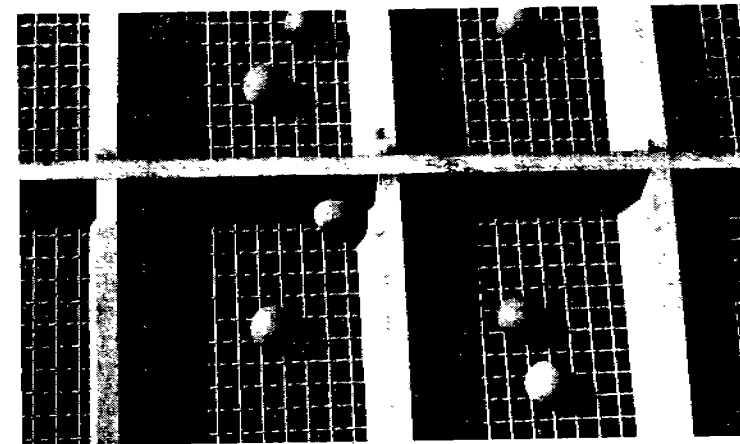


Figure 10.8. Bouncing balls used to prevent screen blinding (Christensen 1975).

Factors Affecting Screen Performance

Because a number of variables affect screen performance, some definition for the means of evaluating and measuring results is needed. Efficiency and capacity are the two principal measures of screen performance. Screen efficiency concerns the quality of the separation, and is not related to power consumption or operating costs. There are several ways of measuring efficiency, the most common and useful being the *percentage of recovery*. This is the ratio of the amount of undersize pieces passing through a certain size screen opening to the total amount of undersize in the initial feed.

Capacity is the maximum feed rate at which the desired results of size separation and efficiency can be produced. No statement of capacity, whether in terms of weight or volume, has any significance unless the corresponding efficiency is known. In an extreme example, an overloaded screen could transport a very high tonnage, acting more as a vibrating conveyor than a screen. This can also happen in the laboratory where an overeager technician, anxious to perform, can destroy an experiment by using the screen as a conveyor rather than as a separating device.

Another consideration deserving mention is the definition of an *undersize* particle. A wood particle, because of its fibrous structure, is inherently irregular in shape, usually with one of its principal dimensions (width, length, and thickness) far greater than the other two. Theoretically, the size of the particle is that of the smallest screen opening through which the particle could be forced to pass. However, it is known that this particle will pass through the opening only if it is brought into contact with the screen opening in that particular orientation. For long, slender particles such as flakes, the statistical probability of this occurring becomes more remote, even with the most violent screening action. The definition of size, then, is not very meaningful when screening such irregular particles.

A practical solution is to use the standard sieve analysis as a basis for establishing particle size and size distribution within a sample of material. One must concede, however, that the screening action of the sieve vibrator, acting for a long enough time on a shallow bed of material, will remove all of the undersize capable of passing any screen. A realistic ratio between screen analysis and production screening must be developed.

Along with the problem of defining particle size for efficiency determination is the question of acceptable shape in terms of the ultimate use. A common example in particleboard furnish preparation is the separation of small *fines* from long, slender particles or *slivers*. If both can pass through the screen, then high efficiency is not the objective. Here the nature of the screening action becomes critical and the results must be judged visually as well as statistically.

There are many variables which affect the capacity, efficiency, and sensitivity of a screen. These should be considered in terms of material factors and machine factors.

Material Factors: Most of the material factors, such as bulk density, particle shape, and moisture content are determined elsewhere and cannot be regarded as controllable as far as the screening operation is concerned. However, problems with screening may indicate that particle generation is out of control.

The most important characteristic of a particulate material is its tendency for natural size classification. A particle size mix classifies itself according to size, with a minimum amount of mechanical agitation. The smallest particles end up at the bottom and the largest at the top. Natural size classification helps bring the smaller particles to be extracted in contact with the screening surface first, thus promoting screening efficiency.

Factors such as increased moisture content and pitch content affect the natural classification tendency adversely. Moisture content above a certain limit is a deterrent to screening efficiency on many materials. For example, wet sawdust particles tend to cling together and it is impractical to screen them commercially. However, these same particles dry are very mobile and can be classified efficiently. The effect of moisture content is dramatically illustrated in Figure 10.9.

A screen is normally selected to achieve a certain size split in a given material as determined by a sieve analysis. The size of the screen opening, defining the desired size split relative to the frequency distribution of sizes in the mix, significantly affects the efficiency of the separation and thus the amount and size of equipment required to handle a given amount of material. The relative amount of particles that are "near size" with respect to the size of the screen openings is especially important, because these particles have low *drop-through* probabilities and tend to cause plugging or blinding problems.

High screening efficiency, therefore, is often difficult to achieve and 100% efficiency would usually be impractical. The particle shape must also be considered by visual examination in determining efficiency. Figure 10.10 compares cost versus efficiency in production screening in a hypothetical illustration. Very high efficiency is costly and the throughput is low in this example. Thus efficiency has to be balanced against cost and undesirable effects in the final product. Each operation will have to determine what level of efficiency is most appropriate for the cost.

Machine Factors: The machine factors to be considered include the size and shape of the screening surface, the amplitude and frequency of the vibration.

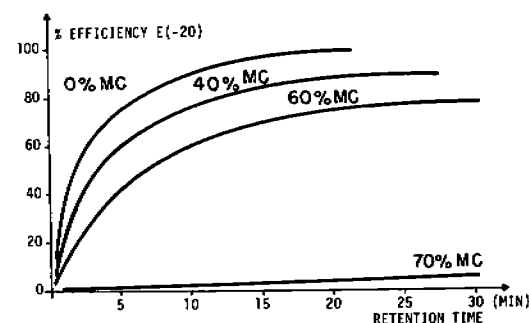


Figure 10.9. Efficiency vs retention time for sawdust at four different moisture levels (Christensen 1975).

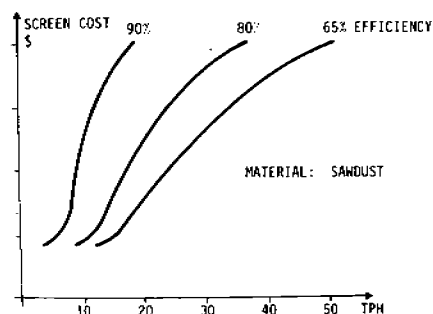


Figure 10.10. Cost vs efficiency in production screening (Christensen 1975).

inclination of the screening surface, effectiveness of cleaning devices (bouncing balls), and many others. It is often more significant to group these variables in terms of their net combined effect on the separation and then analyze each variable within that framework. These will be discussed under the divisions of retention time and feed rate. This discussion is based on the performance of the more popular gyratory, circular or "orbiting" type of screen motion. On this type of screen, all points of the screen surface move in a horizontal, circular path at a relatively low speed. This gentle type of motion is especially effective on materials with a high tendency for natural classification, such as dry wood particles. The circular motion of the inclined screen surface gives the particles three-dimensional motion that improves the mobility of the particles within the material blanket, thus aiding the natural classification tendency by letting the smaller particles filter through the material blanket to the screening surface, improving the particle drop-through probability and hence the efficiency.

Retention Time: The total time the material is on the screen depends on the screen. Assuming a constant rate of travel over the screen, the retention time equals the length of the screen divided by the rate of travel. The rate of travel, and thus the retention time, is a function of the amplitude and frequency of the screen motion, the inclination of screening surfaces, and, to some extent, the material characteristics and the screening medium. The retention time is a measure of the number of opportunities a given particle has to find an opening to go through. Even with long screens, however, wet material is not screened efficiently.

Feed Rate: The quantity of material handled by the screening surface is the factor to consider, not necessarily the gross feed rate to the screen. The screen may have several screening decks operating at different feed rates.

The number of particles of a given size increases proportionately with feed rate. A larger number of particles will be competing for the same number of openings, with the result that the probability of each particle finding an opening to go through diminishes, lowering the overall screening efficiency. With the increased competition for openings, the size of particles to be extracted shifts toward the smaller end of the size spectrum, because of the higher drop-through

probability of smaller particles. Figure 10.11 shows the effect of feed rate on efficiency for screens of different lengths and for material with different moisture content. The effect of feed rate on efficiency and consequently (initial) machine cost was illustrated in Figure 10.10.

AIR-CLASSIFICATION

Quite often particle separation on the basis of size does not satisfy the board maker's requirements. The physical properties of board are dependent on particle shape and surface-to-weight ratio as well as size. Separations made on air-classification equipment help to meet these other requirements. It should be noted that some air-classification may be done further down the production line in the blender or former.

In order to appreciate and evaluate the performance of air-classification equipment, a clear concept of the scope and limitations of this equipment must be grasped. The common use of low-velocity air systems for dust control leads to an association of air-classification with only small particle separation. In actuality, neither the size of the particle nor its weight is the controlling factor. The basis of separation is the particle surface-to-weight ratio, sometimes referred to as specific surface. Any particle situated in a rising column of air is acted upon by two opposing force vectors. The airstream exerts an upward force on the particle called *drag*. The magnitude of the drag force is directly proportional to the area of the particle, the only other factors affecting the force equation being those related to the density, velocity, and viscosity of the fluid medium which in this case is air.

Resisting this vertical drag force is the gravitational force due to the weight (or, more correctly, the mass) of the particle. The vector resultant of these two forces determines whether the particle will rise, fall, or float in the airstream.

On this basis, the wood particle entrained by an airstream might actually be larger in one case, or heavier in another case, than the particle dropping out. Since

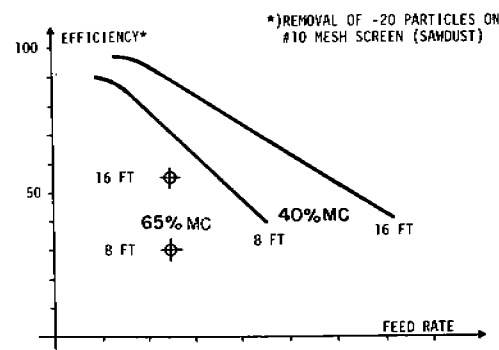


Figure 10.11. Efficiency vs feed rate for different lengths of screens with sawdust at two moisture contents (Christensen 1975).

more than one independent variable is affected in the separation, the evaluation of results requires judgment as well as standard quantitative procedures.

If the feed to a classifier can be limited to a uniform particle size in terms of width and length, then the classifier can perform a reasonably precise thickness separation due to the weight difference between particles of fairly constant surface area. For this reason, it is common practice to use air-classifiers in conjunction with screening equipment.

The differences between the various air-classifiers used in the industry lie mainly in the means of presenting the flow of material to the separating airstream. Some of these types of air-classifiers are the vertical air leg, suspension, and fluidized-bed classifiers.

Vertical Air Leg

The simplest, least expensive, and least sensitive air-classifier is one often referred to as an *air leg*. This device consists of a vertical pipe or chute through which air is lifted by an external fan. Material is fed into this column at or near the top and a two-way vertical separation is made. The lightings are released through a cyclone collector located in the exhaust air system. The material not lifted drops out the bottom into a collecting bin or conveyor.

From this basic concept a variety of machines has evolved, with refinements consisting in most instances of integral fan arrangements, rotary air locks, and feed regulators.

Suspension

The air-classifier shown in Figure 10.12 falls into the general classification of circular classifier. The material enters the top of a cylindrical chamber by gravity flow and is fed onto a horizontal rotating disc or distributor plate which throws the material outward towards the walls in a uniform curtain. Air is drawn upward through the material stream, lifting the lighter (high surface-to-weight ratio) fraction upward into an external fan and cyclone system. The heavy (low surface-to-weight) product falls downward onto a sloped perforated screen and into a discharge spout. Any material screening through this deck may be collected separately as a third product or recombined with the main heavy product discharge. A similar unit uses a closed-circuit recirculating air system with an expansion chamber for precipitation of the aspirated product from the airstream (Figure 10.13). This is a relatively simple, easy-to-adjust machine. Separations are made by particle size or shape or by specific gravity.

The advantage of this type of separator over a simple air leg is the broad curtain of material through which the airstream flows. The entrained particle can be easily lifted from the stream of heavy material without the resistance encountered in a vertical material flow.

There is a very popular suspension sifter in use in many parts of the world that is available in four basic designs: single- and two-stage sifters and fresh-air or air-recirculation sifters. In the single-stage sifter (Figure 10.14), the material to be screened is divided into two fractions, acceptable and oversize; while in the

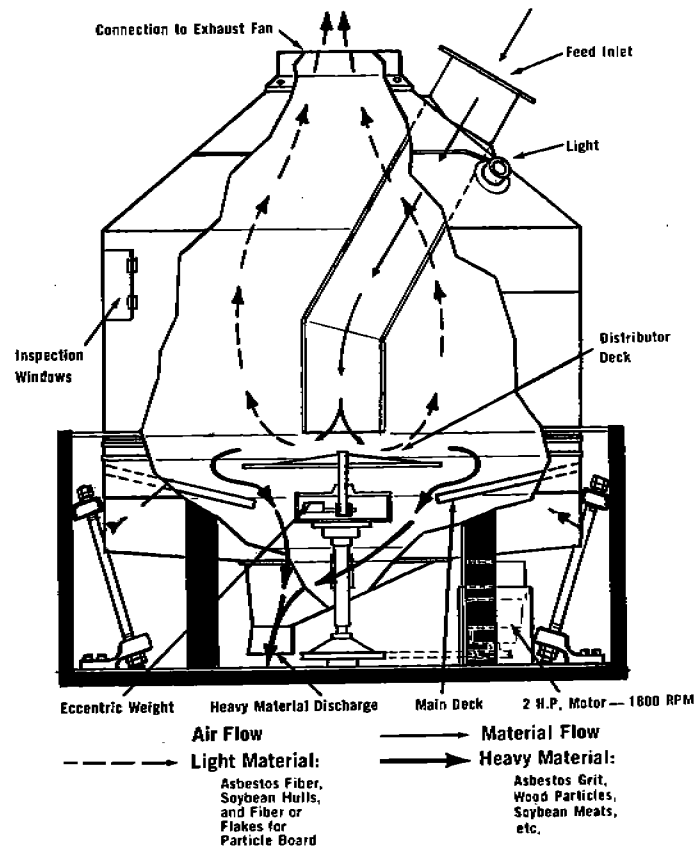


Figure 10.12. An air circular classifier. (Courtesy C-E Bauer.)

two-stage sifters, the furnish is divided into three fractions, for example, face material, core material, and oversize material. The so-called fresh-air sifter uses the air from the immediate surroundings of the sifter and discharges air directly to the atmosphere through a separator. Air-recirculation sifters, however, operate with approximately 95% recirculated air. Thus, only 5% of the air is discharged from the system, either through a separator or through a separate pneumatic system. These types of sifters have the advantage of reducing the amount of dust in the atmosphere around the machine. This has a further advantage in preventing the pickup of moisture by very dry furnish, because the air is constantly recirculated. This can be a significant problem when using fiber which will rapidly pick up or lose moisture depending upon the ambient conditions.

In special cases these sifters have also been used as dryers, where a heat source is connected to the air inlet; thus, drying of the furnish takes place simultaneously with the sifting.

The furnish to be separated falls through a rotary valve and a central feed pipe into the suspension chamber. Rotating stirring arms above the screen floor distribute the material evenly over the area of the screen, through which the airstream enters the suspension chamber from below. With appropriate air velocities, any desired separation of the furnish can be obtained. The portion of the furnish in suspension is removed by the airstream and the oversized material which does not float in air is moved by the stirring arms to the periphery of the separating area and is discharged through rotary valves. Any fines left among the oversized material will be drawn back into the suspension chamber by the bypass air entering the oversize material rotary valves.

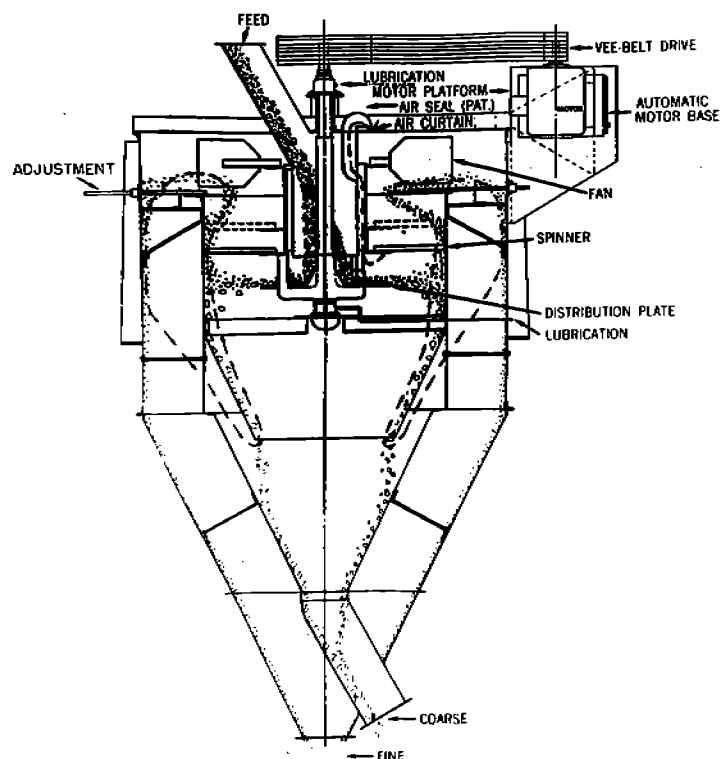


Figure 10.13. A mechanical air separator. (Courtesy Williams Patent Crusher and Pulverizer Co.)

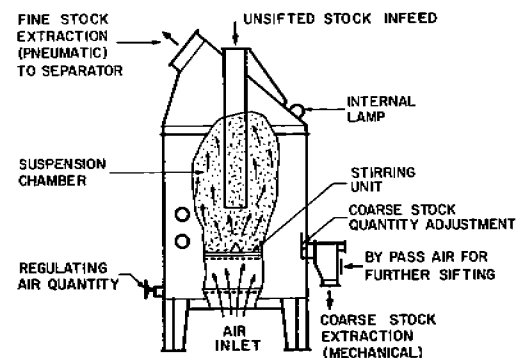


Figure 10.14. A single-stage suspension sifter plant (Shumate et al 1976).

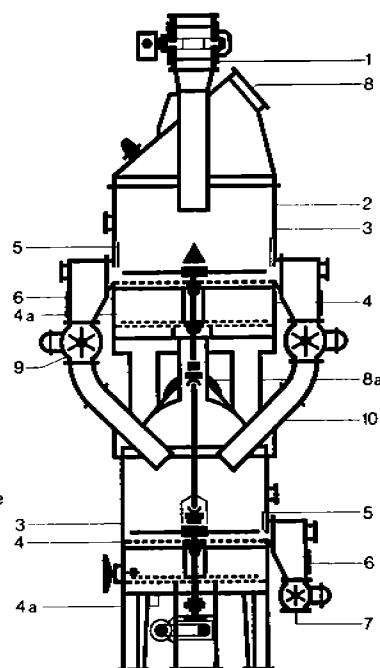
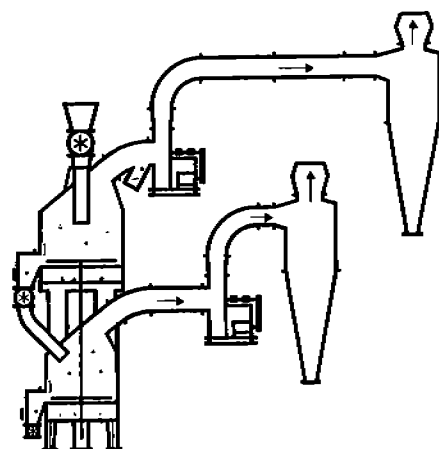
In two-stage sifters, illustrated in Figure 10.15, this same process is carried out twice, first in the upper chamber and then in the lower chamber. Once the fine material is removed in the first stage, the medium and oversized material is fed to the second stage through two exterior rotary valves and attached ducts. The medium material is separated out in this second stage and oversized foreign bodies are removed.

It is reported that this type of sifter is excellent for removing foreign bodies such as sand, stones, metal, or bark from the furnish.

The zigzag type of classifier, which has no moving parts, is used elsewhere in the world. For classifying, it utilizes a number of vertically arranged zigzag channels as shown in Figure 10.16. As many as 12 of these channels have been used in a single classifier. This classifier can be used for separating flakes, fibers, and granular particles. Classification is made by particle thickness, not by the length or cross-sectional area. It is used extensively for separating oversize particles from core furnish, oversize particles from face furnish, and fractionation of particulate furnish into core and face fractions.

The feed material is normally introduced into the classifier (see Figure 10.16) by means of a closed-type feed screw (3). As it flows by gravity across an inclined perforated sheet (1) the furnish is fluidized by jets of high-velocity air blown up through the sheet by the blower (8). The air imparts a high-velocity turbulence to the flowing feed material, which lifts even larger-size particles off the perforated sheet. This effect has been termed the *flying bed*, and is much like the molecular movement in a gas.

The high fluidization of the feed material enables most of it to reach the zigzag channels by air. The feed material is presented to a series of channels, and is classified until what remains at bed level is an extremely clean, coarse material which drops out of the discharge (6). Each channel accepts only as much material as permitted by the classifier air adjustment. The finer particles ascend with air and pass through a cyclone (5) for the separation of the particles from the air. Since



- 1 Rotary feeder valve
- 2 Suspension chamber, first stage
- 3 Stirring unit
- 4 Upper screen tray
- 4a Air throttle plate
- 5 Coarse material slide
- 6 Bypass for further sifting
- 7 Oversize material rotary valve
- 8 Fine material to fan, first stage
- 8a Medium material to fan, second stage
- 9 Intermediate rotary valves
- 10 Connecting ducts to second stage

Figure 10.15. Two-stage suspension sifter plant (Shumate et al 1976).

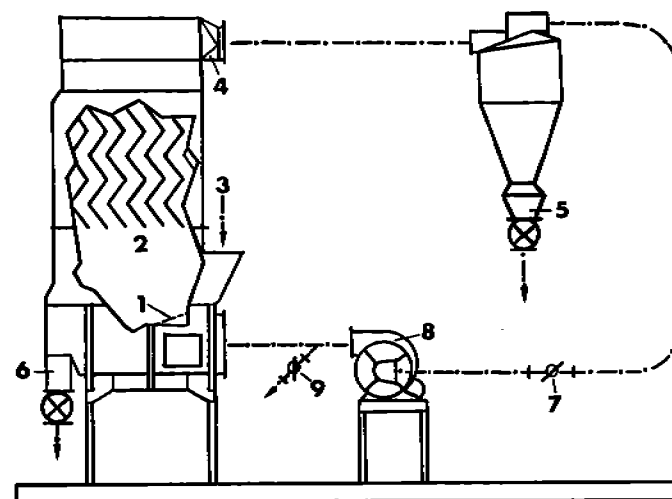


Figure 10.16. A flying-bed zigzag classifier. (1) perforated sheet, (2) preclassifying chamber, (3) particle feed, (4) classifier head, (5) cyclone, (6) coarse material discharge, (7) throttle flap for classifier adjustment, (8) blower, (9) throttle for removal of leaking air. (Courtesy Alpine American Corp.)

this is a closed-circuit machine, the air from the cyclone is returned through the blower to the flying bed.

The classification action in the zigzag channel is shown in Figure 10.17. The flow pattern as illustrated shows how the finer particles ascend the channel and the coarser ones descend as classification takes place. A horizontal vortex is developed in each limb of the channel (Figure 10.17), and classifying is effected at every joint of the channel. Imperfect separations at the lower end of the channel are corrected with each change of direction in the zigzag channel. Thus only the desired small particles are allowed to ascend with the air going to the cyclone.

The classification point (cut point) depends upon air velocity, which can be steplessly adjusted from 1.0 to 10 meters per second, and the feed rate of the material.

Fluidized Bed

In fluidized-bed classifiers, the material is presented to the airstream in the form of a fluidized bed instead of a falling curtain of material. A fluidized bed is achieved by distributing the material evenly over a porous vibrating deck through which air is blown at relatively low velocity. The material is stratified with particles of high surface-to-weight ratio floating to the top of the bed. The final products are derived from this pre-separated bed in several ways.

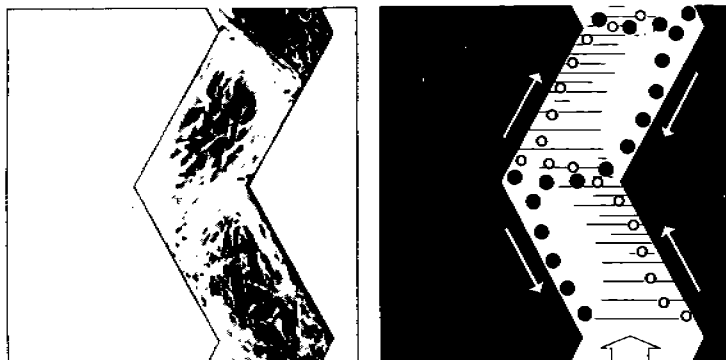


Figure 10.17. A zigzag channel showing the classifying action. (Courtesy Alpine American Corp.)

One type of this classifier performs a straight two-way separation using the fluidized-bed principle. In this unit the deck motion conveys the material down an inclined deck from a feed pan. The air flowing through the deck is controlled and accelerated to lift the desired proportion of the material. A controlled air bleed-in through the "heavy" discharge assists in entraining the more marginal particles. Similar classifiers are built as an integral part of a horizontal resonant screen.

A more sophisticated fluid-bed classifier makes a three-way separation by rejecting a small percentage of very low surface-to-weight particles. This is accomplished by vibrating the inclined deck with an uphill conveying motion which counteracts the gravity flow of the material. With the bed in a fluidized condition, the low surface-to-weight particle lying nearest the deck surface receives this conveying impulse and is transported up to the high end of the deck. There it is restrained and banked into a segregated zone of particles and bled off through a regulated gate.

The high surface-to-weight particles are floated in the material bed and flow by gravity down the inclined deck. The highest surface-to-weight particles are lifted through the hood outlet.

The most sophisticated fluid-bed classifier design is the type which uses an uphill conveying motion whereby the particles near the bottom of the fluidized bed are transported up the deck. However, instead of discharging material at each end of the deck, the entire flow discharges over one side in a continuous stream with a gradual decrease in surface-to-weight ratio from the lowest end of the discharge lip to the highest. The flow is divided into the desired products by means of adjustable splitters which are positioned to divert the material into a series of spouts. An exhaust hood is provided for lifting an additional product. A small unit of this type is shown in Figure 10.18. It is an excellent laboratory tool.

The advantages of fluid-bed classification lie in the ability to produce a multiplicity of products in a single operation, also in the sensitivity gained by stratifying and preseparating the material bed.



Figure 10.18. A fluid-bed classifier in the Washington State University Laboratory. (Courtesy Washington State Univ.)

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13.

RESIN/WAX APPLICATIONS AND BLENDERS

Blending of resin, wax, and other additives with the furnish was relatively simple in the pioneer period of the industry. Pouring the resin onto agitated furnish was practiced much the same as mixing cake batter. Little was known about the effects on board properties caused by the many resin parameters already discussed, by resin distribution, resin droplet size, species, and particle size and geometry. Much research since then, however, has revealed the fundamental information needed for at least a partial understanding of optimum blending. Sophisticated control systems and blenders have been developed for implementing this information. The fundamental information will be discussed first in this chapter, followed by descriptions of some of the control equipment and the major blenders. Emphasis will be on the resin and wax application. Preservatives and fire retardants can be mixed with the resin or applied separately. In general, resin blenders can also be used with preservatives and fire retardants.

RESIN APPLICATION

Many factors are involved in applying resin for optimum use. In addition to the ones discussed in the resins chapter are the actual practices of storing and application. Massive amounts of resin are required to run large board plants; thus storage becomes a significant factor. Such a facility must be well designed to handle the resins, run trials, and determine the amount of resin going into the process at any given time. Next a precise method for controlling the ratio of wood to resin entering the blender is of paramount importance; otherwise, the board properties will vary widely.

It should also be pointed out that one of the more necessary features of any good resin-handling system is a quick and efficient means of cleaning all of the equipment, from the storage tank through the spray nozzles or centrifugal atomizers. Storage tanks should have easy access for workmen to get inside and clean the tank. Tanks should have a bottom drain or resin outlet, a valve on the resin line just outside the tank and/or a valve on the line just ahead of the next storage tank to insure against the possibility of noncompatible resins and additives intermingling in the line. Easy-flush facilities and direct-line access for cleaning all lines should be provided if possible. Readily accessible and easily cleaned strainers or filters should be installed in at least two places before the resin applicators to prevent

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this equipment from being clogged by dirt, gelled resin particles, and other foreign material.

To store the resin within the proper temperature range, resin storage tanks should be installed to allow proper storage temperatures in both winter and summer. A storage temperature of approximately 60°F (16°C) is ideal in that the resin advancement or aging is retarded and the resin viscosities are not too high for handling and pumping. Lower temperatures are rarely needed since resin usage is high and the resins used are usually no older than two weeks.

Provision for easy handling of tote bins or drums for trial runs of new resins and/or special resins and additives for new products should be included and carefully designed for ease of handling and minimum interference with normal production.

Provision to heat the resin in the range of 80° to 105°F (27° – 41°C) before spraying is generally found to be desirable in producing better atomization of the resin. Resin viscosity is very temperature sensitive. Thus, relatively uniform temperatures are needed when spraying resin to keep the resin droplet sizes within the specified range. This heating system should preferably include jacketed mix or use tanks with adequate constant agitation in order to add chemicals or additives to the resin. These tanks can also be used to double-check the hourly or daily resin usage rates, in addition to those meters which are used to record flow rate data.

Spraying or other application systems should incorporate quick-change connections to reduce the time necessary to change spray heads for regular maintenance or in case of a foul-up in the system. All of these features are useful in reducing downtime and in cutting costs on normal maintenance cleanup periods.

Pumping systems should be sized to provide rapid handling with complete flexibility to move resin in or out of any tank, to recirculate and provide blending when desired, and to operate with the least possible maintenance.

In the board industry, the quantity of resin used and the method of application of the resin are paramount determinants both of cost and quality of the finished product. Proper application of the binder is extremely critical in developing quality adhesive bonds.

Most plants apply their resin in a liquid state onto the furnish as it passes through the important piece of equipment known as the *blender*. Wax emulsion is normally mixed with the resin, or it can be dripped or sprayed upon the furnish as it is screw-conveyed to the blender, or it can be sprayed onto fiber as it is air-conveyed through blowpipes. The average blender is a piece of equipment designed to agitate the wood particles while the resin and/or other additives are being either sprayed or applied by centrifugal atomization onto the furnish. The object is to disperse the resin droplets uniformly over the wood particles. Each wood particle should have adequate exposure to the resin and/or additives, and should be coated with sufficient resin to attain the desired properties in the final board.

Most of the particleboard plants in this country have applied the resin by a spray system; however, a newer type of blender is gaining favor where resin is distributed by centrifugal force from a rapidly turning hollow shaft. It should be recognized that a resin and its additives may be satisfactorily introduced into the blender by air spray, airless spray, or the disc or centrifugal distribution. All three

methods have their advocates, and it is possible that only one type may be preferable in certain types of blenders.

Of interest is the fact that the airless sprays, which operate under high pressures of 600- or 800-psi (4.14 or 5.52 MPa) to 1400- or 1500-psi (9.65 or 10.34 MPa) pressure, introduce less air into the blender. On the other hand, airless systems will usually have smaller orifices in the nozzles, and may pose a greater problem with flooding and in keeping the nozzles free from dirt and other contaminants which interfere with the proper spray pattern. Also, as no extraneous air is admitted into the blender during spraying with the airless system, mechanical agitation in some blenders may have to be increased to gain equally uniform distribution of the resin onto the particles.

Whether the spray system is one requiring a low pressure of 20 to 60 psi (138–414 kPa) on the resin as well as 40 to 100 psi (276–689 kPa) of airstream to atomize the resin which is ejected from the nozzle, or whether an airless spray system is used, there are some important features to be kept in mind.

There are two primary factors which apply when the spraying method is considered. One factor is the fineness of spray and the other is selection of a suitable time period of application. Both factors are of cardinal importance. When the spraying method conforms to good practice relating to these factors, then uniform distribution of resin on the particles will be maintained.

It is of prime importance in the application of any resin through the spray system to be sure that there are sufficient nozzles available to do the job, and that the placement and direction of the nozzles are such that the best possible distribution of resin on the wood particles is obtained. Another factor of great importance is that there must be easy access to the spray heads. Any good system will incorporate a quick-change method to replace nozzles which become clogged, or malfunction in some other manner, since this reduces the efficiency of the resin application.

Also critical in the design of the resin-handling system is the consideration of whether the resin will be sprayed on the particles as received, usually a 65% nonvolatile (solids) solution in water for urea or 40 to 53% solids for phenolic, or whether the resin is to be diluted and/or mixed with water, wax emulsion, catalyst, or other additives.

The addition of any of the aforementioned additives to the resin is in essence diluting the resin solution. Theoretically this could give rise to better resin efficiency; however, additional moisture produced by diluting the resin solution might yield furnish with an excessive moisture content. Dilution could also lead to flooding (overloading) of the spray nozzles due to the increase in volume of the resin solution. Thus the apparent value of resin dilution could be negated by poor distribution of the resin over the furnish. Such dilution could also cause the resin to penetrate the wood and thus be lost for bonding the particles together.

All of these factors are important, not only in designing the resin-handling system, but in influencing the ease of application and controlling the method of application of the resin and additives. If the system is not properly constructed, operational difficulties are often encountered. This could result in inconsistent or low-quality board being produced when any one part is not under the proper control and functioning in the manner intended.

Discussion of resin application by the disc or centrifugal application methods will be dealt with in detail later. However, application is still designed to have small discrete droplets of resin uniformly applied to the furnish. These types of applicators are airless in that compressed air is not needed for atomizing the resin. Compressed air can have the disadvantage of causing overspray of the resin and the air supplied must be exhausted from the blender, although the latter is not always a problem.

In only a few plants in this country are resins applied in other than a liquid form, and, in these cases, the resin is generally applied as a spray-dried or finely divided powder.

When powdered resin is used, it is normally metered on a continuous basis along with the particles into an inclined rotating drum. Here the resin and wood particles are mixed as they travel from the inlet to the outlet end of the blender. In these cases, the wax in the form of an emulsion or in the molten state is applied ahead of time. One plant with finely divided furnish blends the wax with the furnish in the grinding operation performed in an attrition mill. Others spray the wax on before the resin is added.

Detrimental effects that could happen with the application of powdered resin are: (1) a poor distribution uniformity which leads to indeterminate dusting loss if levels equivalent to liquid phenolic are used (5 to 7%); (2) segregation of the resin from the particles which could lead to caul sticking; (3) furnish surface moisture content has to be kept at a sufficiently high level to obtain adhesion of the powdered resin to the wood particles, which reduces the cost of drying but may cause blowing problems; (4) proper precautions have to be taken against dust explosions and fires; and (5) the cost factor is higher since most powdered resins are expensive phenolics.

In contrast, manufacturers of fiberboard use at least five systems to apply the resin to the fiber. First, in the wet-process hardboard mills, the fiber is generally carried in a low-consistency water slurry. The resin is introduced to the furnish as a liquid and is precipitated upon the fibers by the use of an acid or acid salt which reduces the pH of the slurry to a point where the resin solids will no longer remain in solution. Second, the resin may be added through the center shaft of the attrition mill or refiner in one of two ways: In method (a), proper resin coverage of the wood fiber particles is accomplished in the attrition mill simultaneously with the generation of the furnish. This furnish is then dried; therefore, phenolic resins are used exclusively as ureas would cure out in the dryer. For method (b), resins are blended with fiber after the fiber has been dried in attrition mills equipped with the *devils tooth* blending plates (Figure 13.1) or regular grinding plates. Third, in some cases the resin is simply added to the wet or semi-wet fiber in the blow line between the refiner and dryer or in the blow line out of the dryer, using air turbulence for resin dispersion. Phenolic resins are used in the blow line to the dryer; however, UF or MUF resins can be used in the blow line out of the dryer. Fourth, resin is sprayed onto the fiber in much the same manner as is commonly done in particle-board plants, usually in short-retention-time blenders. Fifth, a combination system is used where urea is added to the fiber as it is being ground in the attrition mill; and, after drying is finished, the formaldehyde and other resin constituents are added in a short-retention-time blender.

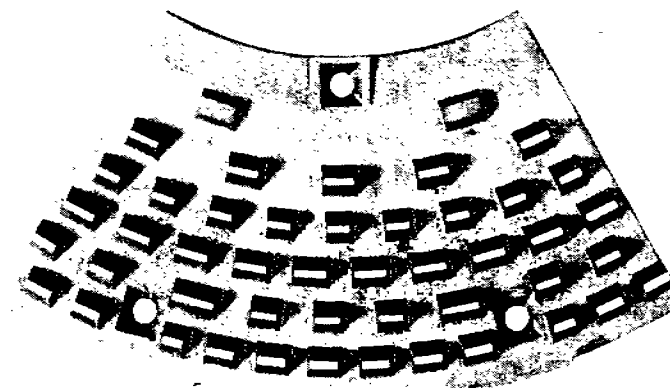


Figure 13.1. A segment of a pin plate disc (McNeil 1967).

Mixing Additives Versus Separate Additions

It can be said that the system which is geared to introduce the additives separately adds a degree of flexibility to the system. However, some plants believe there are advantages if certain or all of the additives are mixed before being introduced directly into the spray system. These advantages include: (1) lower initial cost of equipment, (2) possibility of less human error, and (3) less maintenance. It should be recognized that careful measuring of the ingredients into the blending or mixing tank is just as important as accurate metering into the spray nozzles. Therefore the possibility of error in such a system is just as great as that in which the additives are added through separate systems. It must also be realized the mixing or blending of the various ingredients prior to introduction into the spray system may give less flexibility in raising or lowering resin or wax content, in the event it becomes necessary to change the properties of the board. By proper engineering, either method can be made to work accurately and efficiently with no noticeable difference in results between the two methods.

Use of External Catalysts

Perhaps the addition of external catalyst to promote cure of urea-formaldehyde resins should be considered as a separate problem. This is because the addition of any acid or acid salt type of catalyst, exclusive of the latent-type catalysts which are sometimes integrated within the resin formulation, will lower the pH and accelerate the polymerization of the resin. This will result in a shorter storage or "pot life," and has been known to cause problems in plants which either are not properly equipped to handle the addition of external catalysts or whose personnel are not fully aware of all the problems involved.

The total wood acidity, as mentioned previously, determines the cure rate of urea resins, and aids immeasurably in determining press time. With the effect total acidity has on press times, it appears very probable that it is not the pH value of the furnish alone affecting press times, but rather a complex of pH, buffering capacity, and existing or potential total free volatile acid contents of the wood contributing to the overall effect on board press times. As little is known about the total acidity of wood as defined by pH, buffering capacity, and free volatile acid content, and how these factors function in the pressing process, further investigation with respect to their effects on press time, and to the factors which affect them prior to and during actual hot-pressing, seems to be merited. Knowledge of the value and variability of total wood acidity as defined above is of further help in solving some of the problems correlated to press time. This knowledge can also serve as a very useful guideline to the resin manufacturer in attempting to tailor a resin to a specific board process. Thus, it can be seen that much art is involved in the production of suitable resins for board use.

Woods or furnish low in total acidity require an external catalyst to accelerate the resin cure to realize acceptable press times. If a wood very low in total acidity is used, and the degree of total acidity difference between batches of wood particles is of sufficient magnitude, adverse effects may result. If the acidity were to vary over a wide range, it would be necessary to vary the amount of catalyst or contemplate a change in the resin being used. Excessive use of a strong catalyst could lead to precure of the resin on the particles and, if present in sufficient amount, could weaken the wood fiber on the bonding surface, or cause the glue bonds to deteriorate, thus influencing bond failures.

The addition of external catalyst is fairly common in particleboard plants where wood species have relatively high pH and thus low total wood acidity. Some plants, on the other hand, use wood species which contain enough wood acids and have low enough pH to lower the pH of the resin to a level where the resin cures rapidly in the hot press. As plants have grown larger, it has become necessary to use a wider variety of species, each usually with different characteristics as far as resin addition is concerned. Thus the resin manufacturer's job has become much more complicated, since it is difficult to determine the species mix as it comes in randomly as comminuted wood.

In normal commercial practice, the addition of external catalyst is accomplished by the addition of a dilute acid or an acid salt such as ammonium sulfate or ammonium chloride in a 20 to 30% solution. The catalyst is used in amounts ranging from about 1/4% to about 1% of solid catalyst based on the liquid resin. The catalyst may be buffered with ammonium hydroxide to promote longer pot life and offer some precure resistance. The catalyst may be added to the resin with thorough agitation in a mix tank, through an in-line blending system just prior to the spray nozzles, or after blending. Adding the catalyst in solution before or after blending is unusual, but this is successfully being done. Three advantages accrue to this method: (1) there is no possibility of the resin's setting up in the pumps, pipes, nozzles, or resin application tubes; (2) the system can be easily adjusted to fit the species mix in the furnish; and (3) mixing and mixing errors are reduced because the catalyst is not mixed with the resin. The philosophy is to adjust the wood pH of species other than Douglas fir to the same level as Douglas

fir, which contains sufficient acid to speed resin curing. Thus the control of catalyst level is independent of resin. Troubles may occur when resin levels are lowered if the resin and catalyst are mixed, because the mix is proportional. Such lowering may result in addition of too little catalyst, thus affecting bonding.

With any of these systems, proper precautions have to be taken to insure adequate mixing of the resin and catalyst. Facilities should be included to rapidly flush out any remaining resin in the lines to the blender in the event of a shutdown. It must be remembered that the use of an external catalyst is generally justified only if it will produce shorter press times.

Resin Usage in the Various Grades of Board

Resin levels and the levels of most other additives are calculated on what is known as the oven-dry basis of the wood, and only the solids level of the additive is considered. As an example, the formula for a certain manufacturer's product may be as follows:

All parts by weight	Parts by weight including moisture
100 oven-dry wood	102.0 (2% moisture content)
7 (solids of resin as percentage of OD wood)	10.8 (65% solids resin)
1 (solids of wax as percentage of OD wood)	2.0 (50% solids resin)
Totals 108	114.8

The calculations can be interpreted in several ways. For one, it can be said 7% of resin was used as shown in Column 1 but this is really 6.5% on a true percentage basis. The moisture can be considered as shown in Column 2, and thus the calculation would show the resin level to be 6.1%. The oven-dry basis method is the simplest and quickest to use but the various interpretations should be remembered when discussing *resin content*.

In the case of the few plants which manufacture homogeneous-type board, the resin content is the same throughout the board. On the other hand, plants which are equipped to produce three-layer or multi-layer board have to be able to control and vary the percentage of resin in the surface and core layers. Such board has a higher percentage of resin in the surface, because the fines have a greater surface area for a given weight. In a blender adding resin to all particles simultaneously, fines always pick up more resin than the coarse material. Thus, care must be taken to insure that the fines do not pick up too much resin. Fines must have higher resin levels because of their greater specific surface area, particularly when used in three- or multi-layer boards. The higher resin level reduces strip-off of laminates applied in secondary finishing and reduces the amount of telegraphing. Lower-grade board may contain as little as 4% resin in the core, while specialty boards

may contain up to 8% resin in the core, with resin content in the surface layers ranging from 6 to 12%. Some very fine particles may have more than 18% resin. Dry-process hardboards, as noted earlier, will range from about 2 to 6% in resin level depending usually on board density (less resin in high-density boards and more resin in medium-density boards). In essence, the amount of resin needed in an explicit board type may be taken as that resin level needed to attain a specific level of board properties at a specified board density.

When less than 4% resin is used in the core layer or layers, it is generally found that the board is deficient in properties such as internal bond and screw holding. Most of this may be attributed to the fact that the distribution of the resin on the wood particles is not optimum. Some plants find that the inclusion of a certain amount of fines containing more resin is necessary to obtain the proper strength.

Resin contents in exterior-grade board will usually range from 5 to 10%, depending upon the end use intended. Waferboards made with powdered phenolic resin may have resin levels as low as 1½%. Boards containing phenolic resins require longer press times and produce higher strengths than those containing urea resins, when using equal percentages of resin. However, the cost of phenolic resins has been traditionally higher than that of ureas; and most manufacturers have made an effort to produce a board with acceptable strength, while attempting to keep the phenolic resin usage cost in the same range as urea resins. This results in phenolic resin usage in the board of one or more percent less than is used in urea resin boards. It has been proven of course, that phenolic-bonded boards have less deterioration than urea-bonded boards under exterior-use conditions.

Specialty particleboards are just exactly that and are intended for a specific market where particleboard competes with other materials. These are boards of higher densities, up to and over 60 lbs/ft³ (0.96 sp gr), containing enough resin to produce the desired physical and surface properties.

Factors Affecting Resin Distribution and Quality

Resin distribution must be controlled in all types of boards to produce a uniformity of resin coverage on the wood particles, if a manufacturer is to produce a board with maximum strength while utilizing a minimum of resin.

There are two separate schools of thought regarding resin coverage of the wood particles. One advocates distributing the resin in a uniformly thin continuous film, while the other suggests depositing the resin in uniformly discrete droplets on the surfaces of the wood particles. The commercial blenders are based on the latter principle, as usually there is not sufficient resin available throughout the board to form a continuous film. Obviously the blenders are doing an adequate job, but none seem to provide an optimum distribution of the resin on the particles. Optimum distribution is obtained only when the desired, or necessary, amount of resin coverage is present on all fractions of the particles from the finest to the coarsest sizes. Optimum distribution, however, must be balanced with economics.

Laboratory blenders can be set up with very fine sprays resulting in boards with excellent properties. But the time required for such application is very long. Short-retention-time blenders, as will be discussed later, pass the furnish through

in seconds rather than minutes. Nevertheless, significant strides forward have been made in blender design, and further ones are anticipated with the motivational force behind such developments being the rapidly increasing cost of resins.

In all blending systems the fine particles, on a weight basis, almost always receive a disproportionately large amount of the resin, and the coarse particles end up with a lesser amount of resin. This is because the fines have the largest exposed surface area for a given weight and therefore are subjected to more contact with the atomized resin. Resin pickup in many blenders has been determined to bear an almost straight-line relationship to the exposed surface area of the particles involved.

No single blender apparently will produce the desired distribution of resin on fines and coarse particles for a layered board when both size particles are run simultaneously through the same blender. In a homogeneous board, poor distribution is largely negated by the intermingling of various-size particles in the finished board.

Many plants producing layered boards have overcome this problem by installing separate blenders for face and core portions of the board. This produces resin distribution which more closely approaches the optimum, since resin coverage on core and surface material can be better controlled. Also resins specifically tailored for faces and cores can be used. For example, as mentioned previously, slow-curing resins can be used in the faces to overcome problems with precure, while highly catalyzed resins can be used in the core to effect faster curing in this area which is heated last.

Depending on the specific type of board-making process, certain blending systems produce better results on given types of particles. This effect is lessened in a homogeneous board-making operation, and when separate blenders are used in a layered board-making process.

In the blender itself, the degree of atomization of the resin is important. For those with spray guns, atomization is affected by the number and size of spray heads used, their placement, the pressure used, and the type of fan or spray that is obtained. Distribution in the blender is also affected by the amount of air introduced by the spray system. Because these vary widely from plant to plant, each plant must determine the combination that produces the best results. Those with disc or centrifugal atomizers have the droplet size adjustable by the factors controlling the atomizer, such as rotor speed and feed rate.

The tremendous difference in surface area between typical coarse particles and typical fine particles is shown in Figure 13.2. A 1-g sample of the -6+9 screen fraction had about 12 in.² (0.008 m²) of surface area, while the -42 screen fraction had about 100 in.² (0.065 m²) of surface area. Thus the small fraction had almost eight times as much surface area requiring resin.

In addition to the blender, which plays a primary role, there are other factors which influence resin distribution and efficiency. The ability to produce a large number of adequate bonds is dependent upon such factors as particle geometry, the ratio of various mesh sizes of particles present, moisture content, fiber structural integrity, density of particles, resin efficiency, and density of the finished board, as well as variables in the mat-forming process and pressing conditions.

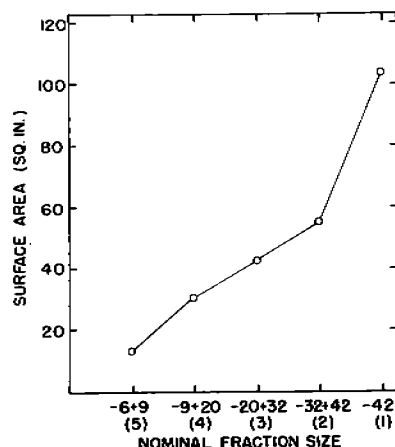


Figure 13.2. Surface area of five screen fraction sizes based on one-gram samples (Maloney 1970).

Particle size and form are definite factors in controlling board properties. The resin probably approaches most closely the desired maximum efficiency when applied to surfaces that manifest the lowest possible surface fiber damage. These intact surfaces allow better bonding of particles at lower pressures than do the rougher, surface-damaged particles. This fiber structural integrity allows the resin to function properly.

The glue-bond efficiency of the resin used in boards produced with a fine degree of atomization will be more uniform than discrete droplets from a coarse spray. In long-retention-time blenders, generally there has been little transfer of resin from one particle to another, even though prolonged mixing may take place. Some distribution by rubbing apparently takes place in short-retention-time blenders. Therefore, each board manufacturer must optimize the degree of atomization. Better spraying may sometimes be obtained by dilution of resin, but care must be taken to insure that such factors as lower tack, excessive penetration, higher moisture content or other side effects do not interfere with the best resin efficiency. Many times, conditions in the forming station will dictate what may be done. Pressing conditions also play an important role here, as do processing variables. Coupled with the importance of the individual components, one readily sees that all of these contributory factors are closely interrelated.

Recent experimentation has shown a possible change in resin transfer characteristics, as transfer of resin from particle to particle has been found. Perhaps the changes in resin formulation through the years are responsible for this transfer.

As mentioned, uniform distribution of the resin is of paramount importance. Regardless of the type of board produced, the most decisive factor is the degree of utilization of the resin. Properties of the board are reflected by the quality and

quantity of glue bonds formed. Properties of the board improve with an increase in resin content, up to the point where the resin approaches filling all voids. But increasing resin content is not always the salvation it seems to be; because maximum resin efficiency must be balanced with economics, and this dictates minimizing the amount of resin used, particularly nowadays with the cost of resin increasing significantly. If resin usage is to be kept at the minimum, then other factors will have to be optimized.

One of the factors to be optimized, if the dictates of defined resin efficiency are to be followed, is the production of high-quality furnish. In making homogeneous board, the particles should only be refined to the size necessary to achieve ultimate board properties. This means that excessive fines should not be generated as they would, in turn, create excessive surface area to be bonded, resulting in poorer efficiency and utilization of the resin. If the particle geometry in a homogeneous board is similar between large and small particles, then an equal distribution of resin, on a surface area basis, between the particle sizes could conceivably take place.

Board properties are influenced not only by particle geometry and inherent properties of the wood species used, but also by resin content, the compression ratio of the species as determined by specific gravity, and moisture content. Increasing resin content of the board is the easiest way to improve its properties, but only to a maximum level. It must be borne in mind that the better properties obtained by increasing the resin level involve considerable expense. There is more resin at higher levels of addition that is not doing any significant bonding. This once again brings about the need for fiber structural integrity within the board so the resin can function effectively.

As noted previously, some hardboard operations apply the phenolic binder resin in attrition mills before the furnish is dried. However, U.S. particleboard plants dry the particles to a low moisture content, which allows for the moisture gained in the application of resins and other additives to give the desired final mat moisture content into the hot press. Some are finding that any moisture needed to adjust the moisture content should be added before the resin application as resin "strike in" or absorption by the furnish is reduced. There is no post-drying of the resin-blended furnish except for that resulting from the heat in the furnish out of the dryer and from exposure to air between the blender and the form station.

The temperature of the furnish directly from the dryer can, and does, affect the efficiency of the resin. Care must be taken to insure that the temperature of the furnish is not excessively high. If high furnish temperature is present, dryout of the resin can occur, resulting in loss of tack, too much resin penetration, and, in extreme cases, some pre-cure. This excessive dryout can be amplified by using hot cauls. All of these should be avoided. Furnish coming to the blender should probably be kept below 100°F (38°C). If it is known that high temperatures exist, however, it is often possible to design a resin specifically to overcome or alleviate these problems.

One of the more irritating problems in blenders is the buildup of resin and particles within the blender, which markedly diminishes the efficiency of the blender and causes periodical maintenance shutdowns. This is because the buildup of resin and wood particles which adhere to the sides of the blender and the

agitators dries out, and eventually becomes a hard mass which interferes with normal operation. This may occur at regular intervals ranging from as little as three or four hours up to several days. Factors which influence this are choice of resins, size of particles, type of agitation, and many of the same factors already mentioned. Some blenders may be more prone to this type of problem than other blenders under the same conditions. Newer blender designs are now helping to solve this problem, and these will be mentioned later.

Resin application, its efficiency, and its effect on the quality of the finished board, at its simplest, involves a myriad of complex interrelationships between all the integral constituents of the board, plus the influences of the many process variables.

WAX APPLICATION

The application of wax emulsion can be done before, with, or after applying the resin. No particular problems occur with urea resins; however, some decrease in sizing quality may occur when blending emulsions with phenolic resins. Emulsions could rarely be mixed with phenolics at first, but most problems have now been overcome. Thus, wax can be added where desired in the blending process with little or no deleterious effects.

Making emulsions work as they should is primarily a matter of maintaining their original quality. They require a well-designed handling system that avoids all the conditions that can make the wax separate before it should.

The best system is the one that requires minimum operating attention and maintenance. Plant personnel should not have to become experts in handling emulsions, as the system itself should take into account all possible variables that could cause trouble. It should be possible to apply emulsion without constant attention to the system, and this goal has been realized by the research and development activities of wax manufacturers and board plants.

Temperature control is important in shipping as well as in storage. Below 60°F (16°C), emulsions have less resistance to shear and are susceptible to damage and deterioration when flowing through pumps and valves. Temperatures below 40°F (4°C) result in separation that cannot be corrected by reheating or agitation. Allowing temperatures to rise above 110°F (43°C) can result in a coarseness of the wax-water mixture. Furthermore, rapid evaporation, which leaves a crust on the surface of the emulsion, can take place. Ideally, emulsion temperature should be maintained between 70° and 80°F (21°-27°C).

Insulated tank cars and trucks usually restrict temperature changes to less than 1°F (0.56°C) per hour while an emulsion is in transit, which is especially needed for protecting the emulsion for one to two days in subfreezing weather. Freezing, of course, breaks down the emulsion.

Outside storage tanks must be insulated and heated for protection against freezing temperatures. They may be heated with either a hot water piping loop at the tank bottom or by electric heating cables wrapped around the outside of the tank. Electric heating cables must be arranged and insulated to avoid hot spots that might cause localized boiling of the emulsion. Steam cannot be used because hot spots cannot be avoided in a steam system.

Spraying or atomizing by centrifugal force will be covered under "blenders," since the resin and wax are usually mixed together. However, as with resin, it is important to distribute the wax uniformly over the particles.

Solid wax must be heated for liquefaction before it can be sprayed. This calls for a completely hot system, including the spray nozzles. A problem can occur if the spray pattern is too long for applying the wax in the blender, as the wax will solidify before striking the furnish and thus it may not adhere properly.

INSTRUMENTATION AND MEASURING

For any blender to function efficiently, good control must be exercised over its operation. Accurate control of the ratio of resin, wax, or other additives to the furnish is necessary. Relatively simple equipment is used for preparing the additives prior to blending in U.S. plants, mainly because many of the U.S. resins are internally catalyzed. In Europe, however, it is common to mix resin, catalyst, ammonia, and even starch extender for face resins in the board plant. The resin preparation areas, which are called *glue kitchens* in Europe, are usually rather messy places. It is, however, a very important part of the plant, as errors here only cause problems with the board properties if too little resin or wax is used. On the other hand, excessive errors on the side of adding too much additive will increase the cost of producing the board significantly.

The simplest method of preparing the additive mixtures is to measure out each material in buckets and then mix them together in a tank. This system allows for easy changes in additive formulas, but is subject to frequent operator errors.

A common metering system is shown in Figure 13.3. It consists of a number of transparent graduated plastic cylinders. The level of the liquid in each cylinder can be varied by the positioning of magnetic switches, which means a plant can easily change its additive formulas. There can be problems with accurately measuring wax emulsion, as it may tend to foam. If a starch mixture is used in the face resin, it has been found that it frequently segregates in the cylinder and sometimes plugs the drain valve. The plastic cylinders used with emulsion also lose their transparency, and visual control of the flow is not possible.

Another system uses scales for measuring the amounts of the various additives. Limit switches are used to interrupt the flow of the fluids at preset scale readings. The use of punched cards makes changes in glue formulation relatively easy. The tolerance of the scale, however, does not allow metering of large and very small amounts of material on the same scale. Consequently, a two-range scale is used, or the main portion of the resin is metered into the mixing tank by a flowmeter or level indicator. The scales work with electronic controls, and at times the maintenance on them is not done efficiently. Stirring equipment is needed to obtain a homogeneous mix of all the materials going into the solution to be applied to the furnish in the blender. Investment costs for such an installation are high.

Proportioning pumps for metering the various materials for blending have been used in the industry for many years. All of the components are stored in containers above or near the pump unit. A pump unit consists of a drive motor, the gears for the pumps, and the respective pump heads. The measuring pumps are oscillating

Nuclear wood measuring devices can also be used elsewhere in the production process, particularly for controlling the delivery of the wood in the mat former, as will be mentioned later, and as level gauges on fiber bins.

BLENDERS

Over the years a number of different types of blenders have been developed for use in the board industry. Some of them, no longer used extensively, will be mentioned briefly in order to gain a historical perspective as well as to indicate approaches that were rejected after experience in the field. Blenders are essentially of two types: long-retention and short-retention time. The first type may take minutes to blend the additives with the resin while the latter type performs the job in seconds. The first type is large in size and the second one small (considering the same capacity). In general, the objective of blending is to achieve an even and uniform distribution of resin, wax, and other additives over the particles. With resin, the goal is to glue the particles together with as little resin as possible. Thus, very accurate metering of the wood, resin, wax, or other additives is essential. The measuring system, therefore, is a very important part of the blending unit used in the board industry.

It is also difficult to work with a nonuniform size wood material which can run from very fine particles to large flakes. Theoretically, the more uniform the particles according to size, the better resin distribution should be. Since there usually is a very wide distribution of particle sizes within the furnish, it is necessary to compromise the blending operation to arrive at the most economical method of blending. Fine and coarse particles may be blended separately, for example. Speed of blending is important in an economic sense. At one time poor distribution of resin was overcome by adding a little more resin. However, the recent resin shortages and attendant price increases have made this an undesirable solution. Consequently, blending is moving to the forefront as a segment of the production process that should be optimized. The importance of such work can also be gathered from the fact that a conventional shavings-type $\frac{3}{4}$ -in. thick (19 mm) particleboard has four to five times as much resin as an equivalent piece of plywood. Composition boards probably will replace plywood in many applications because of plywood shortages. However, having to use excessive amounts of resin will hinder this important development.

Laboratory experimentation has shown that industrial blenders do not perform near optimum conditions. Thus, important developments can yet be made in this critical production step.

In early efforts with liquid resin, the resin was simply dripped upon the furnish for blending. This method was quickly supplanted by the spray nozzle. Many of the early blenders were of the batch type and they worked very well and were reasonably controlled. But these systems could not be used efficiently in large production units. Batch blenders have been applied to a large production unit in Germany where they had four batch blenders on a turntable. One was being filled while two were blending, and one was dumping blended furnish. This turntable kept going around and around, supplying material to the felter. The filling and the discharge of the batch blender and the timing obviously has certain limitations.

About 1953–1954 in the United States, continuous blending became the way to operate as the plants grew in size. Two of the first blenders of the continuous type were the Gresco and the Miller Hoff, both developed in the United States. These two demonstrate the primary difference between the two types of blenders being used today.

One has a short-retention time as exemplified by the Gresco. In this blender, the resin is sprayed or applied by centrifugally operating tubes into a turbulent airstream containing a thin layer of the wood particles. Excellent control in metering the resin and furnish is imperative because of the short blending time. In the long-retention-time blender, such as the Miller Hoff, furnish is slowly blended with the resin, which statistically provides for a greater opportunity for good resin distribution, particularly if the resin/wood metering system is not functioning properly.

In the late 1950s, the wind-sifting blender (a long-retention type) was developed in the Federal Republic of Germany. Both fine furnish and coarse furnish were blended simultaneously. However, the fine furnish was quickly blown to the outfeed end of the blender and was exposed only briefly to the resin spray. Coarser particles remained in the blender for a longer period of time. Even with this system, the fines received more resin than the coarse particles, and the terminology used to describe such uneven distribution was that the fines *hogged* resin. This particular blender, however, was very popular in the United States through most of the 1960s.

Some plants always used the short-retention-time blenders and a move back to them started in the late 1960s. At this time, the short-retention-time blender is the most popular in the United States, having replaced most of the long-retention-time blenders. Its move to the forefront has been so strong that refinements have been made to improve this type in the USA, and new designs have been developed in the Federal Republic of Germany. Indeed it is safe to say that this type of blender is the premier one available in the world today.

Long-Retention-Time Blenders

Long-retention-time blenders, as noted, are slow-speed machines that treat the furnish gently. Resin is usually applied by spray nozzle in fine discrete droplets. The theory is to expose all particle surfaces to the atomized resin so that an even resin distribution is achieved. The longer the blending time and the finer the resin droplet sizes, the more efficient the blending. Such blenders can be quite large; and, because of their size, extensive operating and maintenance problems are possible. Blender lengths of about 16 ft (4.88 m) are known.

Long-retention-time blenders can be generalized under the terms roller, paddle or shovel, rotary, and wind sifting. A number of variations of these types of blenders are possible, and it is not intended to cover all of them in this discussion.

Roller Blenders: One of the first blenders was designed for use in the Fahrni or Novopan system. This blender was intended for use with extended resin mixes that were relatively high in viscosity. One version of this machine is shown in Figure 13.17. The furnish is first divided into fine and coarse, with the fines being exposed to resin only on the lower glue-applying roll to prevent hogging of the

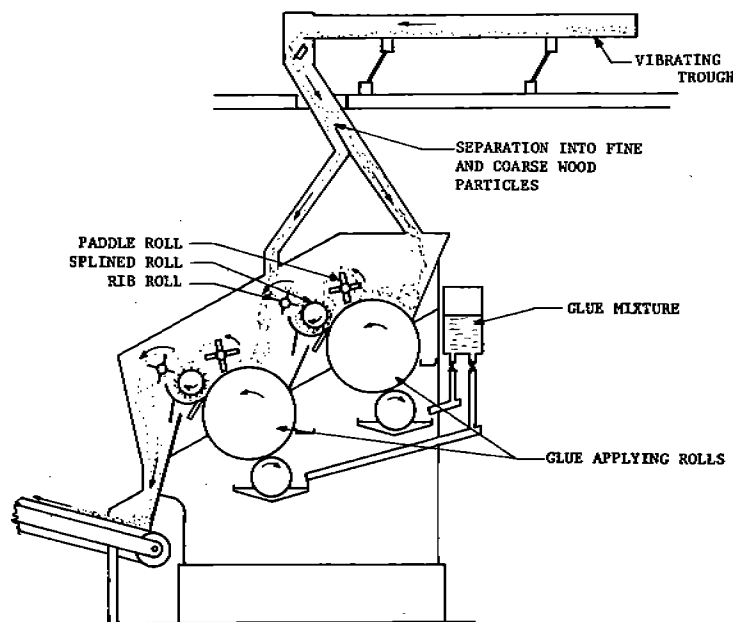


Figure 13.17. Roller gluing machine, Fahrni system (Kollmann 1957).

resin by the fines. The particles are rubbed onto the glue-applying roll by means of the paddle roll. The particles back up in front of this roll and are thoroughly blended with the additives before being carried over either to the next gluing roll or to the outfeed belt.

Paddle-Type Blenders: The early blender known as the paddle type is typified in the Miller-Hofft design developed in the 1950s. This blender consists of a long trough with a paddle arrangement inside that propels the furnish through. The agitated furnish is exposed to a number of spray nozzles set along the length of the blender. Figure 13.18 is a photograph of a small blender of this type showing the paddles.

A sophisticated version of this general type of blender has been developed that gently handles the furnish due to its low speed of operation. As shown in Figure 13.19, one central nozzle operating under higher pressures of up to 70 atmospheres is used for applying the resin or additives. Small droplets of resin are developed by this spraying system, resulting in satisfactory coating of even small particles. No undesirable wind currents are introduced into the blender because of the airless spraying; thus, the flow of the furnish is not disrupted. A centrifugal accelerator is used to form a conical curtain of particles in the blender. This style of blender is used throughout the world, particularly in the Novopan system.

A German design of another such blender took a different approach. Inside a cylindrical drum is mounted a revolving shaft which has heavy steel arms called shovels mounted axially (Figure 13.20). The furnish is picked up by these shovels, which are traveling fast enough to form a revolving envelope or ring of particles within the blender. Blending is accomplished in one and one-half to two minutes. The shovels are shaped to interchange the particles continuously from the outside of the ring through the center of the blender and back again as shown in Figure 13.21.

A different approach for applying the additives is used, namely high-speed centrifugal atomizers (Figure 13.21). No air, therefore, is necessary to achieve atomization of the additives. Each atomizer has about 125 holes for dispersing the additives and each one takes the place of several spray nozzles.

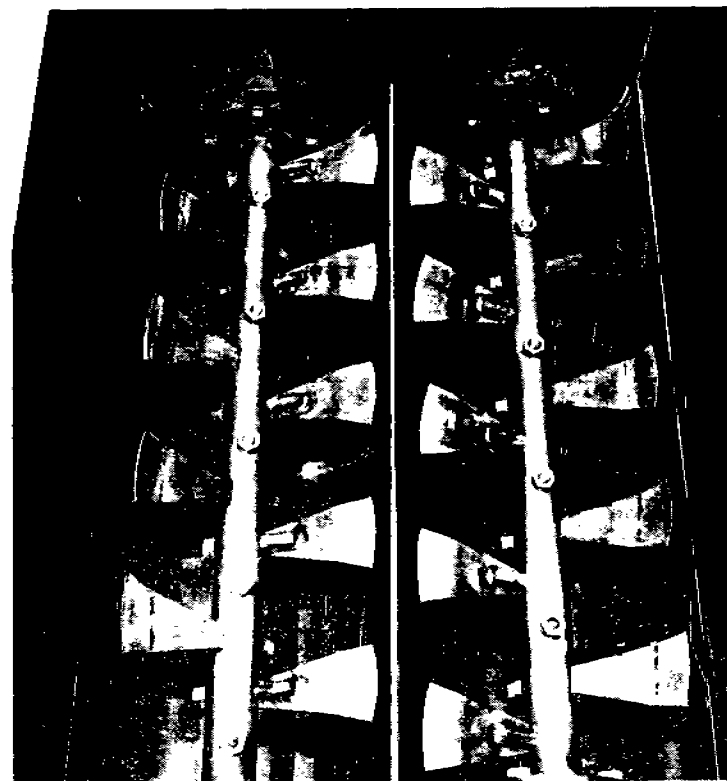


Figure 13.18. Pilot mixer interior, looking down into blender. (Courtesy Miller-Hofft, Inc.)

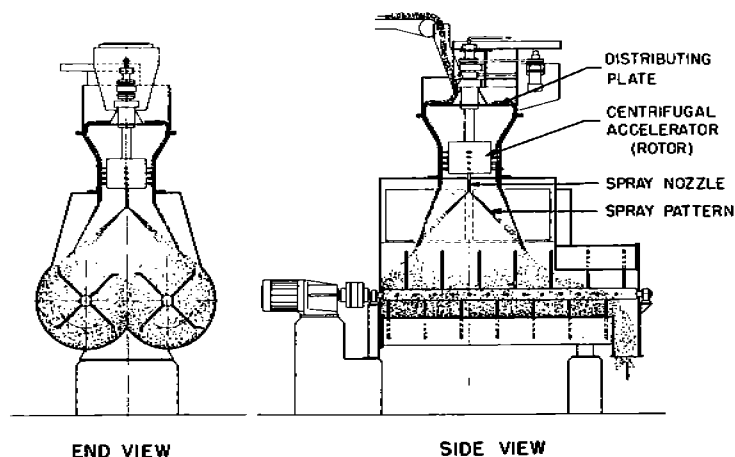


Figure 13.19. Principle of the Fahrni gluing machine with one centrally placed special nozzle. Scale about 1:50. (Courtesy Fahrni Institute Ltd.)



Figure 13.20. View of the shaft and shovels in a Lödige Blender (Young 1967).

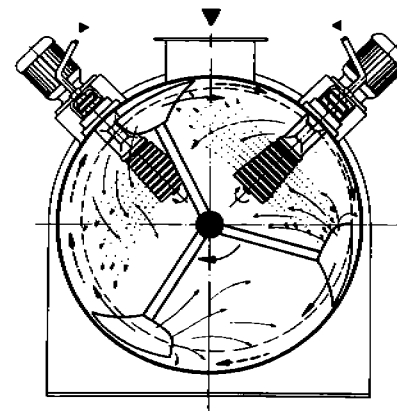


Figure 13.21. View of ring of particles and disc atomizer (Young 1967).

A blender for blending all of the furnish simultaneously is shown in Figure 13.22. Figure 13.23 is a view of a more sophisticated blender for separating the furnish by particle size before blending. Figure 13.24 is a drawing of the inside of the upper chamber shown in Figure 13.23. The furnish is screened with the coarsest furnish entering the blender so that it is exposed to the spray coming from all of the atomizer heads. The finer material is delivered to the blender at points

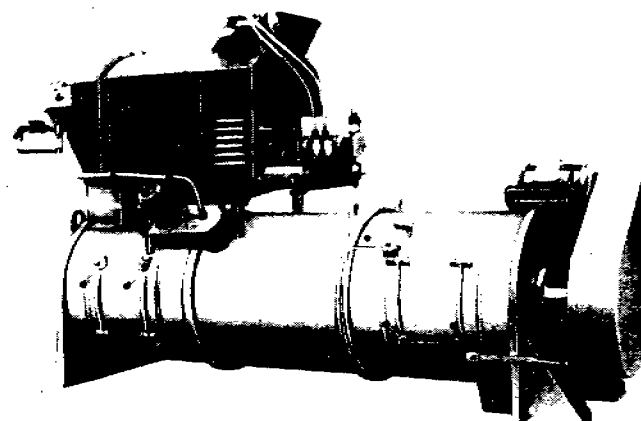


Figure 13.22. Overall view of standard blender (Young 1967).

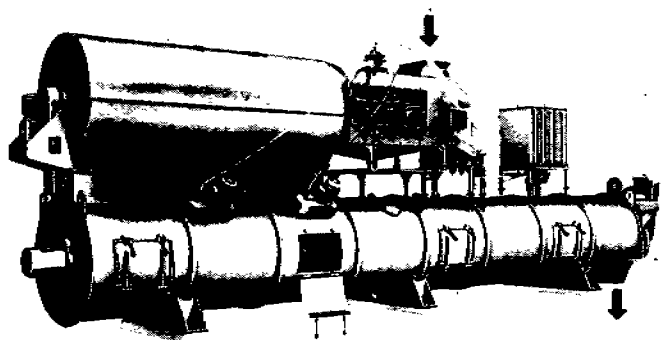


Figure 13.23. Overall view of sophisticated blender for preferential blending of furnish by particle size (Young 1967).

beyond the first atomizer. This approach prevented at least some of the hogging of the resin by the fines.

Rotary Blenders: Probably the most obvious technique for blending is to use a rotating drum for tumbling the furnish and to spray the resin upon this tumbling mass. A number of designs have been developed and used, and this system is a popular one in research and development.

In one design, inside the revolving drum conveying the furnish through, is mounted a boom parallel to the axis of the drum. On this boom are mounted spray nozzles, the resin and wax manifolds, and the compressed air lines. The additives are sprayed at a right angle to the drum axis. Figure 13.25 illustrates this blender. The particles are exposed to resin spray the full length of the blender. The tumbling particles form several "curtains" of material so that overspray losses are minimized. It is important that spray nozzles on blenders can be observed and easily

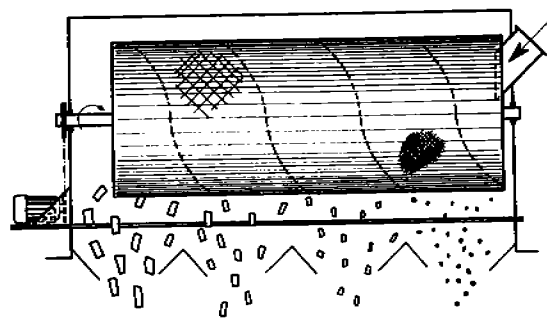


Figure 13.24. Particles separating above blender (Young 1967).

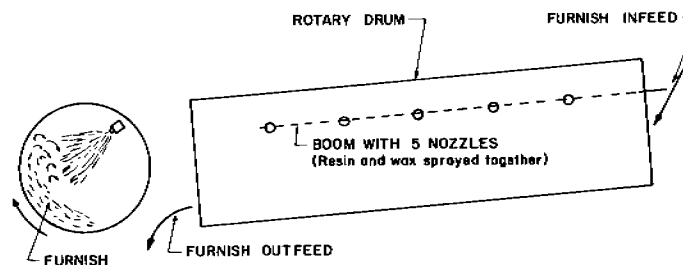


Figure 13.25. Schematic drawing of a rotary blender with the spray nozzles set radially to the long axis of the blender drum. (Courtesy Washington State Univ.)

maintained. However, in this blender they cannot be seen and spray nozzle problems can only be determined after the fact. Figure 13.26 shows the inside of one of these blenders during a maintenance shutdown.

Another design shown in Figure 13.27 has the additives sprayed parallel to the tumbling furnish. In this model, the spray nozzles are easily accessible so that malfunctions can be quickly rectified.

Wind-Sifting or Air-Classifying Blenders: This blender, which gained great popularity in the United States, was developed by Bähre Metallwerke (now Bison-Werke) in the 1950s. This manufacturer's first efforts with particleboard equipment were for its own use in its furniture manufacturing complex. With success in its endeavors, Bison expanded in the field not only with its own board plants but in manufacturing equipment and complete systems worldwide. One of

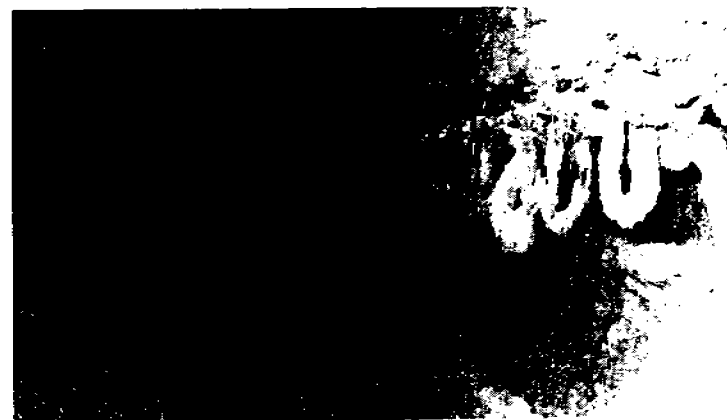


Figure 13.26. The inside of a rotary blender, showing spray nozzles and flights (Thompson 1967).

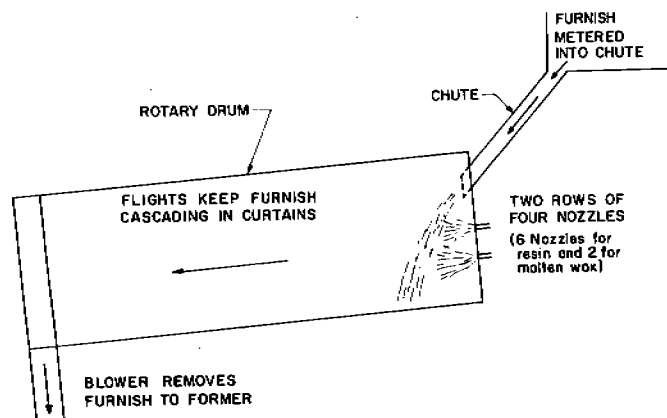


Figure 13.27. Schematic drawing of a rotary blender with the spray nozzles set parallel to the long axis of the blender drum. (Courtesy Washington State Univ.)

the pillars on which it has built its reputation is air-classifying of the furnish, particularly in blenders and forming stations.

Reportedly, the concept was first recognized while one of the individuals charged with coming up with a new approach was standing in a plant yard sifting dirt through his fingers on a windy day. He noticed the fine particles were blowing farther than the coarser particles. At the time a trough-type (paddle) mixer was being used in the operation. The air-classification idea was adapted to the paddle concept; the Bison air-classifying or wind-sifting blender and former were born.

A number of variations were developed for different applications. Figure 13.28 illustrates the basic principles. The furnish is dropped into an airstream at the inlet end of the blender. The coarse and therefore heavier particles drop straight down into the blender and are exposed to all of the spray nozzles. The rest of the particles are classified by size in a gradation from coarse to fine. Medium-size particles fall into the blender through the center of the blender and the very lightweight fines are propelled to the far end before being exposed to the resin spray. Rows of picker rolls or paddles propel the furnish through the blender thereafter. Resin is applied by two rows of spray nozzles mounted on top of the blender (shell) as shown in Figure 13.28. While the fines are not exposed to many of the spray nozzles, they still pick up a higher percentage of resin than the coarse particles. However, they would have an even higher resin content if exposed to all the spray nozzles. Thus this blender is capable of effectively blending various sizes of particles with additives simultaneously. These are large blenders as shown in Figure 13.29.

The furnish is fed into the blender off a weight scale on top of the blender. The weighed material is dumped into the surge bin on top of the blender and is then fed out of this bin at a controlled rate of feed. A picker roll or leveling device smooths the furnish out before it is fed into the blender proper.

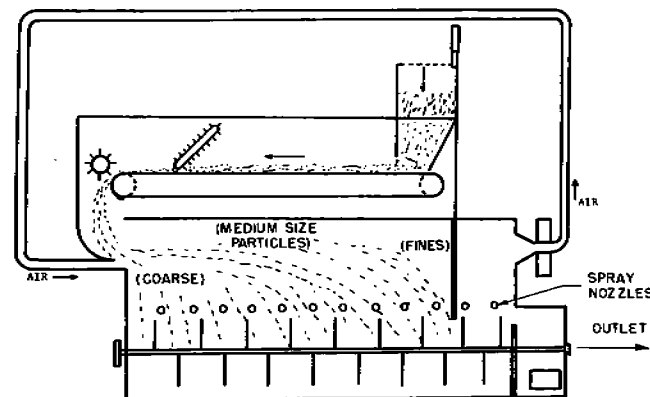


Figure 13.28. Schematic drawing illustrating basic operating principles of a wind-sifting blender (Haigh 1967).

Maloney (1977)

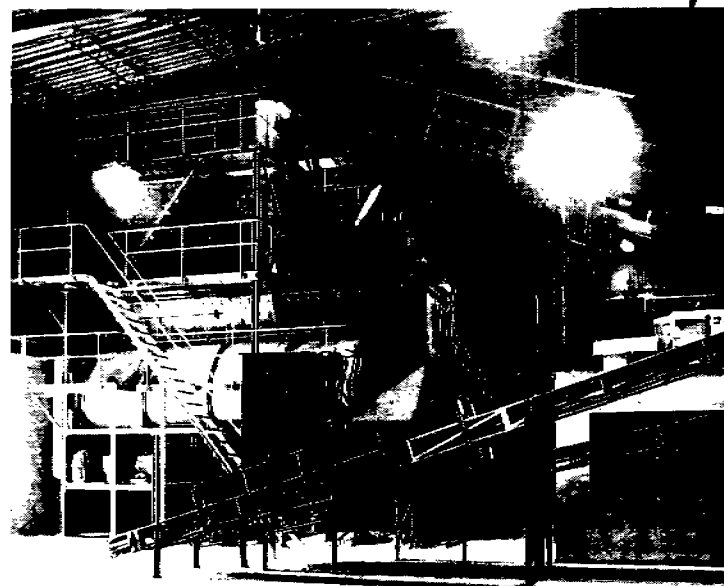


Figure 13.29. Long-range view of a wind-sifting blender (Haigh 1967).

Short-Retention-Time Blenders

Short-retention-time blenders generally operate at high speeds as compared to the long-retention-time type. Blending, as mentioned previously, is accomplished in seconds. Four general types are available: blowline, attrition mill, vertical, and paddle. These blenders are relatively small and compact and their smaller size should reduce maintenance problems.

Blow-Line Blending: The simplest blender is the application of the additives into the blow line leading from the attrition mill to the dryer or from the blow line out of the dryer which is transporting the furnish to the former. The droplets strike the rapidly moving furnish, and further blending is done by the violent tumbling of the fiber in the blow line. This system is used in dry-process fiberboard plants.

Attrition-Mill Blenders: Attrition mills (normally double-revolving disc types) can be used for blending in two ways. In one, the additives can be blended with the furnish simultaneously with the grinding of fiber. Additives can be metered in with the basic wood raw material or they can be metered through a hollow shaft holding one of the grinding discs into the "eye" of the mill. In the other, special devil's-tooth or peg plates (Figure 13.1), or for that matter any other plates with the desired configuration, can be used to blend the additives with the fibrous furnish. The gap setting between the plates is much greater than when grinding fiber. This is usually a fiberboard blending technique; however, at least one particleboard plant blends wax and powdered resin with planer shavings in an attrition mill. The attrition mill also reduces the planer shavings in size simultaneously.

Vertical Blending: In a vertical blender, as shown in Figure 13.30, the furnish is dropped from a metering bin into a tower. Spray nozzles mounted at the top of the tower spray into the falling furnish. The resin and wood then spiral together onto a conveyor belt leading to the former. Vertical blenders have also been developed which spray the resin upwards through the falling furnish, but their use has been very limited.

Paddle-Type Blenders: Paddle-type blenders are the usual ones thought of when discussing short-retention-time blenders. The paddles are also called other names, such as *shovels* and *plows*. Long-retention-time blenders try to expose all particles to a fine mist of resin and other additives. This, as noted, takes a considerable length of time. A different approach is taken with the short-retention-time blenders.

Figure 13.31 is a schematic drawing of one type of these blenders. The furnish streaming through the inlet has a high resin level on those particles directly exposed to the spray while the others have little or no resin. The uniform distribution takes place during the violent subsequent tumbling action in the blender. A concentric ring of material forms in the blender as the furnish transits the blender, although there is some evidence that the furnish passes through in a helix or spiraling pattern. In general, depending on blender diameter and length, the rotor may turn between 700 and 1400 rpm. It is important that these blenders run loaded with furnish to insure that resin transfer takes place by rubbing particles together.

These are much smaller blenders than the large retention types illustrated in Figure 13.32. Because they are small, these blenders are much easier to operate and maintain. Malfunctions can be quickly corrected. Adjustments in resin and

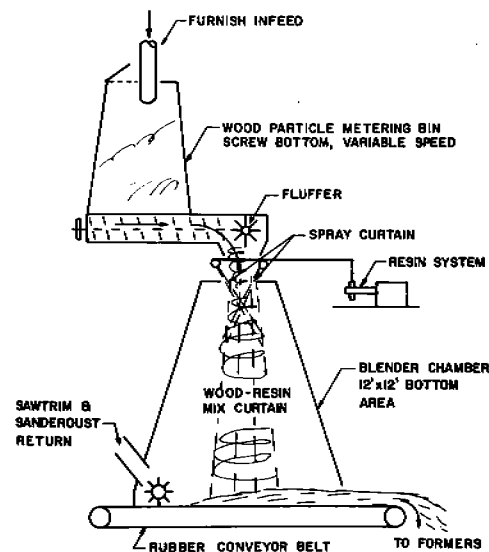


Figure 13.30. A vertical blender. (Courtesy P. R. Walsh)

other additive levels are fast to accomplish, which is important when changing production to a different product.

The first blenders of this type reportedly were used to blend molasses with alfalfa for cattle feed. They were first used for board in about 1948 in the development of the dry-process hardboard system. Later on they were used in early board plants of this type but were then supplanted by the introduction of simultaneous grinding of fiber and blending of additives in the attrition mill.

The first particleboard plants to use this blender were built in 1954. Others followed suit but the blender did not receive widespread use until about 1968. At

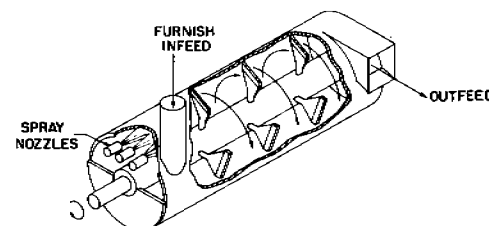


Figure 13.31. Schematic view of operation of a short-retention-time blender using spray nozzles (Maloney 1975).

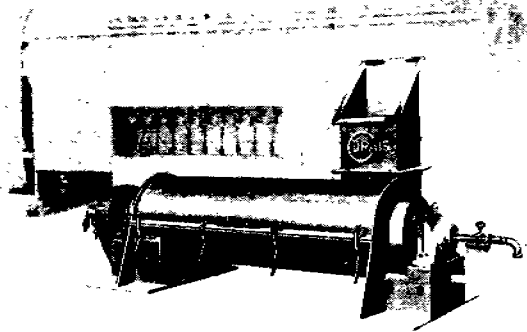


Figure 13.32. Continuous Drais Turboplan blender superimposed over a long-retention-time blender. (Photo composite courtesy Draiswerke GmbH.)

that time, many U.S. plants using long-retention-time blenders started converting to the paddle-type short-retention-time blender. Today it is the dominant type used. Grencos and Keystones are made in the United States. In recent years, Bison, Drias, and Lödige (Littleford builds the Lödige in the United States) have developed competitive models.

These blenders have been used to blend all types of furnish. Resin can be applied by air and airless spray guns (Figure 13.33) dripped upon the furnish entering the blender or by centrifugal force within the blender. In this application resin is delivered into the blender through a rapidly rotating hollow rotor shaft.

The retention time in the blender depends upon several factors: blender size, shaft rpm, angle of the paddles, and furnish feed rate. The furnish passes through the blender along its periphery and is expelled tangentially, usually onto a belt.

Because of the relatively high operating speed and multiple-paddle rotor, the blender in a non-loaded condition also acts as an axial-type fan and can discharge high air volumes, thus creating a dusting problem. Blender loading and air intake have a significant effect on the amount of air discharge. If intake air can be restricted on the inlet side of the machine, then the air discharge is similarly restricted. The high-speed shaft action also ejects the furnish with sufficient force to make it self-conveying for a distance of 6 to 8 ft (1.83–2.44 m). Air-dusting can also be reduced by reducing the rotor speed and the paddle pitch.

The most popular type of discharge appears to be directly into a plenum-chamber-type housing over a belt conveyor feeding the blended furnish directly to the forming machine. In some installations, a return loop duct vents this plenum

chamber back into the inlet side of the blender, thereby recirculating fines through the blender. In other installations, the plenum chamber over the conveyor may be directly vented into the suction side of the forming machine air system. Each installation seems to have its own peculiarities. There are also installations with a suction fan pickup for air-conveying of the blended furnish to the forming machine. Such installations should not be directly coupled to the blender since this additional suction tends to pull a portion of the resin spray through the eye of the blender right into the suction blower system which creates buildup in the fan piping and blower system. Air pollution problems are possible if the air is vented to atmosphere.

The capacity of these blenders can vary over a considerable range depending on style and manufacturer. Initially, when these machines were first considered for blending the new pressurized-refined fiber, the low bulk density of the fiber created concern that the short-retention-time blender would plug. This proved not to be the case. The concern was in error because the bulk density of the fiber was rated on a static basis instead of a dynamic basis. At rest, pressure-refined fiber may have a 2 lbs/ft³ bulk density (0.032 sp gr). However, when this fiber is injected into the short-retention-type blender, the centrifugal action of the rotor separates the fiber from the static air in a similar manner to that in which a centrifuge separates solids from liquids. Thus, the dynamic bulk density within the blender may be 10 lbs/ft³ (0.16 sp gr) or higher. That this occurs was readily evident in the blender installation at one medium-density fiberboard plant where, in operation, all the fiber transited along the periphery of the shell and the center of the machine was void of any material.

Experiments with the Grenco blender have been conducted comparing shaft injection of resin versus spray application. It was found that no significant difference in blending occurred. Thus, spray application has usually been chosen in the past as the optimum method because plugged nozzles can be observed immediately, and cleaning and maintenance can be performed easily. Some plants

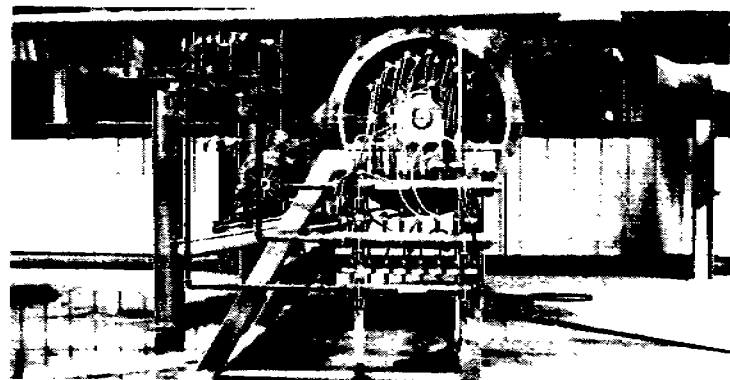


Figure 13.33. Spray nozzles applying additives in Grenco blender (Knapp 1971).

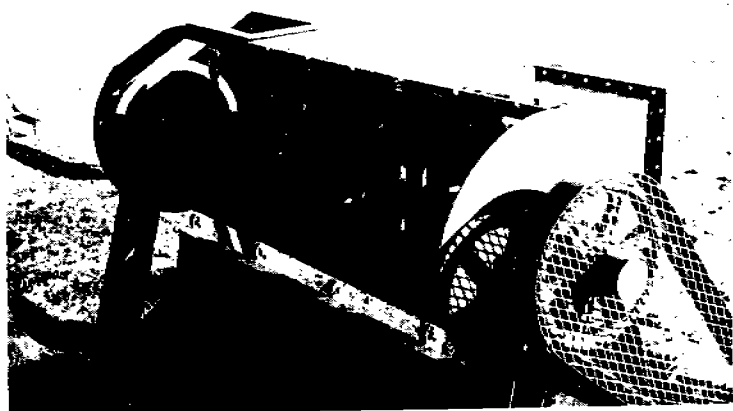


Figure 13.34. View of the rotor in a Keystone blender (Frashour 1967).

also apply wax emulsion by shaft injection, as well as extra water needed for tack control in the formed mat.

Greco and Keystone blenders use a paddle arrangement in the blender which has adjustments for paddle length and pitch (Figure 13.34). Removable inserts on the paddle ends can be replaced when excessive wear has taken place.

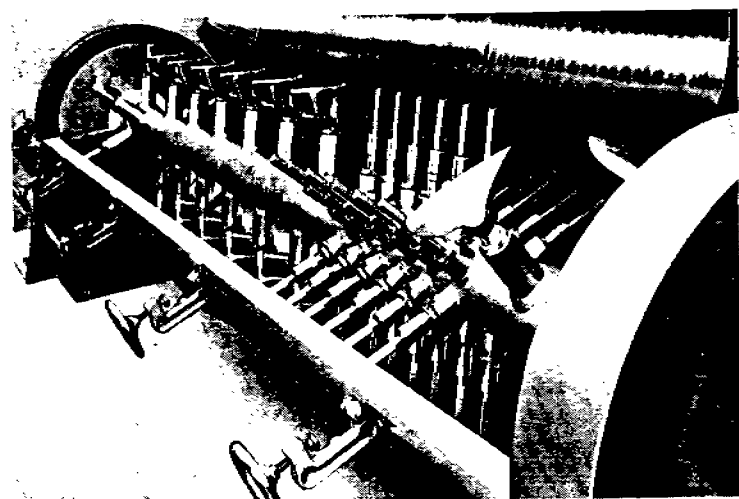


Figure 13.35. View of rotor in a Lödige-Littleford blender (Campbell 1974).

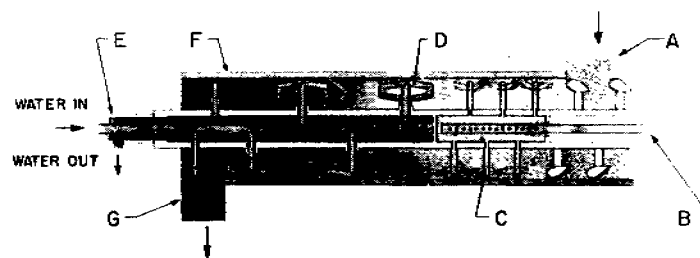


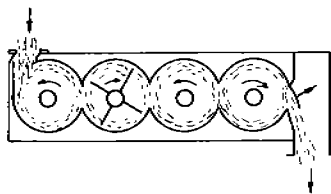
Figure 13.36. Centrifugal application of resin in a Lödige blender (Campbell 1974).

The Lödige-Littleford equipment shown in Figure 13.35, illustrates its shaft design. Figure 13.36 shows a slightly different approach to the blending action, compared to the models previously described. Particles are fed into the blender at (A) and formed by shovels into what the manufacturer calls the *chip-ring*. The resin is introduced through a distribution pipe (B). Note that this is not a pressurized system. The resin runs out of the distribution pipe into the glue arms which extend from the hollow shaft (C). About 96 holes for applying the resin are in the trailing edges of the resin-application tubes. These holes are about 0.100 in. (2.54 mm) in diameter; thus, small particles in the resin are not apt to plug the holes. Such resin application also eliminates the air introduced with air-atomizing spray nozzles. The resin is thrown from the glue arms into the *chip-ring* being propelled through the blender. Final blending is accomplished by action of the mixing plows (D) mounted on the shaft (E). The hollow shaft and the mixing plows are water cooled. These blenders are jacketed and water cooled (F). This water cooling results in a water-condensate layer, which inhibits the buildup of resin and furnish. The shaft, the tools, and the inner shell wall usually remain 100% clean. The cooling water, maintained at 53°F (12°C) or cooler, results in a heavy film of condensate on the surfaces of the shaft, tools, and inner shell wall. A counterbalance discharge flap (G) serves as a retention control system and prevents surging of discharge material.

The special design of the Lödige-Littleford blender has proven effective in providing good resin distribution and the elimination of resin spots. Competitive models from other manufacturers can also be found with water cooling. Since no air is added, problems with air pollution are eliminated.

An earlier version of a Lödige short-retention-time blender which is not emphasized at present is shown in Figure 13.37. In this design there are four cylindrical chambers with the resin added through centrifugal dispersion tubes in the second chamber. The furnish is driven transversely to the machine axis through the four chambers. The furnish is dispersed into a ring in the first chamber, blended with resin in the second, and post blended in the third and fourth chambers (a fifth one is also available).

Figure 13.37. A four-chamber short-retention-time blender (Schnitzler 1971).



The Drais blender (Figure 13.38) shows the same general approach as the other single-chamber short-retention-time blenders. Of particular interest is their precision chain-belt-wheeler for accurately metering the furnish into the blender. The resin is applied through a hollow shaft and "slinger" tubes on the shaft in the blending zone. Cooling of the shaft and housing is stressed.

In this blender, the resin is fed out of the ends of the resin-applying tubes rather than out of holes in the trailing edge as in the Lödige-Littleford. The first set of resin-applying tubes injects the resin into the inner rim of the concentric ring of furnish, the second set of tubes applies resin into the center of the ring of furnish, and the third set of tubes applies resin into the outer rim of the furnish.

Problems can occur if the resin sets up in the hollow rotor shaft of this type of blender. If all piping and pumps are kept below the level of the resin-delivery pipe inserted into the hollow shaft and if the holes in the delivery pipe are always in the upright position, insignificant amounts of resin will be deposited in the hollow shaft if the blender is shut down. Problems with the setting up of resin in the hollow shaft can thus be negated.

With some relatively fragile furnishes, the violent action of short-retention-time blenders may cause some particle damage. However, research with nominally 0.030-in. thick (0.76 mm) flakes (wafer) of Douglas fir has shown relatively

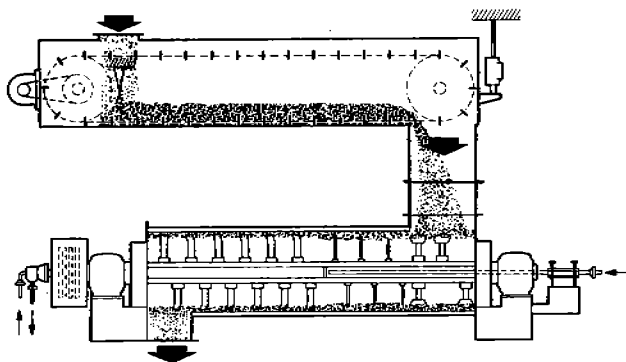


Figure 13.38. Schematic drawing of Drais Turboplan blender. (Courtesy Draiswerke GmbH.)

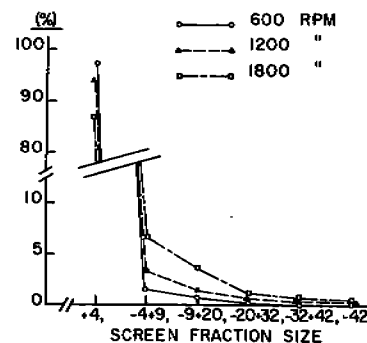


Figure 13.39. Screen analyses of large-flake furnish processed through a short-retention-time blender at three different speeds (Maloney 1975).

little breakage of these large flakes under conditions appropriate for good blending. Figure 13.39 shows a screen analysis on such flakes blended under these different conditions of blender rotor speed.

SUMMARY

As can be seen after the previous discussion, much effort has been devoted to the development of sophisticated, efficient blenders. Such development is very important nowadays with the increased cost and possible scarcity of resins. Work is underway on further improvements. It must be noted that even the most sophisticated blenders fall far short of the efficiency found with laboratory blenders. Thus, the optimum blender is yet to be built.

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14.

CAUL AND CAULLESS SYSTEMS

Before discussing mat formation and formers, prepressing, and hot pressing, it is necessary to first discuss the caul and caulless systems used in board production. It is difficult to separate mat formation, mat transportation, prepressing, and hot pressing, without first gaining an understanding of the two types of systems used in board plants. There are many possible ways that a forming and press line can be put together. There are a number of different formers available for use with different geometric shapes and sizes of particles. There are different types of prepresses and single-opening, multi-opening, and continuous hot presses. In this chapter, the forming press line will be presented in general, and in following chapters mat formers, prepressing, and pressing will be handled in detail.

CAUL SYSTEMS

The caul and caulless systems refer to the type of transport system used for moving the mat through the former and into and out of the hot press. The oldest system used in the board industry is the one using solid metal plates, usually called cauls or caul plates (see Figure 14.1). These plates about 3/16 in. (4.8 mm) in thickness are made of aluminum, steel, or alloys. A new system uses very thin flexible metal cauls of a special alloy, which can be heated quickly because of their thinness. It is reported that caul expansion takes place before full pressure is applied in the press, thus reducing problems of caul deformation caused by heating while being restrained.

The main advantage of the caul system is that it is relatively simple, as once the mat is formed it remains on this plate until after hot pressing is completed. Technological restrictions as to the particle geometry, the amount and quality of the resin, the tack of the resin, and particle moisture content are not as great as when using the caulless system.

With the caul system the mats are formed on the caul plates; the mats are cut to length at the juncture between caul plates, prepressed if desired, and then loaded into the hot press. After pressing, the finished boards are removed from the caul plates and the caul plates are returned around the forming-pressing line back to the infeed end of the former. Sometimes it is necessary to cool the caul plates on the return line so that the residual heat will not preure the resin on the first particles laid upon them on their next pass through the former.

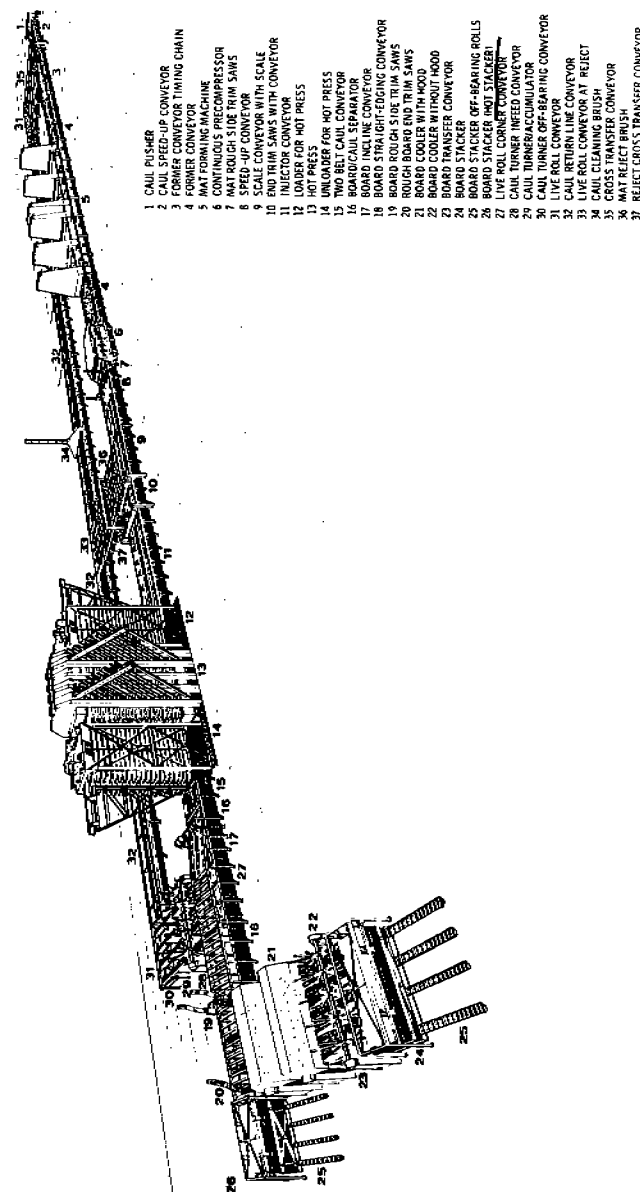


Figure 14.1. Particleboard caul-type forming and pressing line. (Courtesy Tallman Machinery Co.)

Normally a caul plate is not used on top of the mat. However, one may be used in certain cases where sticking is a problem (the board or particles stick to the caul plate and not to the press platens) or where a caul plate on top helps keep the mat from blowing apart as the press is rapidly closed.

A relatively recent development, similar to the caul-plate system, is one where a tightly woven metal mesh cloth is used in place of the caul plate. This flexible carrier is made of special woven steel wire 0.055 in. (1.4 mm) thick and is shown in Figure 14.2. The development of this system had the objective of eliminating the disadvantages of the caul system and the disadvantages of the caulless system, while at the same time combining their advantages. This system, called the Flexoplan process, has the following features:

1. After the mats are once formed they are transported into the hot press without any disturbance of the mat, in contrast to the caulless or semi-caulless processes. Prepressing can be used but it is not necessary.
2. The Flexoplan mesh metal cloth is dimensionally stable under pressure. This cloth can be heated up faster than a solid metal caul plate, and thus the heating time in the press can be reduced.
3. The thickness tolerance of the mesh metal cloth is determined by the tolerances of the steel wire. The wire varies less than ± 0.002 in. (0.05 mm) in diameter and is very resistant to changes in dimension under the influence of pressure and temperature in the press, which is contrary to caul plates.
4. In contrast to the caul system, this system requires much less floor space as the mesh metal cloths are returned under the press and the forming line.
5. After pressing, because of the structure of the weave, the mesh cloth quickly gives off heat to the ambient air so that no special cooling equipment is necessary in the return system.
6. During the time the hot press is being loaded, the mesh cloth insulates the bottom of the mat temporarily and prevents precuring of the bottom surface. This reportedly permits the use of higher press temperatures in the press as contrasted to the caulless system. In the caul system, of course, the bottom of the mat is not heated until the caul plate itself is heated, while at the same time, once the press is closed, the top of the mat is being heated immediately. In the caulless system, where the mat is deposited directly upon the hot platens, the bottom of the mat surface is immediately heated before the press is closed and there is the possibility of precure. The objective of the Flexoplan process in using the mesh cloth carrier is to control the heat applied to the mat in the press to such an extent that the heat is transferred to both faces of the mat at the same time and at the same temperature.
7. The very fine weave of the cloth makes it possible to lay down a very fine particle on the cloth without any sifting through the screen openings.
8. A very fine imprint is made on the bottom face of the board. This imprint is sanded off in the final dimensioning step.

The systems noted so far are normally used for multi-opening presses. For single-opening presses, the mats can be formed on a thin-gauge steel belt (a type of caul), prepressed if desired, followed by the belt moving the mat into the hot press.

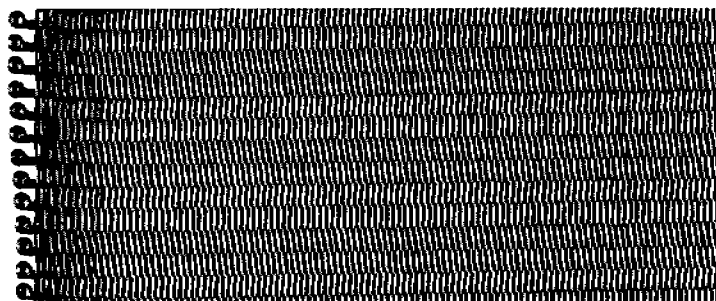


Figure 14.2. Photograph of mesh metal cloth (Strisch and van Hüllen 1969).

The steel belt, of course, stays in place underneath the mat during hot pressing. It is also possible to form the mat on steel wire mesh or woven fabric belts, prepress the mat, and then transfer it to a steel belt or wire mesh belt for transport into the hot press.

Continuous presses have been developed where the mat is formed on thin-gauge steel belts which then carry the mat through the hot press.

CAULLESS SYSTEMS

The caulless system uses either flexible or rigid plastic sheets as the transport medium through the former. It is then necessary to prepress the mat, with the exception of one system as described later. Afterwards the mat is deposited into the hot press for pressing into a board. The plastic sheet is returned to the head of the former to receive the next mat. A tightly woven wire screen (fourdrinier) or cyclone herringbone wire screen belt can also be used in the caulless system, particularly with fiber where vacuum formers are used.

The caulless system was developed for a number of reasons. There are problems with the caul system, particularly with the cauls themselves. They have a relatively violent treatment in being heated and cooled over and over in fairly rapid succession and they are also subjected to rather rough handling on a process line. Consequently they have a tendency to warp, twist, change their dimensions, and become defaced. The development of the caulless system meant eliminating the problems with the cauls themselves, plus eliminating the caul return system and caul cooler. Another improvement was the ability to employ slightly shorter press cycles, since the cauls did not have to be heated in the hot press prior to transmitting heat into the bottom face of the mat. The elimination of the cauls was also designed to contribute to improved pressing accuracy as far as thickness is concerned, because variations in caul thickness and imperfections in their faces were eliminated. Thus, the stock removal required during sanding can be minimized, which is important in that usually the face material of a three-layer or multi-layer board has the highest resin level and resin is quite expensive. The press must be well maintained to accomplish this objective.

Because the mat is usually prepressed in the caulless system, part of the compression as far as mat thickness is concerned has already taken place prior to hot pressing. Thus, the hot press daylight can be reduced slightly. Because the mat has already been formed into a relatively solid cake, the press can be closed quite rapidly. If the mat was not prepressed, the rapid closing of a press, particularly of the multi-opening type, could cause a great deal of what is called *blowout*. The rapid expulsion of air from the press openings blows the surface particles off of the mats and out of the press, thus ruining the final board product. Simultaneous closing devices on the press, as will be discussed later, lessen this problem. However, the blowout problem is minimized when mats are prepressed.

Another saving in raw material is possible with the caulless system because less trimming is needed with the mats and when cutting the pressed board to size. With a well-prepressed mat, it is possible to trim the mat edges and ends closer to the final board dimension. This trim material, because the resin has not been cured, can be reintroduced into the board former, thus conserving wood, particle quality, resin, wax, and other additives. In the case of the caul system, relatively wide strips, perhaps 2 to 3 in. (50.8–76.2 mm) or more in width, must be trimmed from the pressed board in order to obtain sound edges. This material can be milled back into particles and reintroduced into the furnish going to the blender, but this increases production costs since the resin has been cured and thus lost.

The caulless systems do have some technological restrictions that call for greater care on the production line. The mat must be one that can be held together after prepressing for deposition into the hot press. As such, particle geometry configuration has to be appropriate for holding the prepressed mat together. Greater amounts of resin might be required, or more precise control of the mat moisture level might be necessary. If a slightly higher mat moisture level is needed, problems with certain species and board blowing may occur. Tack in the resin is definitely necessary. Prepressing (with the one exception described later) is mandatory, and this adds a further cost to the production line.

It should be noted in passing that there are also three general types of prepresses. The first is a *platen type* where the formed mat is stopped momentarily for prepressing. The second is a *belt type* where the formed mat passes continuously underneath a belt compressor at the same linear speed as the former line. In this case the mat is gradually compressed as it passes through the prepress. The third type is similar to a *giant caterpillar tractor tread*; it operates much like the belt type and continuously compresses the formed mat.

Other problems have occurred with ambient conditions where the resin tack has suddenly disappeared at the wrong time, destroying the mat integrity. Also, certain species are apparently not suitable for use with the caulless system unless precautions are taken. One of these species, ponderosa pine, is relatively low in density and tends to develop a board with rather impervious faces. Plants running exclusively with ponderosa pine, or with a high proportion of this species in the furnish, have been ones having problems with blisters or blows. One plant using ponderosa pine almost exclusively for the raw material was originally built as a caulless plant. It was forced to convert to a caul line so that the moisture content could be lowered in order that good boards could be manufactured with a minimum number of blows and mat fractures.

Particle geometry, of course, is significant in assisting with the development of easy-to-handle prepressed mats. The high degree of fibrous material, particularly on the faces, will result in a mat much easier to handle than ones made up of small granular-type material. The fiber helps provide a good mat integrity. In fact, an all-fibrous furnish, as will be mentioned later, does not need any tack to assist in holding the mat together after prepressing.

Let us now consider some of the individual types of caulless lines that have been developed. They include the *tray-belt*, *tablet*, *flexible plastic caul*, *continuous belt*, and *wire screen systems*.

Tray-Belt System

The essential element of the tray-belt molding system is a retaining box, or mold, similar in principle to a deckle box with rigid side retaining walls. This mold, shown in Figure 14.3, has three features. First is an integral conveyor belt assembly which serves as the bottom surface covering the full area inside the frame. Second is a front gate which pivots from a point near the upper portion of the frame. Third is a movable rear wall located inside of the rigid stationary wall of the frame. This movable rear wall is fastened to the integral conveyor belt in the bottom. This is the system that does not require a prepress.

The tray-belt mold arrives at the press full of the board furnish laid down in the forming line. It enters the hot press with its front gate closed. During the press-charging portion of the loading cycle, the front gate pushes the board that has just been consolidated in the press into the unloader. Then, at a preset point in the forward overtravel of the mold, a mechanical latch opens the front gate permitting the deposition of the mats onto the press platen.

Figure 14.4 illustrates the principle with a single-opening press. Up to the point of maximum forward travel of the mold, the bottom belt assembly has been at rest relative to the mold frame. As the mold is withdrawn from the press, the bottom belt conveyor is activated to deposit the mat on the press platen. Withdrawal of the frame from the press is back toward the press loader. The conveyor belt is not independently powered, but derives its relative movement from the movement of the press loader. The function of the traveling rear wall inside the mold frame is to contain the rear edge of the mat during the period of its discharge from the frame. Part of the reset cycle to prepare each frame for its next orbit through forming and pressing is to return this movable rear wall to its original position inside of the

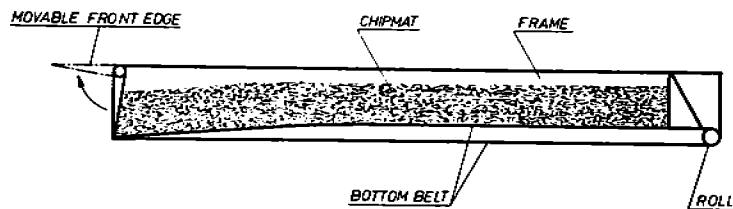


Figure 14.3. The principle of the tray-belt molding frame (Steck 1970).

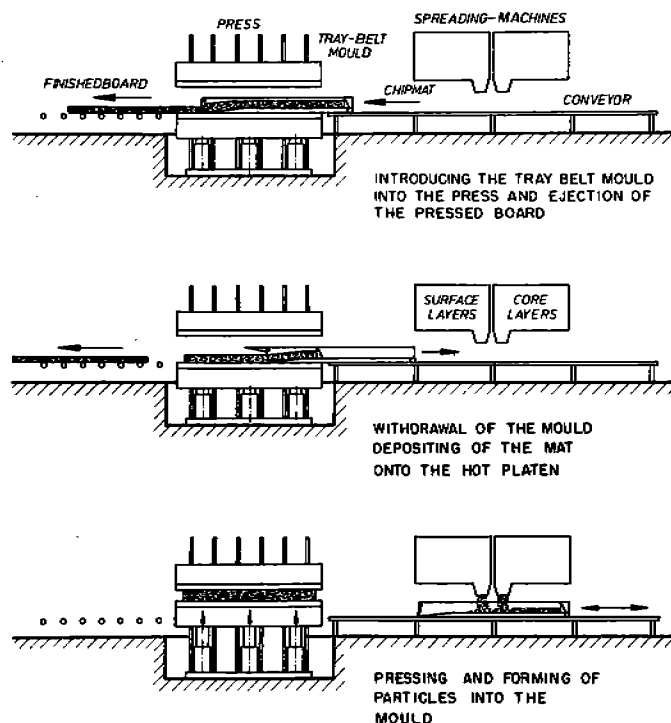


Figure 14.4. The sequence of operations in the tray-belt molding system (Steck 1970).

fixed wall of the mold. The front gate must also be closed again before the mold receives the next charge of raw material.

The mat makes its vertical drop from the belt surface to the platen surface by means of a prestretched, thin, and very flexible belt material. It is possible to use as little as a $\frac{1}{8}$ -in. (3.2 mm) radius at the nose end of the conveyor, while still retaining mat support beneath the entire belt surface. The approach to the nose is a long and very gradual mechanical decline to the point of mat transition from conveyor to platen.

Figure 14.5 illustrates various ways in which tray-belt molding plants may be arranged. In case of the single-opening press line, the forming station is normally directly in front of the press. Thus, the line is very compact and mechanically simple. During the pressing cycle, the tray-belt mold passes underneath the forming machines in a forward and reverse direction. In making a three-layer board, the bottom of the conveyor belt is first spread with face layer material

followed by the first layer of core material. The reverse occurs when the travel of the molding frame is reversed under the forming line.

The center diagram illustrates a multiple-opening press line. Here a press loader is located in front of the press, and the frames are fed into the press by a loading boom. The shortest version of this system is one in which each tray-belt mold leaves the loading station, has a mat formed into it, and returns to the loading cage in sequence. This eliminates a merry-go-round system where the molds circle around and through the former and back into the loader.

Another operating variation is shown in the lower diagram in which a two-level conveyor is used to transport the tray-belt molds through a forming line and back to the press loader. While a filled mold is entering the press loader at the forming level, an empty mold is simultaneously removed from the press loader at a lower level. A lifting platform at the end of the forming conveyor accomplishes the transition from one elevation to another.

The system therefore can accommodate a relatively wide range of plant capacities, although the majority of tray-belt molding press lines built have employed presses with four or fewer openings and have been equipped with the single-level, self-reversing forming conveyor. Board sizes as large as 7 x 42 ft (2.13 x 12.8 m) are being produced with a version of this system.

By changing molds, board size can be varied in both length and width within the limits of the hot-press design. Since no prepress is used and a minimum of mechanical support equipment is required to complete the line, a captive plant with as little as 30 tons (27.2 mt) of daily capacity has been found to be economically practical.

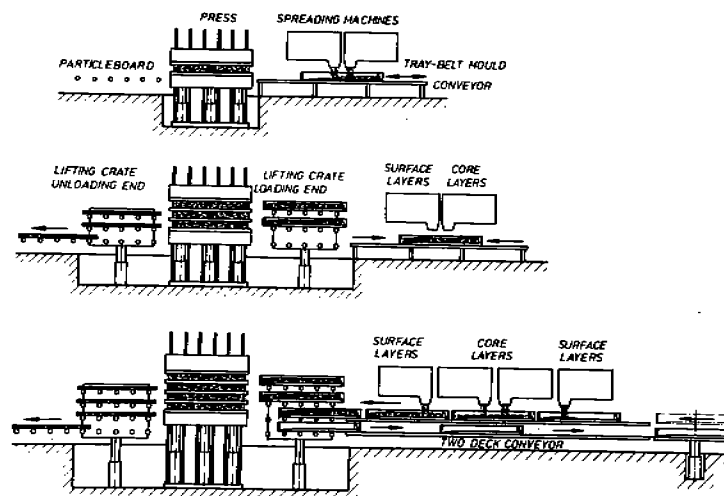


Figure 14.5. Particleboard manufacturing with tray-belt molding (Steck 1970).

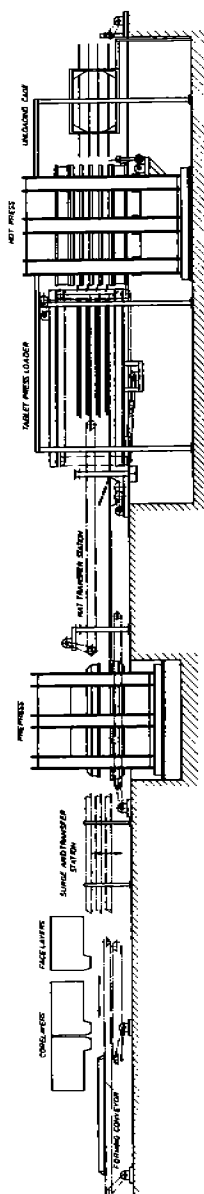


Figure 14.6. Tablet loading particleboard system with self-reversing line (Steck 1970).

As with all systems, the tray-belt mold has its limitations. The transporting frame assembly is a relatively complex mechanism. Also, the timing necessary for the press loading, loader indexing, and forming sequence functions must be handled by accelerating and decelerating speed controls in the frame transport system. There is no opportunity to reject the mat before pressing. The normal maximum capacity of this system is about 160 to 170 tons (145–154 mt) per day. Attractive aspects of tray-belt molding are the range of product thickness capabilities, including thin boards, efficient utilization of floor space, and large board size capabilities.

Tablet System

The tablet system also has a rigid frame in which the mat is formed. There is also some similarity in the flow of the frames through the mat forming station. The primary difference occurs in the floor for the frame, which is a rigid plate or tablet made of reinforced plastic instead of the integral conveyor belt used in the tray-belt system. The frame is not attached to the floor plate, but instead rests upon its edges with mechanical provisions to keep the frame properly centered on the plate. There the similarity between systems ends, because the tablet system centers around the use of a stationary prepress. In its prepressed state, the mat can be handled without damage by sliding it over smooth surfaces onto the hot platen.

Figure 14.6 illustrates a self-reversing tablet line. The surge and transfer station moves one frame on its supporting plate, or tablet, to the forming line at the left while a second tablet and frame assembly is simultaneously moving into the transfer station from the single-opening downward-acting platen prepress. The third level of the elevator is the surge station to compensate for the time the frame requires to make its forward and reverse path under the formers without a time penalty to the prepress.

Experience indicates that the prepress pressure should approximate the pressure of the hot press, or be at least in the 350- to 400-psi (2.41–2.76 MPa) range. Also, a distinct holding time in the neighborhood of 15 to 18 seconds for the total prepress cycle time is required. The prepressing technique consists of a rapid approach to the mat with a speed reduction before actual contact. Mat contact is followed by relatively slow pressing. The prepress platen fits inside of the frame within close tolerance. Before full pressure is exerted on the mat, the frame is stripped off the tablet surface in an upward direction so that lateral expansion of the mat is not restrained under the final thrust of the prepress platen. This prevents the mat from binding inside of the frame. Normally, the prepress platen is the same size as the pressed board after trimming.

A conveying mechanism inside the prepress slides the cake off the original conveying tablet to the mat transfer station to the right of the prepress shown in Figure 14.6. The mat is either passed through or dumped into a reject mat station, whichever is appropriate. Finally it is slid into the press loader. The loader is equipped with a series of thin, flat metal plates, usually aluminum, which carry the mats into the press openings. In the top diagram of Figure 14.7, the last prepressed mat is being pushed by the preloader onto the transport plate of the press loader. In the center diagram, the loader plates are conveying the mats into the press and

pushing out the finished boards. In the bottom drawing, the loader plates are being withdrawn from beneath the mats, after restraining crossbars (one for each press opening) have been moved into the press opening to a position on top of the loading plates and behind the mats to hold them in place. At that point in the loading cycle, the plates are pulled back into the press loader. The restraining crossbars then move out of the press openings and return to their "at rest" position.

The frictional forces between the mat and the carrier plate determine the pressure exerted by the trailing edge of the mat on the restraining crossbar, and it is predominantly the length of the mat which determines the specific pressure between crossbar and mat. If the force is too great, the mat structure will crumble. In practice, mat length is normally restricted to between 12 and 14 ft (3.66 and 4.27 m) in the tablet system. In these lengths, the resin content is usually no higher than would be required by the raw materials in any other system, caul type or caulless.

A different approach on one arrangement of this type of line is to form part of the mat on the return conveyor, in order to limit the internal shear stresses in the board which some feel occur when the mat is laid in only one direction (Figure 14.8). In this merry-go-round system, the first forming machine for a three-layer

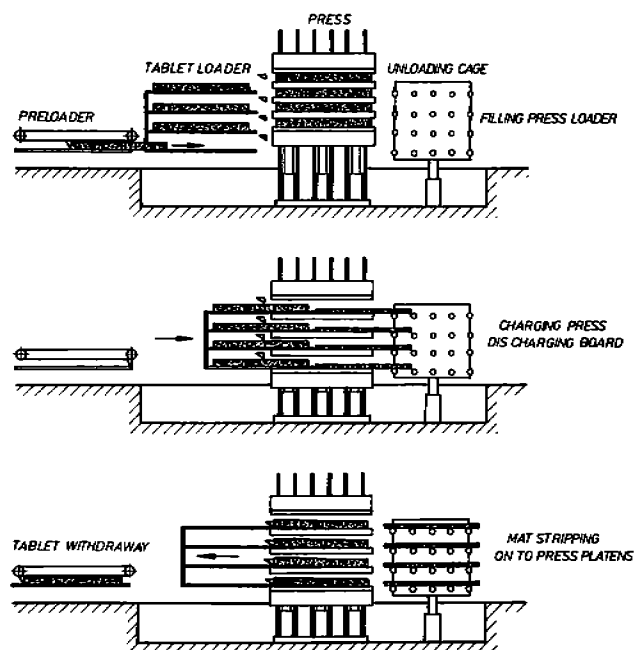


Figure 14.7. Tablet loading particleboard system (Steck 1970).

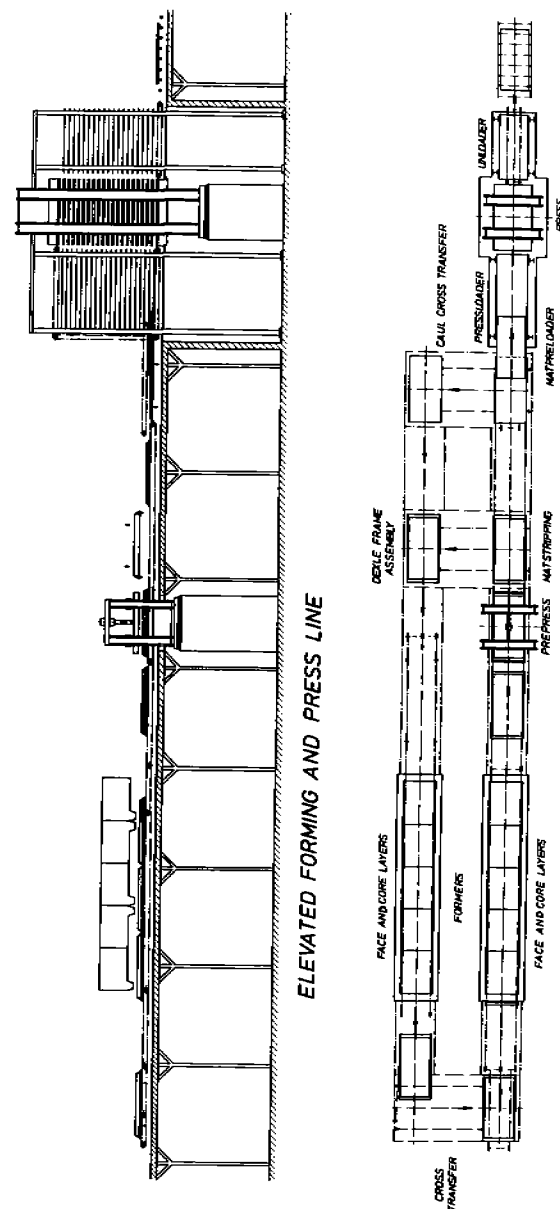


Figure 14.8. Tablet loading merry-go-round system (Steck 1970).

board on the return line is a face layer former. Next come one or more core layer forming units, depending on the capacity of the plant. The partially filled frame assembly is then cross-transferred to a position in line with the remaining forming heads leading to the prepress. In this fashion, the lower half of the mat is laid with particles oriented in one direction and the upper half of the mat with particles oriented in the opposite direction. In the self-reversing line, the same structure of mat buildup occurs. Even in homogeneous board, the reverse orientation of the particles in each mat is a desirable structure.

As in any system, the tablet-type plant has certain limitations. One already mentioned is that of board length. Another is minimum board thickness. The normal minimum considered to be safe is $\frac{3}{8}$ in. (9.5 mm) with any dry refined wood as the basic raw material. Under certain selective conditions, that minimum might be as low as $\frac{1}{4}$ in. (6.4 mm), but a careful analysis of both raw material and the properties required in the finished product would be essential before positive commitment to such a product. The prepress is a machine of major magnitude and represents a significant portion of the total cost of the line. Economically, its cost can be justified, but mechanically, it represents the critical path in the board-manufacturing process. Since a specific holding time in the prepress is required to solidify each mat, the prepress is the limiting factor in the productive capacity of the system, especially when producing thin board.

Flexible Plastic Caul

Compared with previously mentioned caulless systems, the flexible plastic caul system is the most popular in the United States. It is a combination of using a wind-sifting former, a platen prepress, and multi-opening hot press. A flexible plastic forming sheet is used as the mat transport on which the mat is formed. A popular material for the sheet has been polyvinylchloride-covered belting. On the head end of the sheet is a metal puller bar that extends 6 in. (152 mm) beyond each edge of the sheet. The forward movement of the forming sheet is initiated when lugs on forming and speed-up chains alongside the forming line engage the puller bar extensions. As the formed mats leave the mat-former, a flying cutoff saw cuts the continuously formed ribbon of furnish into individual mats by making a cut directly over the forming sheet puller bar. This is the same type of cut used on a caul line to divide the mats as to length. After the flying cutoff saw has performed its function, the puller bar is engaged by a speed-up chain lug, and the individual mat is then accelerated to a speed approximately four times that of the forming-line speed.

The mat is rapidly moved ahead into the platen prepress where it is then stopped and prepressed for a few seconds. By the time the prepressing is completed, the next newly formed mat has arrived for prepressing. The top platen in the prepress is usually heated to about 130°F (54°C) in order to prevent buildup of the tacky furnish on the platens, but prepresses of this type are operating without heat.

A typical cycle that has been used for prepressing takes about 17 seconds. A fast approach speed and two pressing speeds are used. During the approach phase, if too high a speed is used the air currents developed disturb the top surface

of the mat. In the second phase, most of the air is evacuated from the mat. In this case, if an excessive speed is used there is some rupturing of the mat, particularly along the edges. The final mat consolidation occurs during the third phase where the final pressure of about 350 to 400 psi (2.41–2.76 MPa) is held for three seconds. A tightly stretched curtain is used over the bottom of the top platen (the moving platen). Polyethylene sheet can also be stretched over this curtain to serve as a release agent.

After the prepress is opened, the consolidated mat is advanced onto a fabric belt. As this action takes place, the flexible forming sheet is separated from the prepressed mat and travels downward underneath the forming line and back to the start of the forming station to receive another mat. At this time the prepressed mat has a high degree of integrity and is formed into a fairly hard biscuit. To get this type of integrity, it is necessary to have a resin with tack that will assist in holding this partially consolidated mat together as it proceeds down the forming-press line. The mat is carried forward on a series of individually driven wide belt conveyors where final end trimming and side trimming are performed.

The mat ready for pressing is then injected into a press loader tray which is equipped with belts for loading and unloading as shown in Figure 14.9. When the press is ready for a new load, the press loader moves onto the trays of the unloader

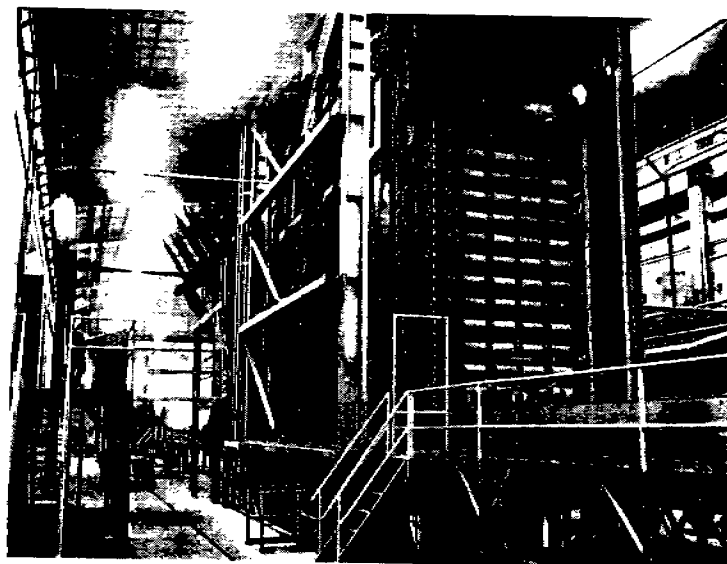


Figure 14.9. Caulless press loader. Each loader tray is in effect a conveyor equipped with four belts. The belts move forward at the same speed that the loader is withdrawn from the press and deposits the mats directly upon the press platen (Peinecke 1967).

shown in Figure 14.10. Compressed air can be released from the nosepiece of the loader as it passes into the press. This air blows all loose particles off the press platens. As the loader is withdrawn from the press, the belts on the loader trays move forward at the same speed as the trays are withdrawn, depositing the mat onto the press platens (Figure 14.11).

Changes in ambient temperature have caused problems in this type of line as well as others. At lower temperatures a phenomenon called *peel-off* has been seen. This is a separation of the bottom face of the mat from the core. This separation has occurred as the mat leaves the prepress at the time the forming sheet is being separated from the mat. *Lift off* is the term used by some when the top layer sticks to the top platen on the prepress and is then lifted off when the prepress opens.

As noted previously, problems have also been exhibited with resin tack by changes in mat temperature and humidity. The resin companies have been tailoring their resins for different seasons of the year in order to assist with the proper operation of caulless lines, although newer resins may have overcome this problem. In the prepress it is necessary to keep the mats from falling apart as they move down the line into the press loader and finally into the press. Problems are found when rapidly accelerating the mats out of the prepress, decelerating and finally stopping in the press loader. At least one company makes a conscious effort

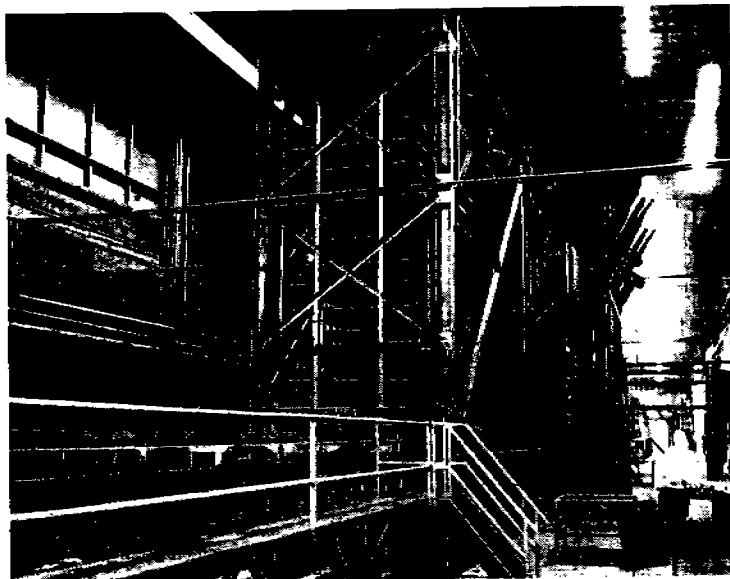


Figure 14.10. Caulless press unloader. No caul-board separator or caul-return system is required (Peinecke 1967).

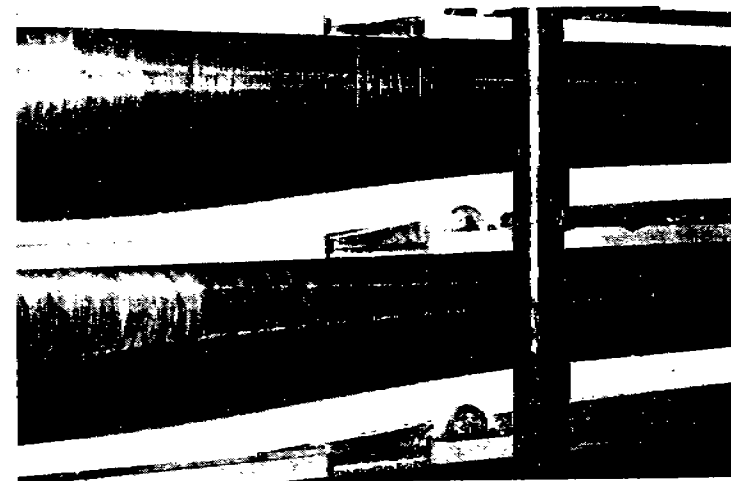


Figure 14.11. Photograph of mat being deposited on platens. (Courtesy Robert K. Carter, Boise Cascade Corp.)

to keep the plastic sheets on which the mats are formed at a constant temperature. This is done by spraying steam and water upon the sheet just before it passes through the former. They try to maintain an approximate temperature of 75°F (24°C).

CONTINUOUS BELT SYSTEM

In recent years, there has been a trend toward larger board sizes and plants of larger capacities throughout the world, as larger boards can better serve certain specialized markets. Edge trim and cut-to-size losses decrease in percentage of raw board produced as the panel size becomes larger. In general, plant cost per ton of productive capacity in a single-line plant becomes lower as the output of that line increases.

Two obstacles had to be overcome to make plants of very large capacity feasible. The first was industry's acceptance of the practicality of making board wider than 4 or 5 ft (1.22 or 1.52 m). The press manufacturer was not the only one involved. The forming machine producers, the resin scientists, and the process engineers all had to work together. The second major problem was one arising from the discontinuous pressing process. It was obvious that, when the press was consolidating and curing a load of boards, a number of mechanical devices were needed to transport and store the mats that were being formed in the meantime.

A system for continuous forming with minimum mat loss is schematically depicted in Figure 14.12. In this system the mat remains at the same elevation from the beginning of the forming line until it is in the press loader.

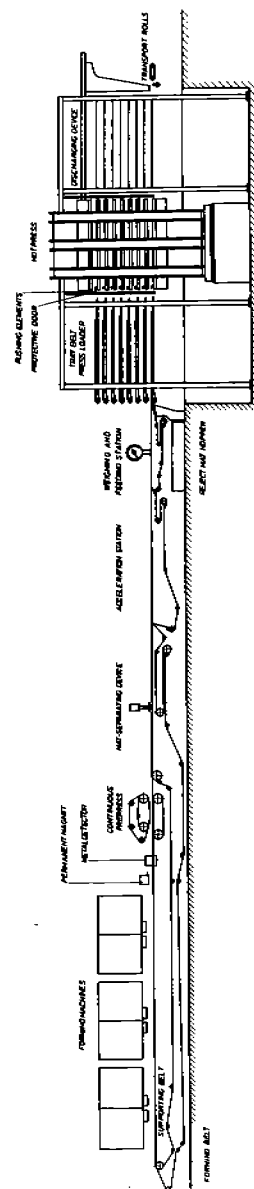


Figure 14.12. Continuous forming belt system (Steck 1970).

The method of mat separation is shown in Figure 14.13. This figure shows three conveyors in tandem. The forming conveyor is at left. For a specified board thickness and density, its speed is constant. The conveyor section in the middle is the acceleration station. It must run at two speeds: (1) the speed of the forming conveyor during the period of time a single mat is in process or transfer from the forming conveyor until that mat is totally on the accelerating conveyor and (2) at a higher speed to create the time separation between mats required to accommodate the capacity of the total press line. At the right of the diagram is the preloading conveyor which receives the mats from the acceleration conveyor and delivers those mats to the press loader. The preloading conveyor must similarly run at two speeds: (1) at the high speed of the acceleration conveyor during the period of mat transition, and (2) at the speed required to load the press loader in balance with the capacity of the total press line.

In the top diagram (Figure 14.13), one mat is on the forming conveyor, one on the accelerating conveyor, and one on the preload conveyor. In the second diagram, the higher velocity of the separating conveyor has taken effect and has created a larger separation between the mats. Meanwhile, however, the leading edge of the mat on the forming conveyor has advanced, still at its constant forming speed. To prevent a gap between the forming and mat-separating conveyors, the front nose of the forming conveyor has advanced at the same velocity as the forming belt conveyor. The forming belt take-up system has actually permitted the forming belt conveyor surface to become longer.

In the third diagram, the nose of the forming belt conveyor has advanced even further, but at this point, the previous mat has traveled beyond the mat-separating belt section. The second and third diagrams show that, as the nose of the forming conveyor was advanced, the trailing edge of the mat-separating conveyor was similarly advanced. With the mat off of the separating belt, the leading and trailing edges of these two conveyors can be brought back toward the original starting

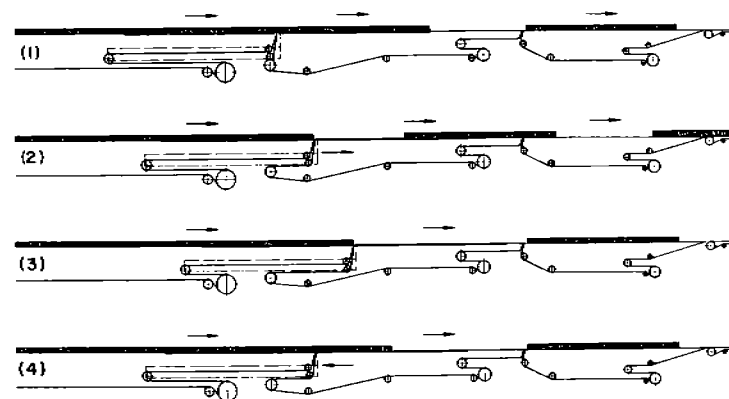


Figure 14.13. Mat movements in the continuous forming belt system (Steck 1970).

position. That movement is occurring as shown in the fourth diagram and establishes the starting position once again. Transition from the separating station to the press loader prefeeding station is always at the speed of the prefeeder. Transition from the forming belt to the separating station is always at the speed of the forming line. It is only the speed of the separating station which changes to either the speed of the preceding or the following conveyor. Since all are mechanically locked to a common drive, and the relationship between sections always remains constant, perfect synchronization is automatic.

The functioning of the press-loading mechanism is important since it could easily destroy the well-prepared mat. The press-loading action is shown in Figure 14.14. A minimal vertical drop through a long gradual slope to a relatively sharp nose and full support for the belt is the key. Normally, a separate pushing mechanism is used to eject the pressed boards out of the hot press far enough to be picked up by nip rolls in the press unloader.

Wire Screen System

When working with dry-process lines that use fiber for the furnish, the caulless system is relatively simple. Fibrous furnish can be laid down by a number of different formers, but one of the more popular ones is the vacuum former which will be described later. In this system, the fiber is laid down onto a wire mesh screen and then passes through one or two belt prepresses. The mat is then cut to length by flying cutoff saws and placed in a press loader of the same type discussed under the flexible plastic caulless system. Pressing is also accomplished with much the same type of press. With this line, tack is not as important as it is with the granular types of furnish. Indeed too much tack would create problems with the fiber, causing it to roll up into balls which would cause problems in the conveying system and in the former itself. Figure 14.15 shows this type of forming line ahead of the press loader.

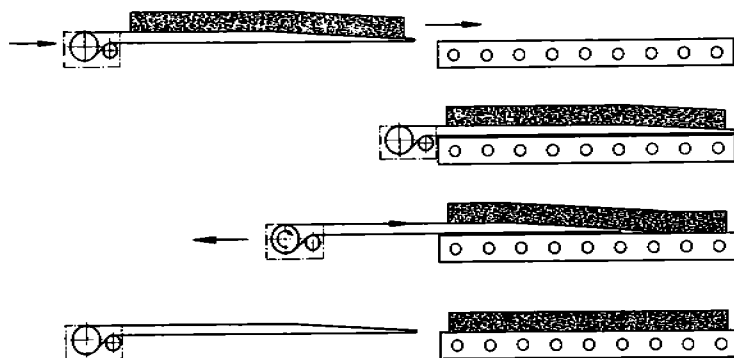
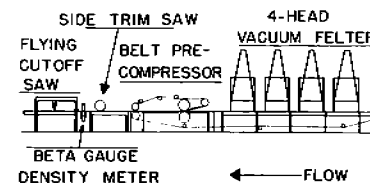


Figure 14.14. Press loading in the continuous belt system (Steck 1970).

Figure 14.15. General arrangement of the forming line in a typical dry-process fiberboard plant (Peters 1968).



CONCLUSION

As discussed, there are many ways to put a forming-pressing line together. For any new plant using a multi-opening press, the differences between the old reliable and relatively unsophisticated caul system, the metal cloth system, and the various types of caulless systems have to be carefully evaluated on the basis of the raw material available, production rate desired, the climatic conditions, and the technical expertise that can be secured for proper operation of the plant. The cost of investment and operating will be different, of course, for each system. It would be of great benefit to have a sophisticated formula developed to determine the best system for a particular location. So many factors must be evaluated, however, that it would be very difficult to come up with such a universal formula.

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15.

MAT FORMING AND FORMERS

Felting, forming, or spreading of furnish all refer to the formation of a uniform mat for consolidation in the press into the final board. Some feel this is the most important piece of equipment in the process line. There are many types of forming machines in use today around the world, and not all can be considered here. Most are manufactured by equipment companies; however, in addition, there are many custom-designed forming machines in a number of plants. No other area in the manufacture of board has such a large variety of machines available. Also, many problems have been found in this area. As in the rest of the process line, many factors have to be considered in deciding which former to use. The type of furnish used and the type and quality level of the board all have to be considered. Some machines require more raw material preparation than others. Some machines require constant adjustment and higher-caliber operators. Some are rather simple while others are quite sophisticated.

Some of the factors involved in mat formation will be explored first, followed by a review of some of the popular types in use employing different operating principles. Company names are used for easy identification. Several companies may be taking similar approaches to mat forming.

IMPORTANCE OF MAT FORMING

The preparation of a consistently uniform mat of furnish is one of the most important parts of the board manufacturing process. A lack of uniformity in this distribution will result in physical property variations, wide density variations, and excessive thickness springback in the high-density areas. Even if mechanical properties were not of prime importance, the uneven mat formation would result in a board more susceptible to warp. Poor mat formation may affect appearance and, therefore, the saleability of the board due to poor surface and edge characteristics. Unevenly formed mats can also cause damage to the press.

PROBLEMS ENCOUNTERED IN MAT FORMATION

The greatest problem encountered in the process of mat formation occurs because a volume of wood of varying bulk density is metered into the former with the expectation that an even weight distribution will result in the mat. The bulk

densities of the prepared furnish will constantly change with the variety of conditions under which the furnish is prepared. Its properties will also be changing depending on the source from which it comes and, perhaps, the season of the year. Further compromises must be made depending on the desired product to be manufactured, such as homogeneous or layered board for different end uses calling for high and low physical properties. Most plants will be wanting to make several grades or types of board, thus compromises must be made all through the production process. Perhaps the raw material will impose certain limitations, while advantage can be taken of other characteristics. For example, fibrous furnish cannot be used successfully in some formers but can be in others.

Bulk density and its variation is consequently of prime importance. If a highly refined fiber is allowed to fall freely, in all probability the mat will have a relatively uniform bulk density. However, this bulk density will change dramatically when conveyed in a screw conveyor or if stored in a large high-surge bin.

Carefully prepared flakes will also have a uniform bulk density, since all of the flakes have a similar shape and size. This will change as a result of manufacturing circumstances, such as breaking of the flakes if conveyed through fans.

Most of the raw material used in particleboard is not, for one reason or another, as well defined as those just described. In fact it covers everything from wood flour to large chips and slivers. Fiber is more uniform but wide variations are also found in its sizes. Periodic screen analyses of the furnish will show changes from hour to hour, day to day, and season to season. The particle geometry and size range will also change as knives, plates, or hammers become dull in the particle-generation process. The moisture content of the log, slab, or shavings will vary causing a further change in the particle. The resultant particle will also vary, depending on whether it is from a kiln-dried or air-dried source, as well as on the characteristics of the planer which produced it. Planer shavings may be thicker when planed from lumber produced in a circular sawmill than in a band mill.

With the wide bulk-density variations found, the approach is to try to establish average conditions and then to minimize wide fluctuations. This is another example of why the manufacture of board is an art as well as a science, since the human element must correct for and control fluctuations as well as other constantly changing factors.

FORMING MACHINE DESIGN

All forming machines meter the fiber or particles based on an average bulk density and spread it uniformly across the width of the machine. In some cases the furnish is weighed just before it is metered out to fall on the caul or other transport medium. Sometimes there is a leveling device to assist in forming a uniform mat as it leaves the forming machine. All forming systems have certain things in common, although the mechanics of each may vary. They all have a surge area, which may be integral or slightly remote, and usually a weighing section incorporated with a final surge or metering section. All have some method of dropping the furnish as individual particles onto the caul or transport medium. The fall is by gravity in almost all cases. The surge bin may be slightly remote as in the vacuum felters, on top, or behind the former. The primary purpose of this surge area is to

insure a continuity of material flowing into the machine. It is also important for spreading the wood uniformly across the width of the forming area. A uniform level in this bin must be maintained for bulk-density control. If the bin is too full, the density will rise; if it is too low it will decrease from material weight alone. With tacky resins, bin level change also causes tack change, which affects some former designs more than others.

Since this surge area is usually large, many, but not all, forming machines meter the fiber into a batch-weigh section to help overcome varying bulk densities. The batch-weighing machine can be preset for a given weight and number of weighings per minute. The scale is interlocked with the feed conveyor. The batch-weigher discharges into a final small surge area for final metering. This final surge area is small to minimize density-variation problems. From this final surge area, the wood is metered out on a volumetric basis by means of rakes, picker rolls, or similar device. Some, such as the Microfelter, use a bank of metering rolls. Other machines use only a single surge area but keep it low and long instead of high, so as to control bulk density in an attempt to be very accurate in metering.

Very few of the machines let the particles fall freely onto the caul or other transportation medium. Originally, forming machines were raised high above the cauls, and the material fell freely in the belief that the long fall would result in an even mat. Unfortunately, the particles, instead of falling down evenly, were affected by natural air currents and drifted to one side or the other being heavily influenced by the final flow direction of the air current created by the falling material itself. The forming machines were then lowered as close as possible to the transport medium. In some forming machines, screens were placed in the path of the fall furnish to break the material fall and to help the particles, particularly flakes, fall flat. In others, small screens were placed in the former to allow fines to fall onto the transport medium first, with coarser material on top. Other machines used picker rolls to spread the material out in the direction of caul transport movement. Still another machine dropped the material into a high-volume, low-pressure air duct to give a graduated layer effect. Another forming machine fed the material in the direction of the rotation of rollers and thus gave a grading effect from each forming head.

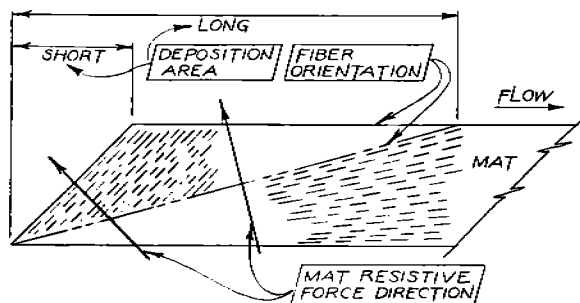


Figure 15.1 Mat-deposition angle (Newman 1967).

Originally, many mats were formed in a small area with the flakes or particles at a steep inclination (Figure 15.1). This was satisfactory with smaller presses. However, as presses became larger, this steep angle created a horizontal component to the pressing force which actually moved the press crown off its longitudinal centerline. It then became necessary to flatten or minimize this particle-deposition angle. The devices for dropping the particles were sophisticated in design to lengthen the mat-formation area, lessening the particle-deposition angle.

In spite of all of the elaborate mechanisms, some units still require leveling screws, picker rolls or shave-offs to level the final mat.

TYPES OF FORMING MACHINES

There are many different types of forming machines, each designed for specific types of raw material and end products capable of doing a variety of jobs within reason. With multi-opening presses, the former is stationary. There are some single-opening press line plants, however, where the forming machines must move. In these a single steel belt transits the former and press. Consequently, while the press is closed, the belt cannot move. In this case, the forming machine moves over the board area laying a mat down. Thus, the forming is intermittent and not continuous. Other small single-opening plants use individual cauls and a stationary forming machine.

In larger plants, an individual forming head has definite capacity limitations. In these cases, it is desirable to have multiple forming heads for continuous forming. Individual forming head capacities should not be pushed to their limit since, almost without exception, they will form a more uniform mat at lower rates. As a general rule, it can be said that for a given volume of wood, the more forming heads or drop points used, the more uniform the resultant mat. Further, with a given quantity of material, the more forming heads employed, the lower the particle-deposition angle.

With multiple heads, advantage should be taken of the opportunity to separate the finer material and place it on the faces. It is now also possible to work effectively with different particle-moisture contents and resin levels and resin formulations—for example, more moisture and resin in the faces and slower curing resin in the faces. This also means specialized equipment in the milling area of the plant for efficient separation of various-size particles. Some plants make three separations and use five or six forming heads. The two end heads are used for fines, the center one or two for coarse particles, and the two intermediate heads for a semi-coarse particle.

The capacity of a forming head should not be overextended. An additional head is inexpensive compared to the cost of rejects and sales complaints. Multiple-forming heads with a given amount of raw material will ease quality-control problems and make the plant generally more flexible to serve a variety of markets.

INSTRUMENTATION

The importance of accurate metering of furnish to the former has already been noted. Different approaches will be noted in the discussion of the different types of

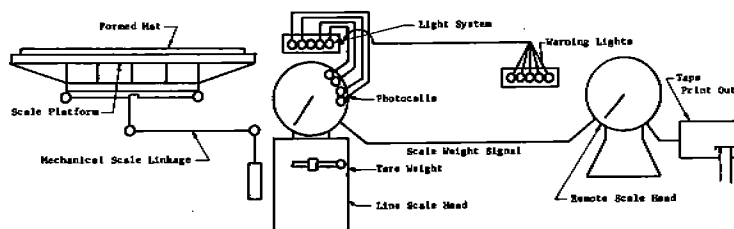


Figure 15.2. A schematic drawing of a mat-weighing system (Carter 1969).

formers available. Recently, nuclear gauges have been incorporated into the metering system on some formers. It is important also to weigh the finished mat after forming to insure uniformity. As noted, this is extremely important if boards of consistent quality are to be produced. Two systems are used: (1) weighing the entire mat with a conventional scale and (2) continuously determining the weight by means of a nuclear gauge.

Figure 15.2 is a diagram of a conventional mat-weighing system. The lever system transferring the mat weight to the scale-control box is similar to the continuous wood weight-o-meter used in blending. Mat weight is read directly from the scale face in one-pound increments.

For a superior mat-weighing system, some attachments have been added to the scale. Since the operator is located at a remote distance from the scales, a remote scale head is installed for close observation of mat weights by the operator. Attached to this scale head is a printed tape readout system to allow mat-weight trends to be monitored for correction before reject limits are reached.

An auxiliary light system is also included. The purpose of this attachment is to actuate automatically the mat-reject system if mat weights are too high or too low. Four photocells are used on the scale face in order to detect the position of the weight-indicator arm. Two of these photocells actuate the reject system, and the other two photocells indicate "accept over" and "accept under" mat weights. No photocell is needed to show accept values on mat weights.

Figure 15.2 shows the part of the auxiliary light system above the scale face. This part of the system, connected to the warning lights, may be used by the operator to control mat weights in case the remote scale head ceases to function. As can be seen, five lights are above the scale head. If either of the two outside lights (red) flash, the mat is rejected. If the second or fourth lights (yellow) flash, mat weights are running slightly high or low. If the center light (green) flashes, mat weights are right on target. The accuracy of this system has been reported to be excellent. The mat scale itself is accurate to better than ± 5 lbs (2.27 kg). The control of the mat weights is ± 15 lbs (6.82 kg). Much of the control of mat weight depends on the furnish bulk density and the skill of the operator.

By using a strip nuclear gauge, measurement of mat-weight-per-unit-length across the machine can be done on the fly, without altering the basic conveyor speed. This eliminates the static weigh station and speed-up device. Short-term variation in mat weight from foot to foot in the machine direction is evident by

observation of the strip-chart readout. Alarm contacts can be installed to monitor excess variations. Long-term trends are also evident on the strip chart.

For nuclear gauge measuring of mat weights, the basic weight or weight-per-unit-area, usually expressed in pounds per square foot, is used. Measurement is by point source and point detector geometry (see Figure 13.13). These elements are mounted on a C-frame, which in turn traverses a base beam, or on an O-frame wherein they ride parallel ways, which are held in line precisely by lead screws or cables. The C-frame is less expensive, requires less maintenance, but it does require aisle space equal to the width of the line, when it is backed off the mat. Newer models are temperature-stabilized, which prevents drift. The C-frame has the further advantage of complete removal from the line; while the O-frame, while it saves aisle space, remains at all times on the conveyor, where it conceivably could be in the way of the maintenance people. The C-frame has been popular.

It is difficult to use such gauges on caul lines as waviness of the cauls and variation in caul thickness cause problems. Consequently, the popular use of nuclear gauges is on caulless lines. In the caulless system, it is popular to mount the basis-weight-gauge C-frame before the prepress (Figure 15.3). In this line the gauge "sees" only the mat as no caul plate is involved. When the air space appears between the individual mats, the gauge changes its reading markedly. To prevent this wild reading and subsequent one- or two-second delay in reading on the next mat, the gauge can be arranged for zero center calibration, and the amplifier input can be zeroed by a photocell, sonic switch, or other external sensor when the gap appears between the mats. The zero center calibration creates easy operator interpretation; since he does not have to remember the absolute value of target-mat-basis-weight, and can be told to take action only when the gauge deviates a given percentage from the zero center.

A typical calibration for such a gauge would be ± 0.5 lbs/ft² (± 2.44 kg/m²). The precision of measurement and the resolution of 1% of full scale is ± 0.01 lbs/ft² (54 g/m²) for this application. Figure 15.4 shows a gauge in operation.

Metal detection and removal are of extreme importance at all points of the production line because of damage to the equipment that can occur. If sparks result from metal striking parts of the equipment, fires and explosions can occur. Rocks also cause these problems, but they have to be handled with rock traps.

The performance of any metal detector is quite variable as it does not detect all metal. Because of this, it is necessary to develop a metal detection and removal

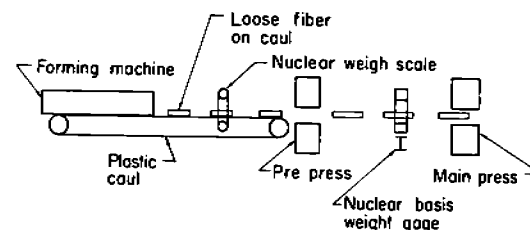


Figure 15.3. Nuclear gauge application on a caulless line (Rowe 1969).

system consisting of magnets, permanent magnets, electromagnets, magnetic-head pulleys, air-system traps, vertical air pickups, chipwashers, as well as metal detectors. Some have discontinued the use of metal detectors, because of variable performance, and depend instead upon the other methods of removal for handling metal and rocks.

After the mat is formed, a metal detector is needed to keep metal out of the press where expensive-to-repair platen damage can occur. Additionally, the metal would end up in the final board, where further damage to equipment could happen when the board is sawn either in the plant or in the field. When metal is detected in a mat, it is normal to reject the mat and not to try to reclaim the furnish.

The principle of operation of a metal detector is to use a radio frequency (RF) generator and RF receiver (Figure 15.5). The radio generator emits an RF magnetic field and the RF receiver is adjusted so it matches the RF generator field. Thus, the generator and receiver are in balance. This balanced condition is disturbed any time a ferrous metal passes between the generator and the receiver. Any change is monitored by the receiver which trips a relay, thereby sounding an alarm or operating a mat-dump gate.

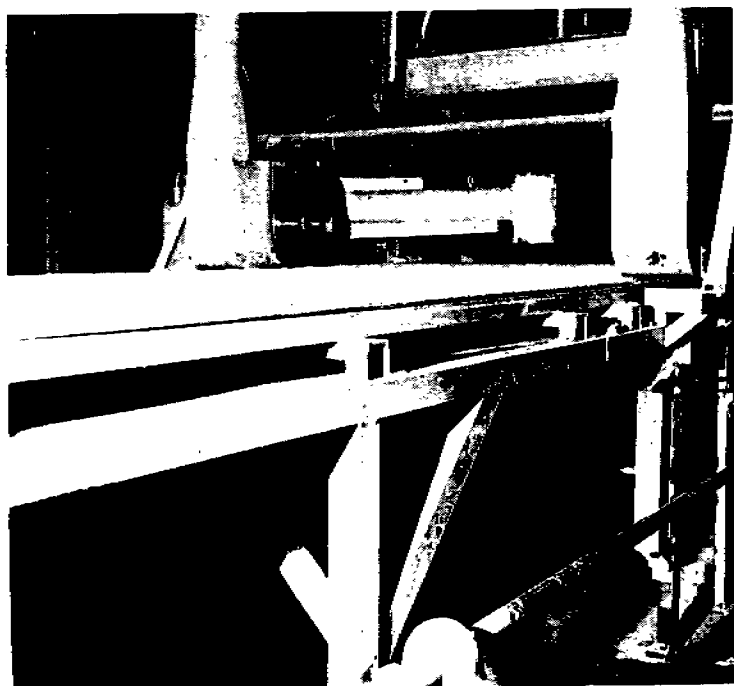


Figure 15.4. Typical installation for basis-weight-gauge (side view) (Rowe 1969).

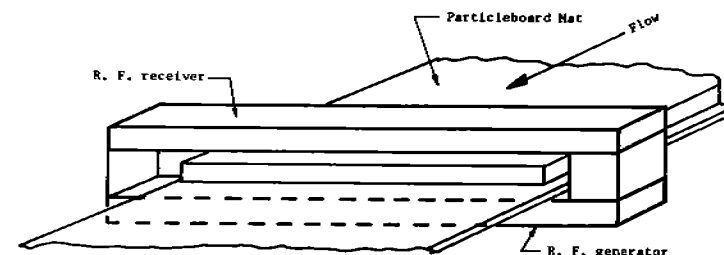


Figure 15.5. A schematic drawing of a metal detector (Carter 1969).

FORMERS

Wind-Sifting or Air-Classifying Forming

One type of forming machine uses the principle of air separation or wind sifting to lay up a graduated or multi-layer board. It was originally developed for single-opening presses and is used extensively around the world. It has been particularly popular in the United States in particleboard plants. It is now undergoing revision for use with fiber.

This former produces a mat with finer on the faces and without distinct layers, unless distinct heads are used for faces and core. The particle size is graduated from coarse material in the center of the mat to the finest material on the faces. This is done automatically, regardless of the furnish being fed to the forming machine, thus no large or thick particles end up on the surfaces of the mat, nor is there a distinct fines face layer subject to sand-through, thereby showing coarse particles. With this system, therefore, the classification of particles is not as critical, and rejects through poor surface characteristics are reduced. Experience has shown that the Bison former can perform satisfactorily with a wide range of furnish (e.g., large and small flakes, coarse, fine and very fine particles).

In this former, the furnish is metered from a surge bin at the top and drops in front of a high-volume, low-pressure air system designed to give a uniform airflow. The effect of the horizontal airflow is to blow the finest particles to the extreme ends of the former, while the heavier particles drop almost vertically. The exact distance the particles travel before deposition is a function of the relation between their mass and falling velocity and the air velocity, except with thin, large flakes with a high "sail" surface. These tend to be carried along with the fine material. Figure 15.6 illustrates how this former functions.

The first part of the former to consider is the surge bin on top of the unit (Figure 15.7). It is long instead of high, to minimize wide bulk-density variations, and meters the furnish by reels which gradually reduce the height of the metered area. In the type shown, some material is always recirculating, which is only a problem when using tacky or highly catalyzed resin. In this case, the furnish must be felted without delay or problems will occur further down the processing line. Other types run without recirculation to eliminate this problem.

On the formers for single-opening press lines, there is one surge bin dropping between two banks of air ducts (Figure 15.8). Each duct is offset from the opposing one to allow the particles to pass through. Each individual duct has its own air-control valve. There are also vertical screens below and behind the air system, to assist in mat leveling. This former is also used in a few smaller multi-opening plants.

The original Bison forming machine used in the United States separated this air duct and reversed the fan system as shown in Figure 15.9. A common fan was placed in the center with a side air intake. This fan discharged in both directions, separating the material as it was metered from two separate surge bins. This unit has a greater capacity than the previously mentioned forming machine and produces a more uniform mat.

It should be mentioned that the original forming machine used in the United States was in a plant with a multi-opening press. Newer plants have not used this former design as it has a limited capacity. As plant capacity increased, more places for dropping the furnish were required. It was also learned that the air direction of the single-fan discharge resulted in different board surface characteristics. On one side, the air discharged in a downward general movement and, on the other side, in an upward movement. The air direction characteristics were different in each side of the machine.

The next innovation was to separate the surface sections and use a separate fan for each. A single surge bin similar to those on the top of the former was placed in

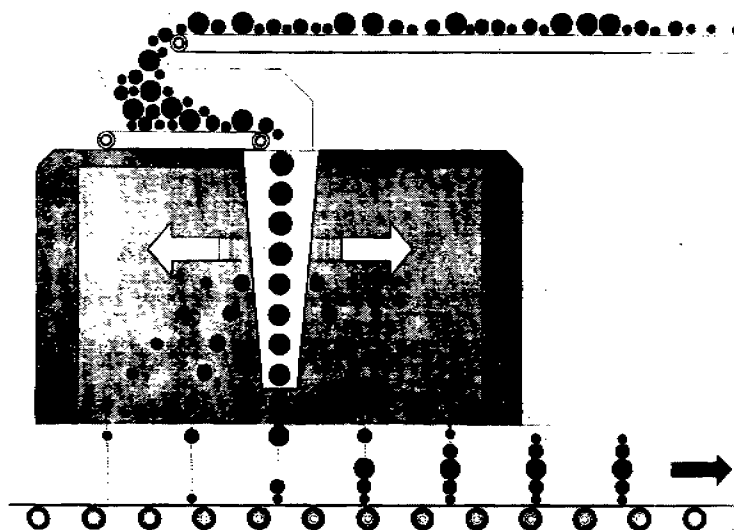


Figure 15.6. A detailed illustration of the Bison-Werke method of forming a particleboard mat (Wentworth 1969).

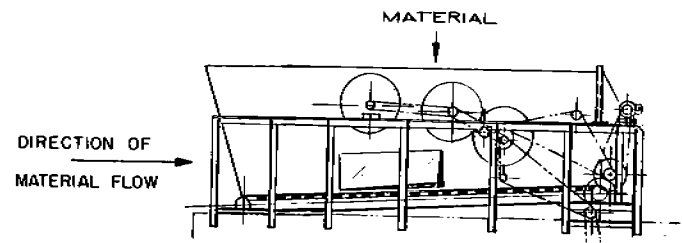


Figure 15.7. Surge bin on top of a Bison forming machine (Newman 1967).

between the fans for accurate metering of a homogeneous core section. This in effect added versatility to the machine. A separate resin level as well as different moisture contents could be used in the core. Further, a different type of flake or particle could be separated out for use in the core section only. At the same time, a series of baffles were added to the surface sections for better air-movement control. A version of the more sophisticated former is shown in Figure 15.10.

As with all formers, the forming action is taking place within a large box. Since the operation is a dusty one, particularly with fine furnish, it is difficult to observe what is going on inside. This is a disadvantage when the former is not functioning properly and the operator is trying to adjust the machine. The larger machines, laying faces and cores separately, have had a recent revision in design making it easier to determine where the malfunctioning of the equipment is taking place. In

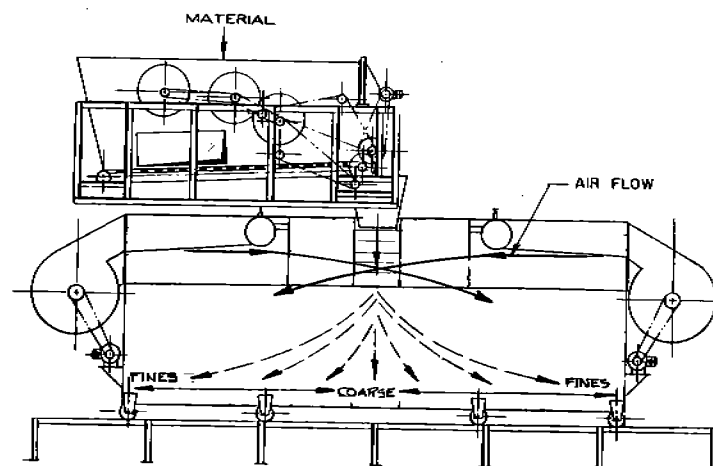


Figure 15.8. Bison former for single-opening press lines (Newman 1967). Note rails and wheels for moving this former back and forth.

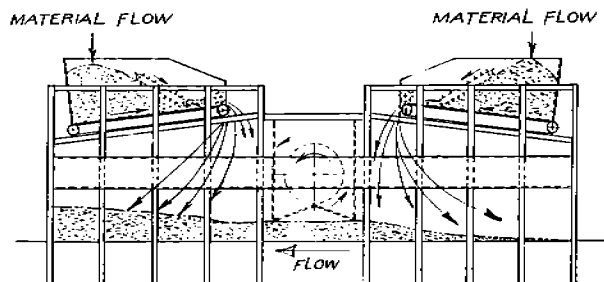


Figure 15.9. Original Bison forming machine used in the United States (Newman 1967).

this design, the face formers are separated from the core former. Thus, the operator can see which part of the former is giving the trouble. Additionally a scalper (a picker roll device that shaves the mat off to a uniform height) has been placed at the outfeed of the core section to level the mat before the top face is laid.

This leveling of the mat before forming the top face was handled differently in the Bartev design, where the mat was prepressed before the top face was laid.

Fahrni Spreaders

Novopan plants throughout the world have been successfully using the older type Fahrni former. The former works on the principle of superimposing multiple layers one on top of the other. Several heads are used to accomplish this spreading, one of which is shown in Figure 15.11. The multiple spreading is designed to insure that the particles are oriented mostly in the horizontal direction, which results in a compact mat. This in turn assists in reducing the need for prepressing and narrows the size of the press opening "daylight" required.

Face and core furnish is fed to separate silos above the forming line. The furnish is then metered onto a vibrating horizontal tray which feeds the particles under a comb roll for accurate metering to a pair of flinger rolls. The gap between

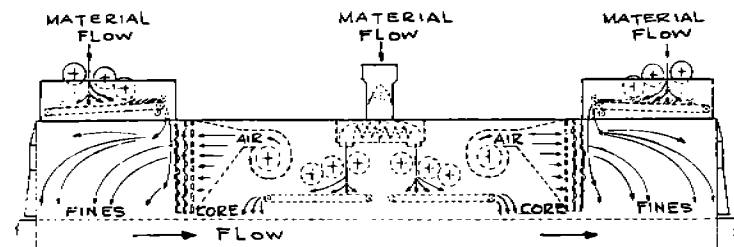


Figure 15.10. A large Bison forming machine (Newman 1967).

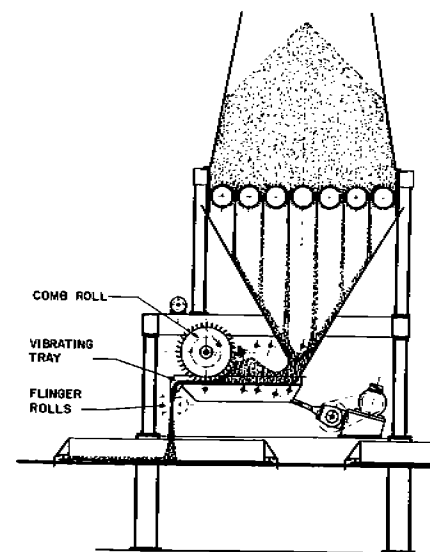


Figure 15.11. Principle of the Fahrni spreader with horizontal tray and dosing system. (Courtesy Fahrni Institute Ltd.)

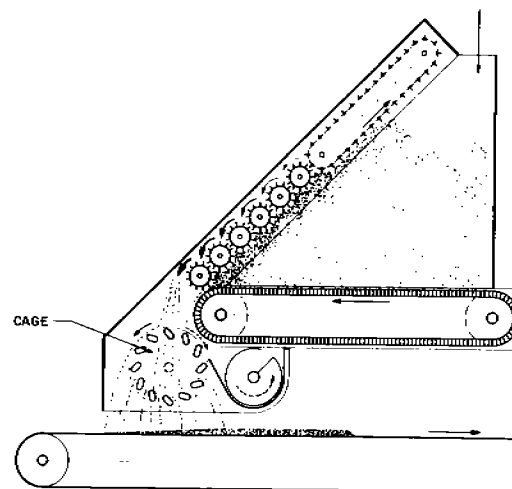


Figure 15.12. A new type of Fahrni former. (Courtesy Fahrni Institute Ltd.)

the vibrating tray and metering roll can be adjusted to suit the desired mat height. The metered furnish then falls between the flinger rolls which deposit the particles onto the mat carrier.

A newer former has been developed specifically for lines requiring a greater throughput. This former is shown in Figure 15.12. The vertical silo or hopper is replaced by a horizontal one. This design prevents fines from running through out of control. Other refinements not shown on this drawing include a pocket feeder roll between the bin and cage for accurately feeding the furnish to the cage.

The cage consists of steel tubes held between two rotating steel discs. The furnish is dropped through the cage for distribution upon the mat carrier.

Schenck Formers

A number of different approaches to forming have been taken by Carl Schenck Maschinenfabrik GmbH. The one shown in Figure 15.13 has a single spreader head. Several are normally used in series, depending on the capacity required. Several dosing bunkers (surge bins) are arranged ahead of the forming station for metering the material to the spreading head. The furnish is discharged volumetrically with the weight of the material flow controlled by a belt-weighing system installed in series.

A gravity spreader head (Figure 15.14) has a roll fitted with steel or plastic spikes for spreading the furnish. The speed of the gravity spreading roll is adjusted according to the desired classification effect (heavier particles are thrown farther), the required quantity of particles to be formed, and the type of particles. A prerequisite for this operation is the precise adjustment of the point where the particles come into contact with the spreader roll in relation to the mat speed.

Figure 15.15 shows a typical line equipped with four of these spreader heads.

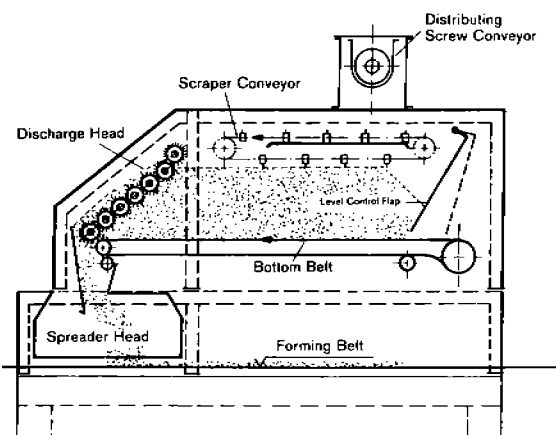


Figure 15.13. A single-head Schenck spreader (Strisch & van Hüllen 1969).

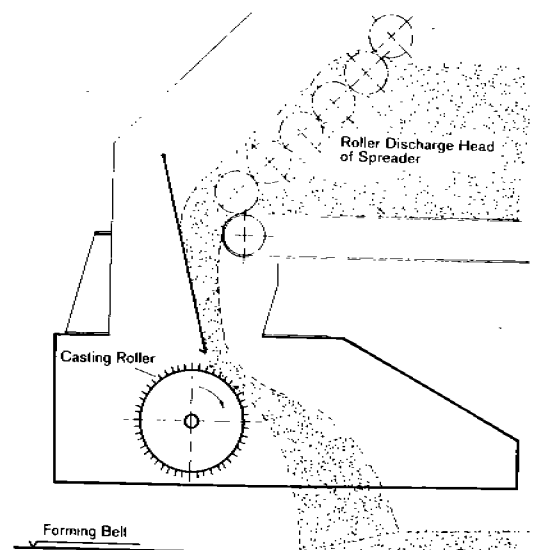


Figure 15.14. A gravity spreader head (Strisch & van Hüllen 1969).

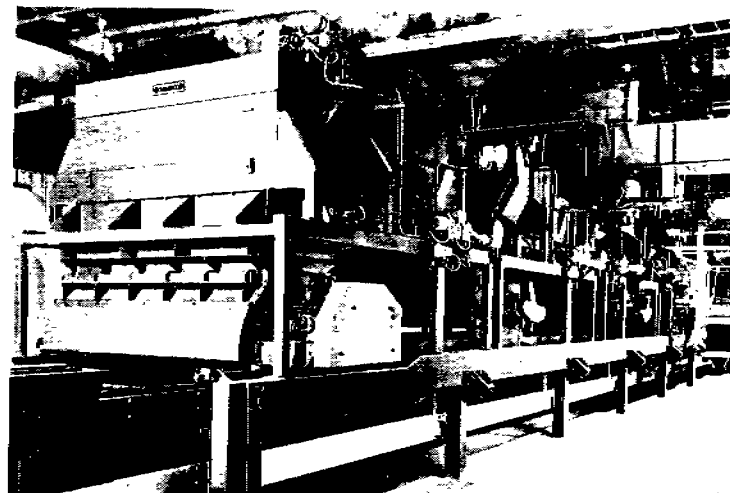


Figure 15.15. A typical Flexoplan forming line equipped with four Schenck spreader heads (Strisch & van Hüllen 1969).

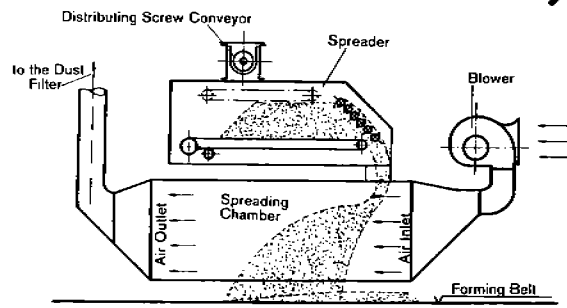


Figure 15.16. An air grading spreader (Strisch & van Hüllen 1969)

The Schenck version of an air-classifying mat former is shown in Figure 15.16. Here the particles coming down from the dosing feeder fall into a controlled airstream. The fines are given the longest trajectory, while the coarse particles have the shortest trajectory. This results in a mat formed with graduated layers. The exhaust air is filtered to the atmosphere.

A mat former with a two-roller disintegrating head is illustrated in Figure 15.17. These two rollers rotate in opposite directions and are fitted with long plastic spikes. The direction of rotation of the rollers is opposed to that of the curtain of

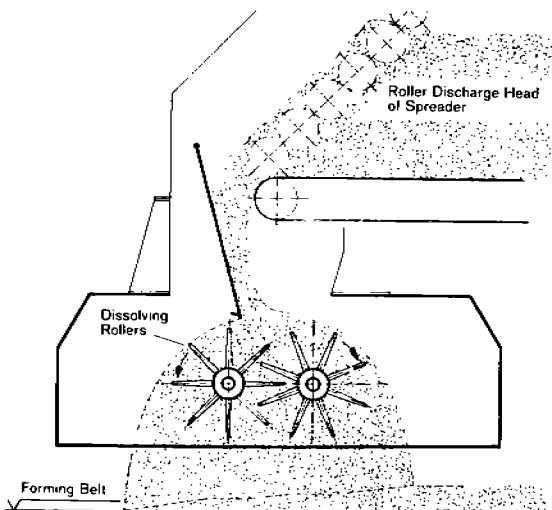


Figure 15.17. A twin-roller spreader head (Strisch & van Hüllen 1969).

material being fed to the rollers. This impedes the motion of the particles as they fall. The counter-pushing action of the rotating spikes causes the particles to fall down in small, different curves of descent. The wide disintegrating area of the particles being formed into a mat develops a low particle-deposition angle, the wide veil concept. This low angle is important in insuring that particles or flakes are in a flat position in the mat, as mentioned previously.

Figure 15.18 shows a triple-roller disintegrating mat former which is designed similarly to the head described in Figure 15.17. The speeds of the three rollers are infinitely variable and, as can be seen, the roller frame is slightly inclined. The first spiked roller transfers part of the particles to the next two spiked rollers, whereas the remainder of the particles fall between the first two rollers. These three rollers spread particles over a great length, resulting in a very flat mat on the mat transport medium. The former is now mostly used for core spreading, although it may also be used for surfaces, unless the desired grading effect is too great.

In Figure 15.19 is shown a specially developed spreader head which is used for spreading fibrous and superfine particles for surface layers. It uses a large spreading roll and two rake rollers covered with plastic spike rings. The spreading roll and the rake rollers rotate in opposite directions. The rake rollers are separately adjustable as to rpm with fixed-speed ratios. Because of the faster circumferential speed of the spreading roll as compared to the first rake roller, the fibrous particles are dammed up to a certain extent. The spreading roll itself combs out a uniform portion of the particles to the second rake roller. The circumferential speed of the second rake roller is slower yet, which again causes the spreading roll to comb out a uniform portion of particles. Thus, the fibrous particles are thoroughly unraveled and the proportioning action of the rollers insures that the required rate of fall of the particles is achieved.

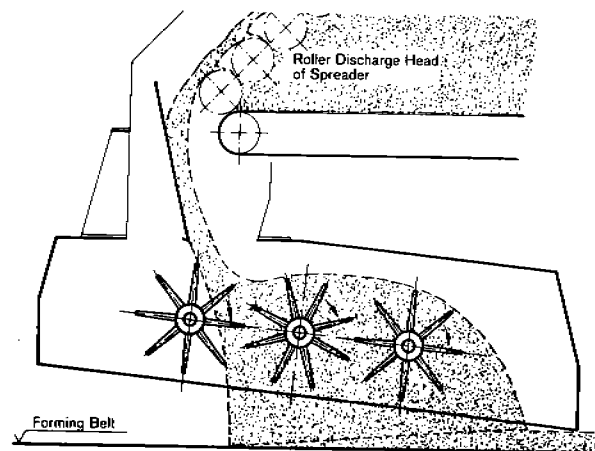


Figure 15.18. A triple-roller spreader head (Strisch & van Hüllen 1969).

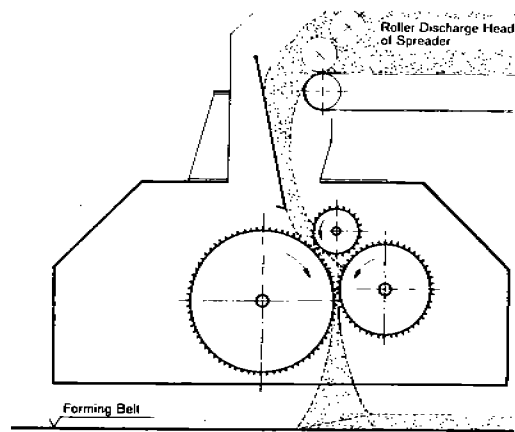


Figure 15.19. A special spreader head for fine-surface material (Strisch & van Hüllen 1969).

Durand Microfelter

The Durand Microfelter (originally known as the Columbia Microfelter) was designed to be used with free-flowing particulate types of furnish. Fibrous particles will "ball up" and jam between the metering rolls as will be seen shortly.

This forming machine (shown schematically in Figure 15.20) operates upon the principle that, in volumetric metering, a constant volume is discharged only when the head and all other conditions at the metering point are constant. In design, the machine is divided into two sections: the upper for primary metering, and the lower for precision metering and mat formation.

The upper metering rolls are so mounted and the design so made that special profiled teeth will form a live bottom to the upper hopper, which is sloped outward toward the bottom to eliminate hang-ups. When running, these upper feed rolls meter an average quantity of material from the hopper to the lower forming bin. The distribution across the machine width is reasonably uniform, and the tooth action tends to break up any particle bundles.

The seven lower metering rolls form an inclined bottom to a constant-volume recirculating material hopper from which they draw a uniform volume across the width of each roll. To insure that the volume of material is constant in this section, the upper feed rolls are adjusted to overfeed the mat requirements. The flight conveyor system sweeps the material along to fill any voids beneath the sweep bars, and carries the excess over into the return screw conveyor across the end of this lower hopper. This excess material is returned via a screw lift or conveyor to the upper hopper.

The seven metering rolls drop seven curtains of material from the former (Figure 15.21). As mentioned, fibrous furnish does not work well in this former.

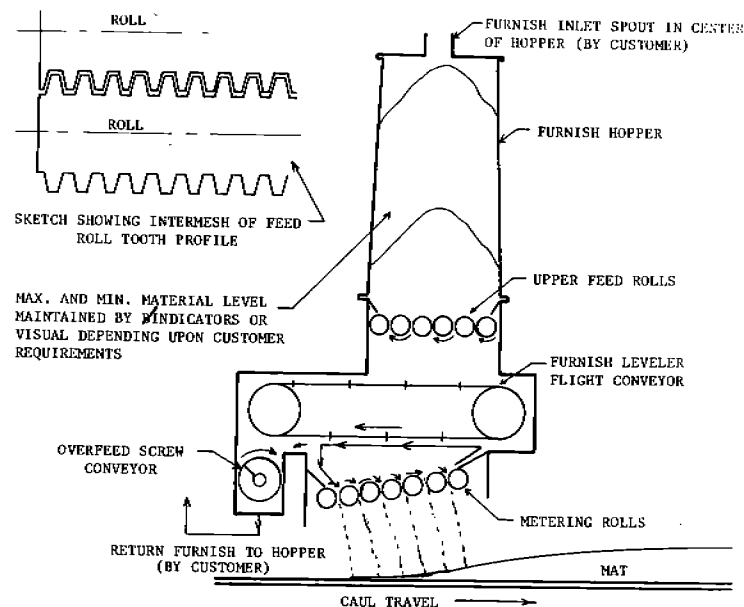


Figure 15.20. Schematic drawing of a Microfelter head (Frashour 1967).

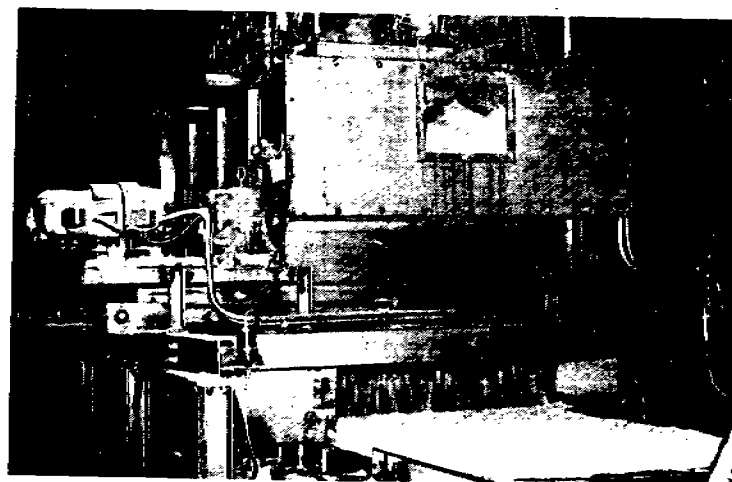


Figure 15.21. Curtains of particles falling from the former (Frashour 1967).

Also tacky or high-moisture-content furnish will tend to cause problems between the rolls. Polished metering rolls or special coated ones will alleviate some of this problem. The forming is affected by air currents and these must be controlled to prevent malformed mats. For producing layered boards, several of these former heads are placed in series; for example, one for each face and two for the core. Width of mat can be easily adjusted by moving side deckles. The unwanted edge portions of the mat are deflected into return conveyors leading back to the infeed of the former.

Würtex Former

The Würtex former controls the forming process by weight and volume and is normally used in multiples of two. As shown in Figure 15.22, the material is fed into the loading hopper (1) of the spreader, preferably by a scraper belt to insure uniform distribution across the full useful width of the machine. The material is then fed from the loading hopper (1) to the weighing or dosing hopper (3) by means of a steep-angle conveyor (2). The kick-back roller (4) insures that a uniform layer is fed into the weighing hopper. As soon as the preset batch of furnish has been delivered to the dosing scale, the feed hopper (5) is closed pneumatically by two magnetic valves while at the same time the steep-angle conveyor (2) is stopped by the action of an electromagnetic clutch until the weighing hopper (3) has delivered the batch and has returned to the closed position.

The batches of furnish delivered at preset intervals by the weighing hopper (3) are fed to the discharge conveyor (7) by a distribution cell wheel. Thus, the latter takes care of the preliminary equalization of the batches discharged after each

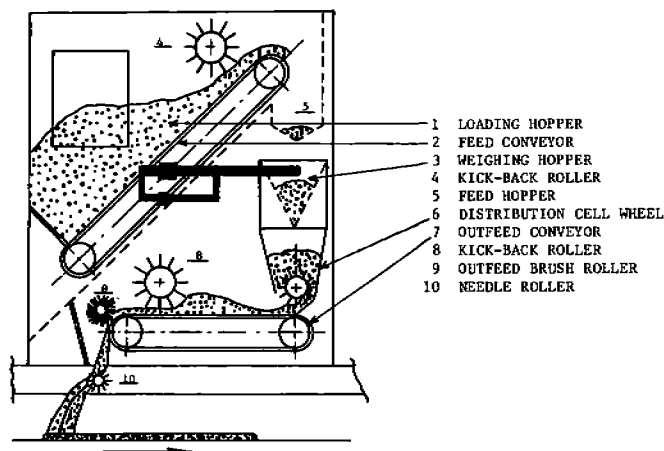


Figure 15.22. A Würtex forming station for conventional particleboard (Young 1967).

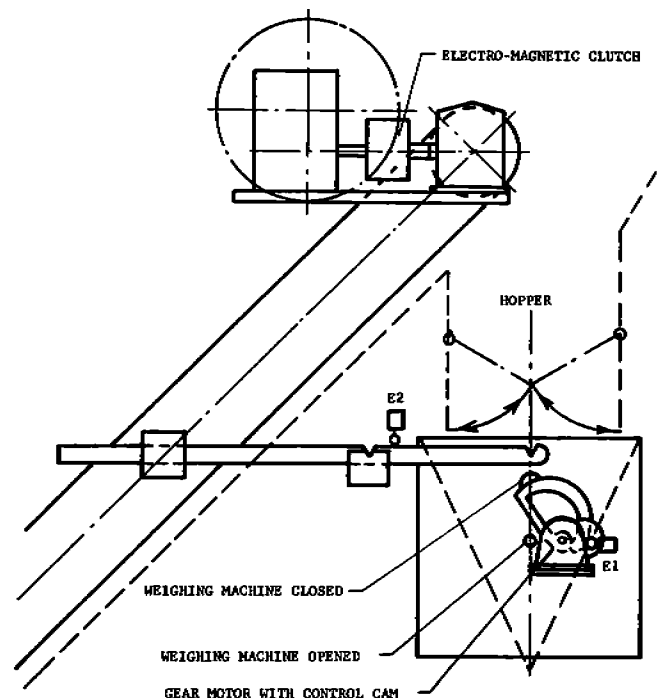


Figure 15.23. Control of the weighing device (Young 1967).

weighing cycle. By vertically adjusting the equalizing or scalping roll (8), the volume of the material is kept at a constant level. The speed of the discharge conveyor (7) is infinitely variable so that the material weighed during the preset time can be handled independently of its bulk weight; thus combined weight and volume batching is insured.

The brush roll (9) with vertical and angular adjustment feeds the furnish to the needle roller (10) which then spreads the furnish on the cauls or belt passing underneath the forming station.

The weighing hopper is a container with two flap-type gates which are opened and closed by a cam as shown in Figure 15.23. When the weighing machine is closed, the motor is stopped by limit switch (E1) in preparation for the weighing of the next batch. The gates of the feed hopper are then opened via two magnetic valves and the electromagnetic clutch is activated to feed furnish to the weighing machine by the means of the steep-angle conveyor. Once the proper weight of material is fed into the weighing hopper, the hopper is pneumatically closed by weighing beam switch (E2) via two magnetic valves and the conveyor is stopped

ment of the electromagnetic clutch. The weighing machine gates are dropping the batch of furnish into the distribution cell wheel.

he furnish falls upon the transport system passing under the forming e varied by the speed and position of the needle roller. By proper he larger particles can be thrown farther than the fines so that, when tations are used, a graduated three-layer board can be formed. When stations are used, the first and last formers form the bottom and top s and the center two formers lay down the core layer.

ssification system has been built into this type of former by using pressure rather than positive pressure as in the former described n other words, the classifying is done by sucking rather than blowing. in flakes have a tendency to fly to the outer extremities of the former ssified and thus end up on the board faces. A clever scheme has been his former for preventing such an occurrence when fines only are e faces. A vibrating screen with large holes placed in the airstream he large, thin flakes, causing them to drop into the core of the mat l. The fines pass through the screen and are deposited on the face in nanner.

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s noted before are large flakes. If they are produced according to the cept, the ends are tapered; however, this is not the case normally as re usually of relatively uniform thickness. These large, flat particles o transport and handle with equipment designed for "conventional" sses. Each wafer is a potential small wedge and a number of these can k together and jam mechanical parts of processing equipment. Use of rs usually will result in breaking the wafers.

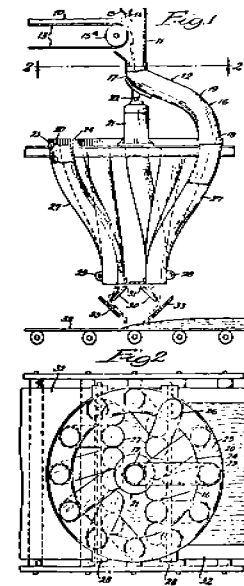
developed for use with wafers is shown in Figure 15.24. Wafers are evolving distributor head (17) at the top of the former from a belt he distributor head drops the wafers into the open ends of a series of ged in a circle (27). The configuration of the tube arrangement at of the former is in the form of rows placed across the width of the mat to

The single stream of wafers entering the top of the former is therefore to a number of small streams which deposit wafers evenly across the aveling beneath the former. With this former no jamming of the wafers

a belt is used for feeding and the passage through the former is by number of these formers or heads can be aligned in series to form the furnish desired.

ern particleboard and fiberboard

Figure 15.24. A former used for laying waferboard mats (Gunn 1972).



The Würtex former and a modification of the previously described Durand Microfelter are also being used successfully for forming mats of wafers. In the Microfelter, the wafers are metered upon a spreader roller in a manner somewhat similar to that shown in Figure 15.14.

Vacuum Formers

Vacuum formers are used when forming dry or semi-dry (about 25-30% moisture content) fibrous furnish. To date their use has been in the hardboard and medium-density fiberboard segments of the industry; however, some may find this approach of value in some of the process lines using more particulate-type furnish.

Vacuum forming is a means of producing a continuous mat by the passage of furnish-laden air through a moving fourdrinier wire screen or a cyclone herringbone wire screen. The furnish enters the former from the top and may pass through a device such as a squirrel cage, shaker screen, metering rolls, or swing-vent to disperse the fiber across the former. Hammermills can also be used. A negative pressure is applied in a chamber below the forming wire. The passage of particle- or fiber-laden air to the chamber traps the furnish on the wire.

One of the more popular formers drops the furnish into the former pneumatically through a swing-vent sometimes called an *elephant trunk*. This swing-vent oscillates perpendicularly to the mat travel. The vent is rectangular with the long

by disengagement of the electromagnetic clutch. The weighing machine gates are then opened, dropping the batch of furnish into the distribution cell wheel.

The way the furnish falls upon the transport system passing under the forming station can be varied by the speed and position of the needle roller. By proper adjustment, the larger particles can be thrown farther than the fines so that, when two forming stations are used, a graduated three-layer board can be formed. When four forming stations are used, the first and last formers form the bottom and top surface layers and the center two formers lay down the core layer.

An air-classification system has been built into this type of former by using negative air pressure rather than positive pressure as in the former described previously. In other words, the classifying is done by sucking rather than blowing. Very light, thin flakes have a tendency to fly to the outer extremities of the former when air-classified and thus end up on the board faces. A clever scheme has been devised in this former for preventing such an occurrence when fines only are desired on the faces. A vibrating screen with large holes placed in the airstream screens out the large, thin flakes, causing them to drop into the core of the mat being formed. The fines pass through the screen and are deposited on the face in the normal manner.

In operating the Würtex former, one user has found that the level of furnish in the loading hopper has to be controlled by an upper and lower bin control. If the level is allowed to rise too high or drop too low the upper kick-back roller cannot do its job properly. A close relationship between belt speeds and the amount of material being passed through the former must be maintained, which requires a skilled operator.

One advantage of the Würtex is that the flakes are thrown with some force onto the mat being formed resulting in a compact and relatively thin mat.

Wafer Former

Wafers as noted before are large flakes. If they are produced according to the original concept, the ends are tapered; however, this is not the case normally as the wafers are usually of relatively uniform thickness. These large, flat particles are difficult to transport and handle with equipment designed for "conventional" board processes. Each wafer is a potential small wedge and a number of these can quickly work together and jam mechanical parts of processing equipment. Use of air conveyors usually will result in breaking the wafers.

A former developed for use with wafers is shown in Figure 15.24. Wafers are fed into a revolving distributor head (17) at the top of the former from a belt conveyor. The distributor head drops the wafers into the open ends of a series of tubes arranged in a circle (27). The configuration of the tube arrangement at the bottom of the former is in the form of rows placed across the width of the mat to be formed. The single stream of wafers entering the top of the former is therefore separated into a number of small streams which deposit wafers evenly across the caul plate traveling beneath the former. With this former no jamming of the wafers occurs, as a belt is used for feeding and the passage through the former is by gravity. A number of these formers or heads can be aligned in series to form the amount of furnish desired.

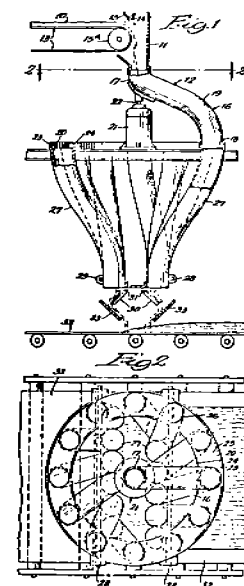


Figure 15.24. A former used for laying waferboard mats (Gunn 1972).

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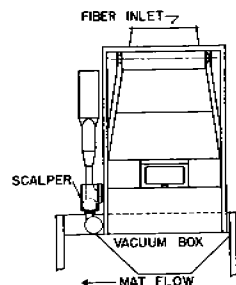
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One of the more popular formers drops the furnish into the former pneumatically through a swing-vent sometimes called an *elephant trunk*. This swing-vent oscillates perpendicularly to the mat travel. The vent is rectangular with the long

Figure 15.25. A vacuum former head (Peters 1968).



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dimension parallel to the mat flow. The action of the swing-vent is analogous to the motion of a reciprocating spray gun carriage in a spray booth for continuously applying a coating to the work passing on a conveyor. Figure 15.25 shows a drawing of one head of such a former.

The air velocity at the swing-vent discharge in some dry-process hardboard felters varies from 4000 to 6000 fpm (1219–1829 mpm). Some users claim that these velocities are necessary for adequate dispersion since fibrous furnishes require high velocities to minimize agglomeration. These high velocities, most likely, would not be necessary for the forming of the nonfibrous furnish used in most particleboard plants. Lower velocities are desirable to prevent disruption of the mat surface in each succeeding felter head.

The distance from the swing-vent to the mat surface tends to decrease the velocity because of the increased volume of furnish in the felter head. Air introduced in vents at the top of the felter also decreases the furnish velocity since the air-to-furnish ratio increases.

As the accumulation of the furnish takes place, the passage of the air through the mat is restricted. Areas of low weight permit greater airflow; thus, there is a greater chance that low-weight areas will subsequently receive additional material. This aids in obtaining uniform mat density. The passage of air through the mat also draws the individual particles into closer relationship with each other. The impact of fibers hitting the mat tends to integrate the fibers with each other. Also, alternate release and application of negative pressures such as occurs between felter heads tends to work the furnish into new interparticle matrixes.

The frequency of swing-vent oscillation depends on the speed at which the forming wire is moving and the length of the pattern discharged from the nozzle. Each oscillation across the mat feels a layer of furnish that overlaps the preceding oscillation. In practice the speed of oscillation may vary from 40 to 120 oscillations per minute.

At the discharge of the felter head, a shave-off roll or scalper rotates in the opposite direction to the mat movement. The shave-off roll removes the excess furnish through a vacuum hood which closely surrounds the scalper rotor. The excess furnish is returned to the fiber bins or is reintroduced into the top of the felter. The shave-off roll is vertically adjustable, which permits accurate reduction of the mat to the desired mat height. The vacuum box under the former is extended

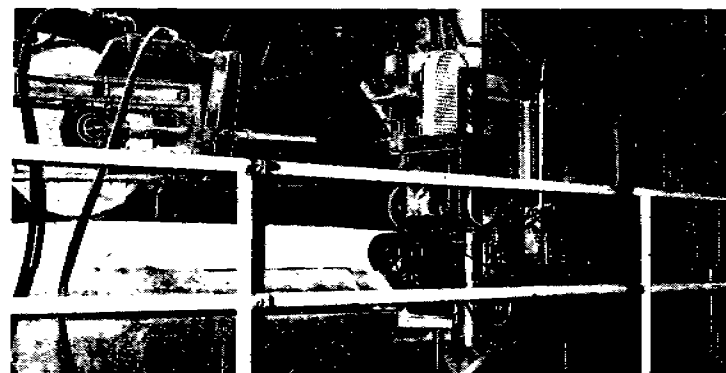


Figure 15.26. Fiber mat emerging from a vacuum former (Peters 1968).

under the shave-off roll to prevent mat springback while shaving the mat to a precise height. Automatic control of the weight of each layer may be had by controlling the shave-off height with a radiation gauge and closed-loop instrumentation. Figure 15.26 shows a mat emerging from a vacuum former after it has been scalped to the desired height.

Additional felter heads may be added, depending on the requirements of the board manufacturer such as production rate, furnish, species, and product design. Figure 14.15 showed a schematic of a typical forming line and Figure 15.27 shows a typical forming line in operation.

Deckles (thin side plates) of several types are used on vacuum formers. The fixed deckle is common but a moving deckle may be used. The deckles are side

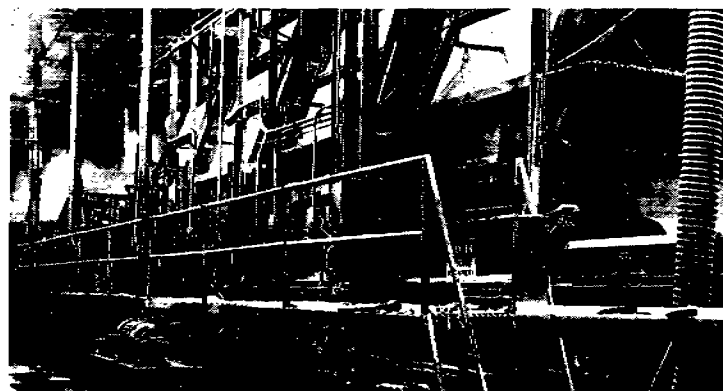


Figure 15.27. A Washington Iron Works dry-process forming line (Peters 1968).

forms controlling the width of the mat formed. Some machines deliberately overshoot the deckles with furnish and the excess furnish is removed from the side-deckle area by a vacuum fan. An adjustable deckle which permits different mat widths is a desirable feature for some processes, because the excess furnish from each head can be reintroduced into the same felter head. Such an arrangement reduces the mixing of dissimilar furnish in the system.

The maintenance of a slight negative atmospheric pressure within each felter head is essential to prevent blowout of the furnish. In order to maintain a negative pressure in a felter head as the weight and density of the mat increase, the horsepower requirement must be increased to remove the same air volume because the mat acts as a filter or damper. For example, one particular felter requires 40 HP (30 kW) in the first head to maintain 1 in. (25.4 mm) of water differential pressure in the vacuum chamber; however, the number four head uses approximately 150 HP (557 kW) to remove the same amount of air at a negative pressure of 25 in. (635 mm) of water.

This system of forming allows for close control over mat weight. The mat is also compressed by the action of the negative air pressure pulling the fibers against the fourdrinier screen. The bulk density of the mat is much higher than the bulk density of the fiber. This provides a mat with better integrity which is easier to prepress and one that is easier to handle on caulkless lines. A roll prepress is normally used in this system and will be described later.

Vacuum felting permits flexibility in mat formation. A layered or homogeneous mat can be formed, depending on the product requirement. Also different wood sources or species can be selectively placed in the face or core layers. This selectivity is also applicable to maintenance of different layer moisture percentages or resin contents. Furthermore, face and core furnish may be felted according to particle geometry. Uniformity of the mat is enhanced by controlled buildup and precise shave-off.

The felter is not a self-contained unit. A separate metering system is required; thus, the accuracy is also affected by the metering system feeding the felter. The former has a relatively high horsepower requirement which again adds to the investment and the operating cost. The system may reduce urea resin tack to an unacceptable level because of frequent pneumatic transfer and recirculation.

The vacuum felter is based on volumetric metering. This principle assumes that the furnish bulk density changes slowly or not at all. Consequently, plants with variable raw materials, i.e., species, wood geometry, or wood source, may experience erratic weight control of the mats.

Rando-Wood Former

Recently a new former has been developed to handle fiber called the Rando-Wood MDF former. This machine is manufactured by the Rando Machine Corporation, which has used techniques involved in its equipment made for the non-woven and textile industries.

Figure 15.28 shows this new former, which is now being used in the board industry. The former is divided into two parts: the feeder and the former. Figure 15.29 is a photograph of the complete former undergoing tests.

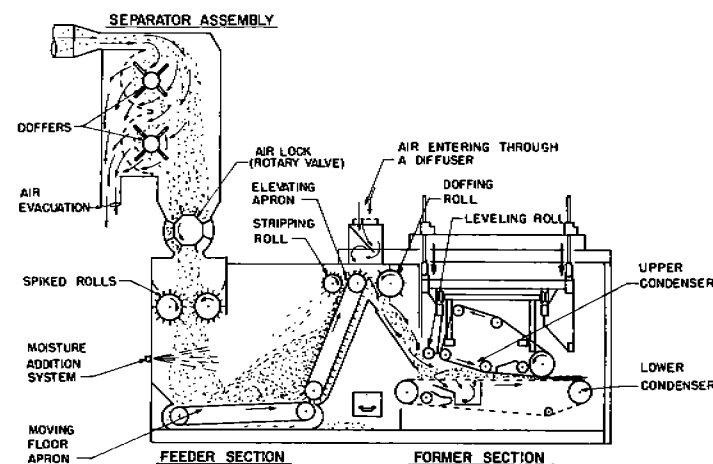


Figure 15.28. The Rando-Wood MDF former (Wood 1976).

The resinated fibrous furnish is supplied to the feeder via a mechanical or a pneumatic delivery system which insures a constant and uniform supply of material to each forming station. The furnish flows through the machine shown in Figure 15.28 as follows. The fiber enters the forming unit via the pneumatic separator where the furnish is separated from the air-conveying system and retained in the chute attached to the first stage of the forming equipment. A fiber beater system consisting of a pair of spiked rolls fiberizes any clumps of fiber and provides a uniform supply across the width of the hopper. Moisture can be added to the fiber as it passes from the beater rolls to adjust the moisture content. The fiber falls upon a moving delivery floor apron, which introduces the fibers to the inclined apron equipped with specially designed slats and pins. This apron picks up the fibers from the creeping delivery floor apron and raises the fibrous mass to a stripping conveyor. At this point, the excess material is removed by the stripping conveyor and returned to the rear of the feeder. This action also reduces any tendency for the fibers to form clumps or balls of material. The material remaining on the incline apron pins is thus distributed across the width of the former at a constant volumetric flow. This remaining material held by the pins passes over the apex of the apron into the mat-formation section.

At the apex of the incline, an airstream is created which strips the fiber from the pins of the elevating apron. The free fall of the fiber is also influenced by the negative air pressure developed in the mat-formation section. In the mat-formation section is an "air bridge" which has a wedge-like cross section. Situated on the lower side of this wedge is a perforated condenser assembly with an inner suction chamber. The wedge developed by the condenser provides an ever-decreasing path for the fibers so as to provide a slight pressing action to the mat structure formed within the air bridge.

The fibers are compacted by the suction pressure drawn through the condenser assembly. As the condensers are rotated forward, the surface movement, combined with the suction pressure, causes the fiber to move forward in the air bridge. Wherever there is a weak packing of fibers, a strong airflow is established; and fibers are immediately pulled into it, thus building up a uniformly dense mat.

The output of the former is measured volumetrically. The packing pressure is dependent upon the intensity of the suction chamber pressure in the condenser and is directly related to the static pressure of the airflow. Output can be controlled by the surface speed of the condenser assembly (all other variables held constant) by increasing or decreasing the cross-sectional distance of the throat, and by increase or decrease in speed of the hopper section's supply aprons.

Each former develops a single ply of mat with the previously mentioned intertwined arrangement of the fibers. The formed mat is laid upon a conveyor for transport down the press line. For thick mats, a number of formers can be used in tandem, laying up a multiple lamination of thinner mats. It is reported that a single former can lay up to 150 tons (136 mt) of mat per day at a maximum mat width of 100 in. (2.54 m).

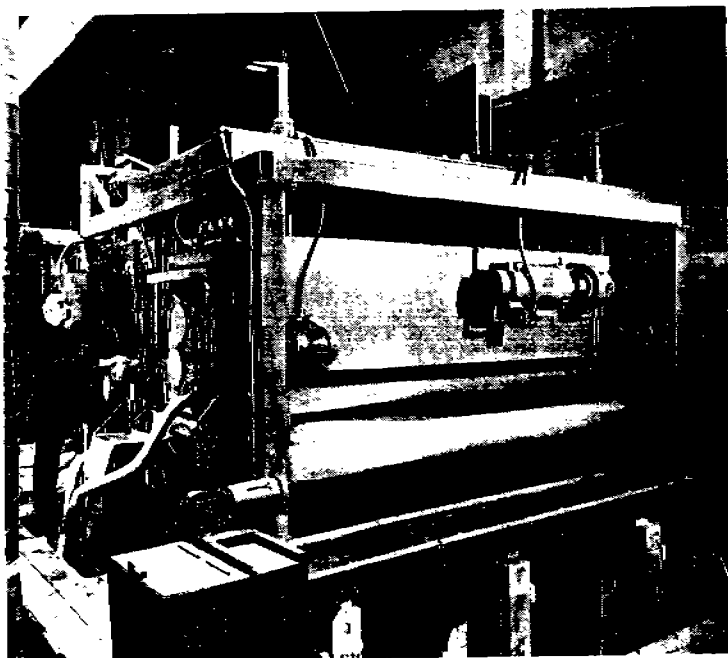


Figure 15.29. A Rando-Wood former undergoing tests. (Courtesy Rando Machine Corp.)

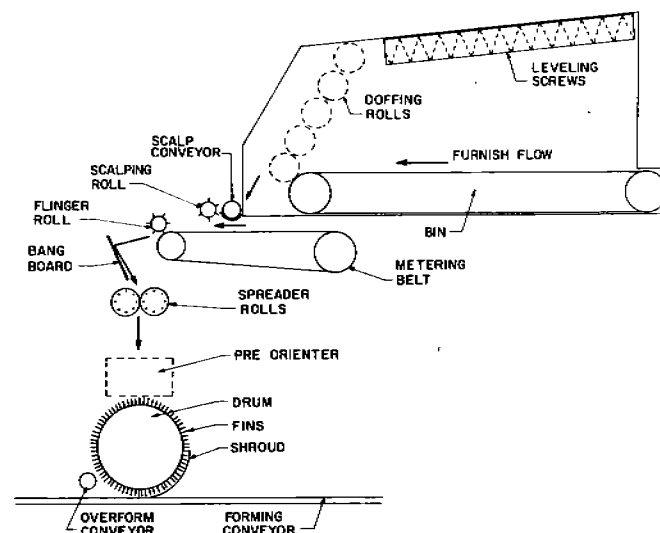


Figure 15.30. Schematic of a flake orienter, the Potlatch Crossorienter. (Courtesy Potlatch Corp.)

Orienting Formers

Orienting or aligning particles in boards is gaining in importance, as stated previously. Two ways of orienting are now available: electrical and mechanical.

With the electrical means, particles are dropped between charged plates (one positive, the other negative). The electrical field aligns the particles as they fall between the plates onto the mat carrier. A wide range of particles from large flakes to pressurized-refined fiber can be aligned by this method. A wide-ranging variety of particle sizes in the furnish can be aligned simultaneously.

A mechanical orienter now in use is shown in Figure 15.30. This machine was developed for aligning flakes. The flakes are fed from a bin onto the metering belt. The flakes are fed through the system into a preorienter. Reciprocating fins in the preorienter align the flakes and drop them into pockets formed by steel fins on a large-diameter drum. The fins hold the flakes in the aligned position. The drum is rotating and deposits the aligned flakes onto the mat carrier. A shroud keeps the flakes from falling out of the pockets until they are dropped onto the mat carrier.

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16.

PREPRESSING

In order for the caulless system to operate without using the tray-belt approach, a prepress is needed to consolidate the mat for subsequent handling. Prepressing is not required when using a caul or metal mesh cloth or steel belt for transporting the mat into the press. However, prepressing reduces the "daylight" or press opening needed, particularly with thicker boards, and allows for faster press closing without blowing the top surface of the mat apart. It is claimed that fast press closing reduces surface precuring and increases the core density with prepressed mats, which in turn provides a higher internal bond. The opposite is true when pressing unprepressed mats, as will be noted later. Because of these advantages, some multi-opening caul-type and single-opening press lines also use a prepress. Pressures of up to 560 psi (3.86 MPa) have been reported to improve the pressing conditions and board properties. Higher pressures have reportedly been used in production plants, but this is unusual. Higher pressures have been shown in laboratory work to decrease board strength properties using conventional pressing. Either damage to the particles or driving the resin from the particle surfaces into the particles, which removes the resin from the bonding areas, appear to be two reasons for this drop in board strength properties.

Two types of prepress are used: a platen prepress which has to have the mat stopped for operation and a continuous prepress which consolidates the mat as it moves from the former.

PLATEN PREPASSES

The platen type previously mentioned in the discussion of caulless lines operates with either a heated or unheated top platen. The top platen moves in such a press. Consequently, care must be taken that hydraulic oil leakage does not spill onto the mats. Figure 16.1 shows one of these prepressees.

For the platen prepress to function, it is necessary to move the formed mat quickly into the prepress and consolidate it before the next mat arrives. This calls for rather sophisticated belt-transfer systems and acceleration and deceleration controls. It is the most commonly used type in the United States for particleboard production.

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17. HOT PRESSING AND PRESSES

HOT PRESSING

The most expensive single piece of equipment is the press, and speeding the press time makes better use of it. Press times have been shortened dramatically since the 1950s through resin and press improvements. For example with $\frac{3}{4}$ -in.-thick (19 mm) board, press time has dropped from 15 minutes to about 3 to 5 minutes at present when using urea resin. Thus, production through the press has been more than doubled.

In pressing, a number of factors are involved, including the resin type, resin catalyst, press temperature, wood species and particle geometry, mat moisture level and distribution and heat transfer, press closing time, pressure, and its relation to the board-density profile, vapor pressure within the board during pressing, and precure and postcure of the resins. As is usual in the board process, all of these factors interact, making it difficult to provide easy-to-use formulas when considering hot pressing. These factors will be considered separately and references made to major interactions; however, all interactions will not be discussed in detail since this part of the production process is still part of the web of interrelated variables that are difficult to sort out and understand completely. This will be followed by a discussion of the major types of presses.

Resin Type and Catalyst

As noted before, urea and melamine-urea resins are much faster curing and less expensive than phenolics. Thus, phenolics are used only when absolutely necessary because of the slower press times. The amino resins are catalyzed for the fastest cure. Recent developments in phenolics have also made it possible to speed the cure; however, the aminos are still faster.

Press Temperatures

High press temperatures, from about 360° to over 400°F (182°-204°C) are needed with the phenolics. The aminos are also speeded in cure rate by high press temperatures, but lower press temperatures can be used successfully. In earlier times, many plants operated with press temperatures for ureas at about 290°F (143°C), and this level of press temperature is not unknown now. However, newer

presses are usually designed to operate at much higher temperatures, in particular the single-opening types where press time is of extreme importance. Heat from the press is also supplemented from the heat developed by the condensation reaction of the resin curing. One study showed that as much as 20% of the total heat needed for polymerization came from this reaction, although 10 to 15% may be a more reasonable level.

Wood Species and Particle Geometry

Wood species and the configuration of the particles are important factors affecting board consolidation. Easy-to-compress species such as redwood require lower pressures for consolidation than harder-to-compress species such as oak (considering that both species are being increased in density in the final board proportionately). Easy-to-compress species have a tendency to "seal" the surfaces of the board, resulting in blows because vapor cannot escape through the face during the latter part of the pressing time.

Particle geometry affects pressure because larger particles that must be "crushed" one into another require greater consolidation pressures than smaller ones that mesh together, such as -20 screen fraction sizes and some small fibers. However, small fractions of high-density species are hard to compress into the smooth surface similar to those with small comminuted particles used in typical softwood particleboards. Voids are readily apparent between high-density small particles used in the faces as they do not compress as well and flow together. In some developmental work, it has only been possible to develop suitable surfaces for overlaying by using a high percentage of small particles (-42 screen fraction size) or by using high face moisture contents (16-18% for plasticizing the wood).

Mat Moisture Level and Distribution

Probably the two most significant factors governing the properties of a given board (considering reasonable resin levels, press times, and press temperatures, etc.) are moisture content and its distribution and press closing time.

The moisture content of a mat entering the hot press is of great importance in pressing composition board. The moisture in the furnish comes from three sources. First, there is the moisture contained in the furnish after it has been dried in preparation for blending with the resin. Depending on the process line, this will range from about 2 to 5%, based on the oven-dry weight of the wood. This level is somewhat on the high side when powdered resin is to be used. Keeping the furnish moisture content as high as possible when blending with resin may help prevent resin "strike in" and its subsequent loss as a binder.

Second, there is the water that enters the furnish as part of the liquid resin used. Urea-formaldehyde resins are normally supplied at a solids content of about 65%. Resin may be applied at this solids level or for production reasons, where better atomization can be achieved, diluted to a lower level of 55 to 60%. A number of different solids levels are found with phenol-formaldehyde resins. A low resin solids level of about 20 to 25% is normally used in the dry-process hardboard-type plants to obtain better distribution. Since the phenolic resin is normally applied in

the attrition mill, the excess moisture can be removed in the dryer. For particleboard, the phenol-formaldehyde resins were manufactured at a 40% solids level for many years, thus 60% of the resin was moisture. In many cases this excessive amount of moisture raised the final mat moisture content above the 10 to 11% maximum that many plants can tolerate when higher resin levels were needed. Since post-drying is not done in particleboard plants, this severely limited the amount of phenolic resin that could be added to the furnish. However, in recent years, newer formulations of phenol-formaldehyde resin have been developed with a solids content around 53%. This solids content is not all phenolic; another additive has been used to lower the moisture in the resin and to aid in its handling and curing characteristics. The phenolic solids content has remained at about 40%.

The third source of moisture in the mat comes from the condensation reaction when the resin cures. In general, two resin molecules combine and thereby split off one water molecule resulting in a small amount of extra moisture. One report notes that on a 6% resin solids addition of urea-formaldehyde, a maximum of 0.9% water can be added to the furnish in this way.

A fourth type of "moisture" can be a problem in pressing board. This is not truly moisture but vapor that is generated during hot pressing from the extractives in the wood itself. A problem species of this type is western red cedar. More on vapor pressure will be mentioned later.

As with any gluing operation, excessive moisture can hinder or prevent the adhesion of two pieces of wood. Most particleboard or fiberboard can be bonded at moisture contents ranging from 2 to 18%. Semi-dry hardboard may go as high as 30% in mat moisture content. At the high-moisture-content level, it may require an excessively long press time. At the low-moisture-content level, problems can be encountered in closing the press so that the desired board thickness cannot be achieved. A highly significant aid to press closing is the moisture in the mat which converts to steam during hot pressing. This steam plasticizes the wood particles, enabling the press to consolidate the mat with relatively low pressures as compared to cold pressing. Indeed, many presses in use would not be able to consolidate the mats to the desired thickness without the use of heat because of pressure limitations.

Boards are pressed at moisture contents ranging between 7 and 16%, depending on the particular plant's operating parameters. Troublesome species like the aforementioned western red cedar and ponderosa pine are difficult to press at moisture-content levels around 11 to 12%. Such a moisture level is relatively high in the United States, but higher levels are common elsewhere in the world. Single-opening presses are dependent upon very short pressing times for achieving economical production. Thus, moisture contents of the mats are held somewhere around 7%. Higher pressing pressures are needed to accomplish board consolidation, but at the same time excessive amounts of moisture do not interfere with fast bonding of the resin.

As the mat is heated in the press, the moisture changes to vapor and migrates to cooler areas, most notably at first to the core of the board. Within a short time after the press is closed, a temperature gradient exists between the faces of the board and the core; and also between the center of the panel and the edges. Most people recognize that such a gradient exists between the faces and the core but some

forget about the gradient between the center and the edges. These gradients, of course, are constantly changing as the temperature of the various zones of the mat being consolidated into a board changes. Because vapor pressure is related to temperature, the pressure gradients will follow the temperature gradient during the initial part of the cycle.

If the board is left in the press for a long time, the pressure gradients and temperature gradients will eventually come to equilibrium, or perhaps even reverse themselves. However, this does not come to pass because boards are taken out of the press long before such an equilibrium occurs. Once the entire core of the board reaches about 212°F (100°C), the final cure is effected within about 30 seconds with urea resins. A somewhat longer press time is needed with phenolic resins. Core temperatures at the panel corners will rarely get above this level unless the board is left in the press for a long period of time.

Many studies have been conducted showing the temperature of the core of the boards at various time periods during hot pressing; however, it can be noticed when running a study to determine the shortest press time that the last places in a board to cure are at the corners. Moisture is always working its way out of the board to the edges during pressing. The corners are the coolest parts of the board because of their exposure to atmosphere on two edges. Consequently, these are the last areas to get above the boiling point of water, and thus are the last areas in which the resin is cured. In press time studies on a 3/4-in.-thick (15.9 mm) board, for example, it may be that at 3 minutes the board is not cured in the core at all. At 3 minutes and 30 seconds there is some curing in the core. At 4 minutes the board is completely cured except at the corners. This is noticeable in that the corners are much thicker, and the core at the corners is not bonded together at all while the core at the midpoints of the panel edges is cured. Within about 30 seconds afterwards, however, the core at the corners will be completely cured.

In the early days of this industry, it was felt that most of the moisture was vented from the board during hot pressing. Since with 3/4-in.-thick (19 mm) board press times ranged between 10 to 12 minutes there was a very good chance that such was the case, particularly with boards 4x8 ft (1.22x2.44 m) in size. However, with the increase in board sizes up to 8 ft (2.44 m) wide to more than 60 ft (79.2 m) in length and the very significant decrease in press time due to improvements in the resins, not much of the moisture can be evacuated from the board during hot pressing. Board moisture content after pressing may be 5 to 7% and not oven-dry as some might believe. Thus, only a small amount of the moisture escapes through the edge of the board. The other moisture that has been turned to vapor during pressing is released through the faces of the board upon opening of the hot press. If the face of the board is relatively impervious because of large flakes or highly densified, resin-rich, small particles, blows occur. Lowering of the moisture content is one possible solution to alleviating this blowing problem.

The moisture level and its distribution is closely related to the heat transfer in a standard contact heating press. The high-frequency heating system is different in that the entire mat can be heated simultaneously, whereas with contact heating, heat is transferred from the mat faces to the core. One study has shown that the heat-transfer process in the hot-pressing cycle involves two interrelated components. The first component is the transfer of heat by conduction of water vapor

flow from the interface of the hot platen and mat to the mat core. The second component is the transfer of heat by vapor flow from the interior of the board to the exposed edges. Permeability and relative vapor pressure are much more dependent upon the board variables than are the heat conduction parameters. Consequently, the rates at which the interior temperature changes are regulated by the flow of water vapor through the porous structure of the board. Vapor flow from the faces to the board core accelerates the temperature rise, while vapor flow towards the edges of the board retards temperature rise by consuming thermal energy as heat of vaporization.

Centerpoint temperatures in low-density board experience a rapid rise and level off quickly near the boiling point of water, while those in high-density boards have slower initial rises but continue to rise steadily throughout the pressing time. Increasing the moisture content hastens the initial rise and causes the low-density board core temperatures to level off faster and the high-density board core temperature to increase more rapidly. Low-density panels benefit from vapor flow from the faces to the core early in the pressing and are penalized by lateral flow toward the board edges later. High-density boards, on the other hand, get little assistance in increasing the core temperature at the start of the press cycle but tend to increase in temperature later in the cycle without the restricting influence of the lateral flow of the vapor. Rates of temperature increase ranged as high as seven times or greater for 1/2-in.-thick (12.7 mm) board as compared to 1 1/2-in.-thick (38.1 mm) boards. A thin board, of course, has a rapid temperature increase in the core during pressing because of the core's close proximity to the hot platens.

Moisture content of the mats, as has been discussed so far, can be used advantageously and can also cause problems. It is easier to close the press quickly at the higher mat moisture contents, and the thickness of the board can be more easily controlled. Presses can be built lighter because less pressure is needed for consolidating the mats into boards. High moisture, particularly on the faces, speeds the transfer of heat from the hot platens to the core of the mat, as is shown in Figure 17.1. This use of moisture for rapidly transmitting heat to the core is also called *steam-shock*. However, the cure time of the resin, particularly in the core of the board, can be impeded by an excess of moisture. The higher mat moisture contents of faces aid in plasticizing the wood particles, providing tight, hard faces. Levels of about 16% in moisture content are excellent for this purpose. This high face moisture has the further advantage of retarding the cure of the face resin, thus reducing precure problems. However, higher mat moisture contents will result in lower-density board cores, lower internal bond strengths, the possibility of blows or delaminations and caul-to-board sticking problems. As will be mentioned later, the press closing time and the various moisture contents and distributions of moisture throughout the mat have a pronounced effect on the final board-density profile and physical and mechanical properties. It may be necessary to lower the mat moisture content if the species or particles compress too easily.

Advantages of lower mat moisture content are: higher general strength properties, in particular internal bond; shorter press times; freedom from caul sticking; and a more uniform density profile. Problems that can result from low mat moisture content are: higher water absorption in the boards, rougher faces due to a

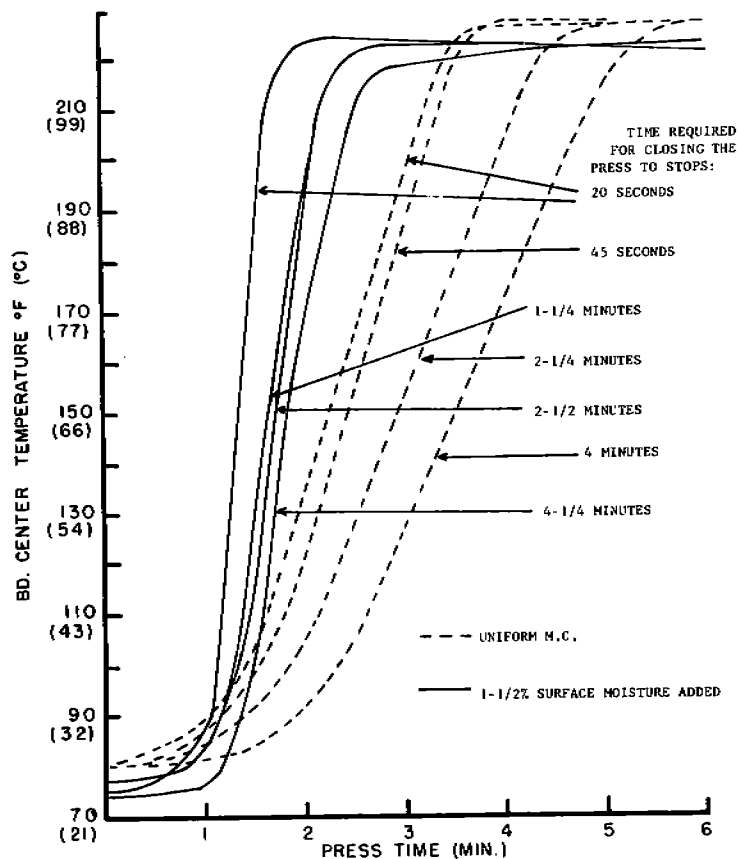


Figure 17.1. Differences in time required for the development of similar core temperatures between boards pressed with a uniform moisture content and boards pressed with 1% additional moisture added to the surface (Crawford 1967).

decrease in the wood plasticization; slower heat transfer to the mat core; slower close time to stops at a given pressure, and possible problems with tack. However, in recent years, newer developments with resins have made possible the development of tack at relatively low furnish moisture content.

It is difficult to define optimum conditions when considering mat moisture content and distributions thereof. It appears 10 to 12% is the optimum moisture content if this alone is considered in pressing board. However, single-opening

press lines are operating at levels of 6.5 to 7.0%. Problems of insufficient moisture to accomplish good resin bonding when using "standard" resins must be overcome by resin tailoring. Higher mat moisture contents may require longer press times, although resin advancements appear to have overcome some of the problems. Variations in total moisture content between boards in a plant will result in differences in final board thicknesses resulting in rejects because of "thick" or "thin" panels.

Vapor Pressure Within the Board

The internal bond of the board in the hot condition as it leaves the press must be sufficiently high to withstand any vapor pressure that exists within the board when the press is opened. Because of the relatively porous structure of composition board, vapor pressures are usually relieved quickly, with the aforementioned exceptions that can cause blows. Since vapor pressure is associated with temperature, it is important to recognize that the relatively low temperatures in the cores of boards being compressed in normal cases does not generate a very high vapor pressure. At 212°F (100°C), a vapor pressure equivalent to atmospheric pressure is found. As the core temperature rises the vapor pressure increases rapidly. If the core temperature of the board exceeded 300°F (149°C), it would probably be necessary to keep the board in the press long enough to evacuate all of the moisture through the edges to prevent blowing. For example, at 300°F (149°C) the vapor pressure would be 67 psi (462 kPa). At 350°F (177°C) the vapor pressure would be 136 psi (938 kPa). Fortunately, the usual case is one where the core temperature is on the low side and thus the vapor pressure does not become extremely high.

The increase in vapor pressure can cause an interesting problem. In one particleboard study where boards of 0.80 sp gr (50 lbs/ft³) were being made at 375°F (191°C), with catalyzed urea resin, it was shown that boards could be pressed in 1 minute. However, if the board was left in the press for another 30 seconds, the board blew because the additional heat added to the board increased the vapor pressure above that of the internal bond of the hot board. Thus, additional press time was needed to relieve the vapor pressure before the board could be removed from the press without blowing. This same experience has occurred in the field with boards as low in density as 0.70 sp gr (44 lbs/ft³). Boards can also blow shortly after leaving the press because of excessive vapor pressure.

There is some confusion existing on the difference between delaminations and blows. A delamination can be defined as a definite separation between the particles in the core of the board. This can be the result of low platen temperatures, insufficient cure time, insufficient pressure, low resin levels, or a combination of these factors. Some of these same conditions can cause springback. In such cases, the thickness of the board leaving the press is much greater than that to which it was compressed in the pressing operation. It is still bonded together but the bonds are not of good quality.

The blows in the board are caused when vapor pressure of the volatiles (moisture and vapor from extractives) exceeds the internal bond strength of the board. The blow normally occurs near the center of the board because this is

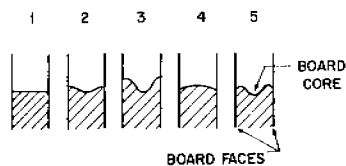
where the board is the weakest. Many parts of the board can be well bonded with the blows distributed throughout. Some people would call the blow a blister, since there will be definite bulges in the board faces where the blows occur.

Previously the sealing of the board surfaces was mentioned as a contributor to blow problems. It should also be noted that the wood density and board specific gravity or density are also causes of the problem. As the board density increases, the sealing effect becomes more pronounced. Thus, it may be impossible to produce higher-density boards from some species without special precautions. Problems have been noted with ponderosa pine and with some of the cedars.

Press Closing Time, Pressure, and Density Profile

Press closing time is one of the most significant factors in determining board properties; and closing is closely associated with moisture content, as well as a number of other factors. *Press closing time* is defined as the time it takes to compress the mat to final board thickness once the press platens make contact with the mat surfaces. A number of density profiles can be developed in a board by manipulating these factors. Figure 17.2 shows the typical density profiles that have been observed. Of course, once an imbalance of heat, pressure, or moisture content occurs, the profile is no longer symmetrical but skewed. Such a board is to be avoided since its properties will be affected and it will probably be warped as well. The drawings show the density of the board from one face to the other. Another term used when discussing density profiles is *layer density* or, in other words, the density of the various layers in a board.

Figure 17.2. Typical density profiles. No. 5 is typical of many particleboards (Polovtseff 1961).



In Strickler's classic research on press cycles and mat moisture content, $\frac{3}{4}$ -in.-thick (19 mm) boards were made with Douglas fir flakes using various mat moisture contents and variations thereof and six press closing times of 0, 1, 2, 4, 6, and 12 minutes. It should be noted that his research was conducted at a time when it took 10 to 12 minutes to cure urea resin in boards of this thickness. Figure 17.3 shows the press cycles that he studied. Cycle here does not include the time for loading and unloading the press, which is normally included in the board industry's measurements.

It is immediately obvious that much higher pressures are needed with fast press closing times. This occurs because these mats are essentially cold during consolidation. Once the heat from the platens starts to penetrate the mass of wood, two things happen which are critical factors in determining final density profile (along with pressure). First, there is a transmission of heat from the mat faces to the core.

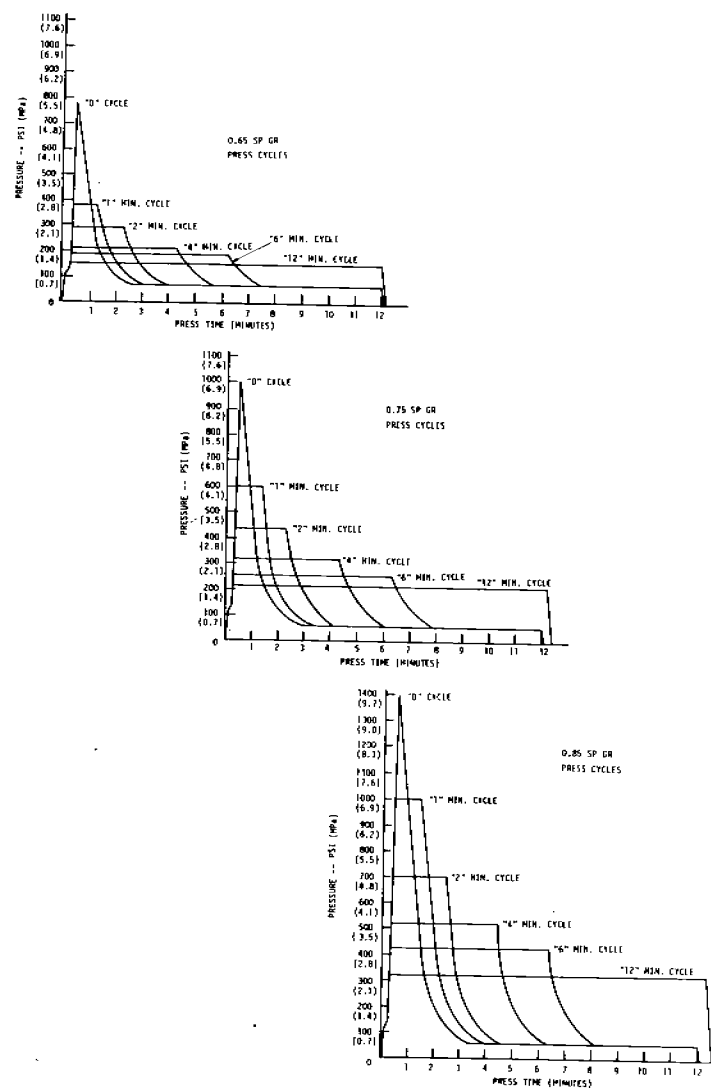


Figure 17.3. Shown here are press cycles that produce $\frac{3}{4}$ -in.-thick (19 mm) Douglas fir flakeboards of three density levels—0.65, 0.75, and 0.85 sp gr—at 12% moisture content. Press cycle designations ("1" minute cycle, etc.) indicate minutes at maximum pressure (Strickler 1959).

Second, the moisture turns to steam and the steam plasticizes the wood, making it easier to compress. This plasticizing takes place first in the faces and with the faster closing times, where the mat is almost at final thickness within a minute or less, the plasticized faces "collapse" to a higher density under the pressure. The core is still cold and is resisting the pressure. When sufficient heat reaches the core for plasticization, the faces are already set at higher density and the resin has cured to hold these layers at the higher density. As a result, there is insufficient wood left in the core to permit compression into a higher density at a given thickness.

At slower press closing times (i.e., using less closing pressure) there is less pressure and thus less compression in the face layers. Also the resin in the face layers may be cured before mat consolidation takes place. Thus the face layers are relatively rigid and at a lower density during the latter part of the closing time, and the plasticization and compression of the furnish under pressure while the resin is uncured takes place at intermediate layers or in the core.

The density profile, however, can be altered by prepressing. Prepressing the mat to final thickness would tend to eliminate density variations throughout the board thickness. This would require high pressures, and some research has shown possible deleterious effects on board properties with such high-pressure cold prepressing. However, by consolidating the mat in prepresses to about 0.30 in sp gr (given a 0.70 sp gr board), it is possible to close the hot press faster and provide a board with a more uniform density profile. A single-opening hot press is able to consolidate a mat into a $\frac{5}{8}$ -in.-thick (15.9 mm) board in about 13 seconds. In this example the pressing pressure is built up to 500 psi (3.45 MPa) within a period of 8 seconds.

It should be noted that once the mat has been compressed to final thickness, pressure must be reduced or otherwise the mat will be consolidated further. In Strickler's study, boards were pressed to caliper or thickness without stops or gauge bars in the press. He therefore shows the pressure required to hold the board at the intended thickness after consolidation was accomplished (Figure 17.3). It is readily apparent that only about 50-psi (344.7 kPa) pressure was needed to hold caliper during the latter part of all but the 12-minute press-closing time (in this case it took the entire time to close the press). Less pressure is required at the end of the press time because much of the resin is cured and holding the particles in their "set" position. The plastic deformation and set of the wood particles themselves is also a factor in reducing the pressing pressure. This may be demonstrated by hot pressing a mat without resin.

Most presses use stops to control final board thickness. If press pressure is maintained at the level needed for closing, it can be seen that a tremendous pressure is built upon the stops which can cause damage to the stop system and perhaps to the press itself. Therefore, even with a stop system, pressure is reduced during the latter part of the pressing time.

Figure 17.4 shows the density profile found when using 0-, 2-, 6- and 12-minute press-closing times, three moisture-content levels and three board-density levels. The important observation is that fast press closing results in high-density board faces and low-density cores. Thus, board properties such as bending and stiffness are enhanced while internal bond is diminished because of the density profile. The

reverse is true when a long press closing is used.

The density profile can also be adjusted by an uneven moisture content between faces and core. Higher face moisture contents developed by adjustments in blending or by spraying water on the mat faces can accentuate the density profile obtained by fast press closing. Reversing the face and core moisture gradients produces a more uniform density profile as shown in Figure 17.5.

Press temperature is also involved with the press closing and resulting density profile. Higher press temperature increases the core density while decreasing the face density because of faster heat transfer to the core. Similar pressing approaches to low-, medium-, and high-density boards result in different density profiles although the profiles in general are similar (Figure 17.4). This is a complicated subject, and other factors can come into play providing a different density profile than anticipated. Species has been one of these. The important point is that by manipulating all of the factors involved with density profile, it is possible to control board properties to the manufacturer's advantage.

Face quality can be improved by post-pressing board at temperatures around 700°F (371°C) for a few seconds as shown in recent experiments. This high temperature setup would call for an additional press, but it would not need to apply high pressures.

Precure and Postcure of Resin

Figure 17.5 also shows the characteristic found in many boards of a slightly lower face density on the outer part of the board faces, probably because of complete resin cure before final board thickness is reached in pressing. Much of this "softer" (low-density) surface is removed in the sanding step. These soft surfaces are related to the *precure* or dryout of the resin caused when the hot platens first come in contact with the mat. At the normal temperatures of 325° to 375°F (163–191°C), resin curing is almost instantaneous at the faces and happens before the mat is consolidated to final thickness. Although the *precure* can be alleviated by the use of higher face moisture levels, this may extend the press time.

It is interesting to recall the relatively slow closing of some of the early multi-opening board presses. Very soft surfaces occurred and sanding off as much as 0.125 in. (3.2 mm) of material from faces was not uncommon. Many early multi-opening presses were plywood presses modified for use with composition board. These closed from the bottom so that the bottom opening closed first and the top opening last. In a 16-opening press, this resulted in each board having a different density profile and also different properties. This problem was rectified by the development of simultaneous closing systems so that all boards are pressed identically.

Postcuring can be useful or deleterious. First, it is of advantage to hot stack phenolic-bonded boards to complete the cure. Second, hot stacking of urea-bonded board can break down the resin bond by hydrolysis, which is a function of temperature, moisture content, and time. Hydrolysis is where the resin molecule is cleaved but the effects on the board are being argued. It is claimed by some that the effects are exclusively in the wood because it is more sensitive to strength loss. Others feel the breakdown is in the wood-resin interface.

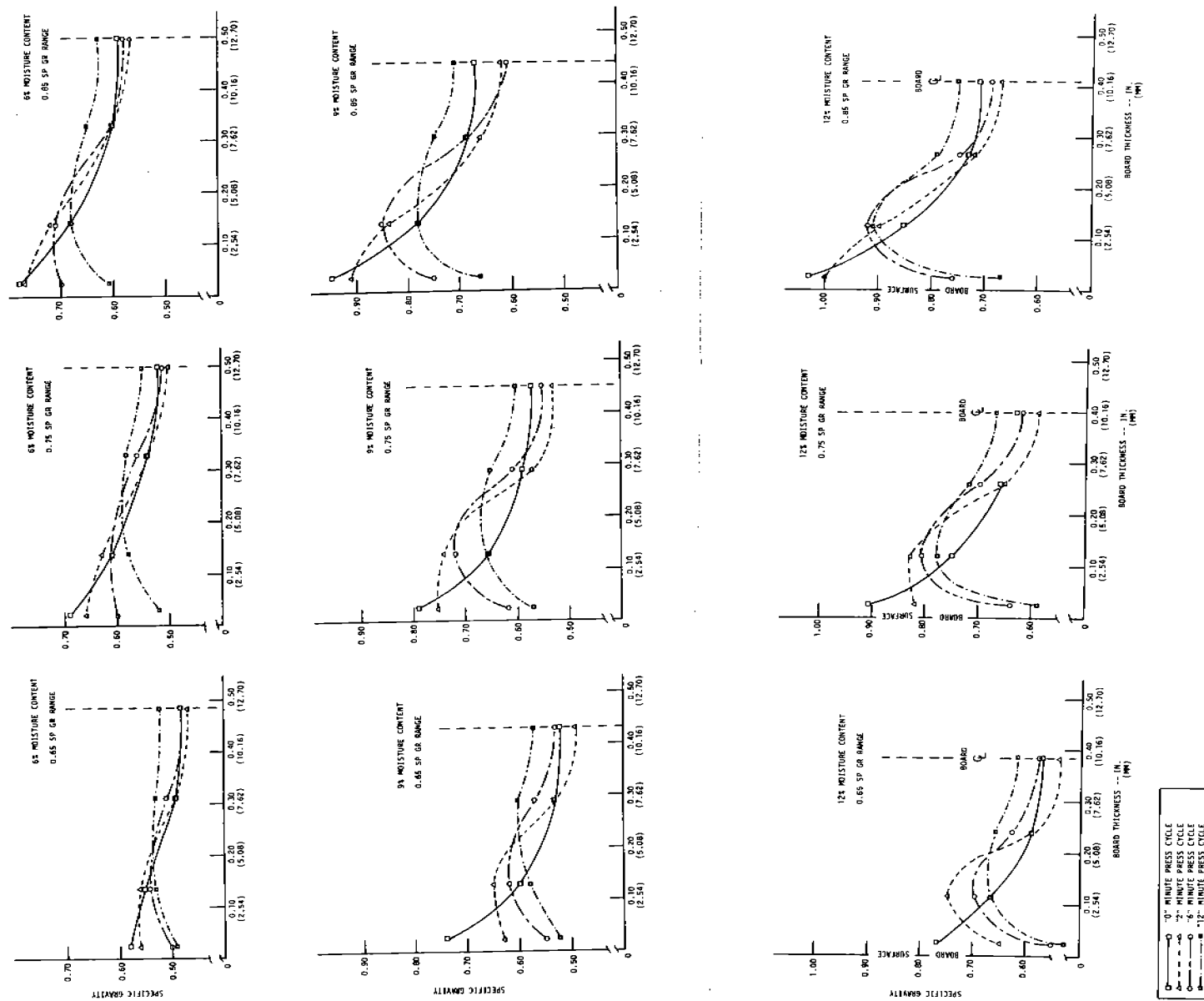


Figure 17.4. Adjusted layer density curves from board surface to center line for four press cycles, three moisture content levels, and three density levels. Curve points indicate only the average density for each layer (Strickler 1959).

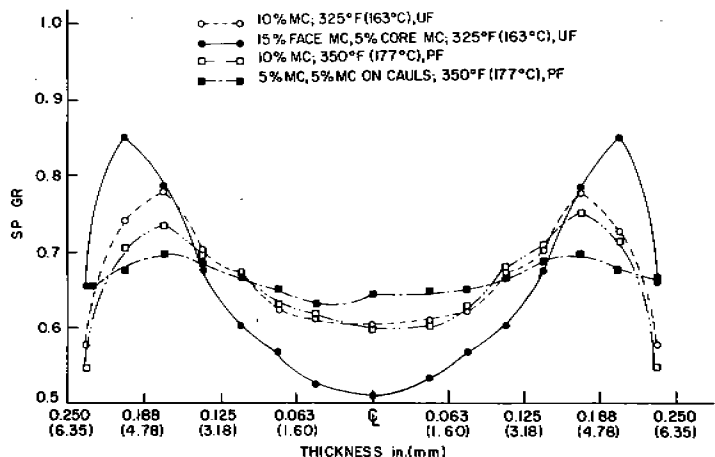


Figure 17.5. Effect of various moisture and temperature conditions on density gradients in $\frac{1}{2}$ -in. (12.7 mm) particleboard. Each line is average measurement of two panels (Heebink, Lehmann, and Hefty 1972).

PRESSES

Presses can be divided into platen (of which there are multi- and single-opening types) and continuous types. The type of press to use must be carefully evaluated for each individual case. Advantages and disadvantages may not be the same for each. Multi-opening presses are dominant in the industry at present; however, many single-opening types are in operation. Continuous presses are being installed worldwide with the development of a system for making thin board. Few such presses for thicker boards are now in operation, although they were developed in the 1950s.

Important factors to consider when evaluating the pros and cons of any press line are the quality of the board to be made; the input of the raw material (wood, resin, energy) in relation to the produced quantity of boards; the length of the scheduled down times for maintenance, changing of stops or thickness control devices, cleaning, and the length of the unscheduled down times that can be expected.

Early multi-opening presses were adapted from the plywood industry. These were not suitable for pressing dry-process fiberboards and particleboards; consequently, the multi-opening types were developed and now are the most widely used.

Further development in the industry has made possible the construction of presses for producing larger and larger board sizes in both single- and multi-opening presses. Both multi- and single-opening presses are as wide as 8 ft (2.5 m). Multi-opening presses are as long as 33 ft (10 m) with single-opening presses being

offered up to 100 ft (30.5 m) long. The longest known in operation is 68.8 ft (20.96 m). Flexibility in cutting-to-size resulting in lower trim losses is a particular advantage with large boards. There are difficult production conditions in making and handling such large boards, and these must be considered in the plant design. Investment costs are higher per unit of produced board.

Multi-opening presses operate with the caul, metal cloth, or caulless systems. Most of these have many openings running as high as 40, although 14 to 18 are more usual. For high production capacities, multi-opening presses are used. Capacities of 572 to 715 tons (519–649 mt) of board per day are not unique. The greatest capacity found is about 1300 tons (1179 mt) per day.

The single-opening presses operate with either a steel belt or the special metal mesh cloth used to transport the mat into the press, which is simple and reliable. Single-opening lines have lower production capacities than the large multi-opening lines; however, single-opening lines have found great favor for smaller plants. Some plants run with more than one such line, with perhaps the extreme example being a plant reportedly with nine single-opening lines. Technological progress in single-opening press lines in recent years has made these systems more attractive as alternatives to multi-opening systems, even for large production capacities where two or more presses are used.

Single-opening press lines are now available in sizes up to approximately 592 ft² (55 m²) of pressing area, corresponding to an output of 286 to 358 tons (400–500 m³) of board per day, based on a reasonable thickness; but considerably larger presses are being discussed. There are a number of reasons why single-opening presses are favored for use in board plants. It is possible to insert the new mat into the press in 10 to 15 seconds, depending upon the press length. It takes only a short time for building up the full pressure upon the mat, particularly if the mat is prepressed. One firm claims approximately 10 to 15 seconds for such an accomplishment. High press platen temperatures ranging around 390°F (200°C) can be utilized with a minimum of surface preheating because of the fast charging and closing of the press, which also reduces the press time. It is also possible to preheat the steel belt carrying the mat into the press and to preheat the formed mat. Both of these procedures contribute to shortening the pressing time. For three-layer boards with a density of 41 lbs/ft³ (0.66 sp gr) and with a thickness of $\frac{5}{8}$ in. (15.9 mm) after sanding, a total press time of 150 seconds is reported. This is compared to a total pressing time in multi-opening presses of about 250 to 350 seconds. A further reduction of 50 seconds in press time with single-opening presses is anticipated with the use of high-frequency preheating of the mat.

It is claimed that there is a better thickness tolerance in pressing a single mat rather than many, as in the multi-opening presses, and thus less sanding is required, saving wood, resin, and other additives. If sanding can be minimized—and this applies to all types of presses—there is less risk of exposing coarse particles in layered-type boards. This is important in cases where the boards will be used for secondary processing such as printing or laminating. The single-opening-panel sizes are quite large, and thus there is less loss in edge trimming compared with the smaller boards produced in multi-opening presses. Single-opening presses are less complicated, and the mat loading system is also relatively simple, compared with multi-opening presses.

Because of the relatively long length of single-opening presses in comparison to multi-opening press lines, however, the equipment—including the former, prepress and press—requires a much larger building area than the multi-opening presses. To date, the total single-opening press line is generally more expensive in capital investment on a production unit base. In large plant operations where more than one single-opening line is involved, more operators are usually required. Single-opening presses, because of the large size of the board, usually require mat moisture contents of about 7%. This is several percentage points lower than normal for multi-opening press lines. Such dry mats can require a greater pressure for closing the press to the final board thickness. Since the closing takes place in a relatively few seconds, there is little, if any, plasticization of the mat during the press closing time. The requirement for extra pressure capability in these types of presses also can add to the capital cost.

Another approach has been taken with a system that does not require as much space as a single-opening press line but is designed for production capacities similar to the single-opening lines. It generally uses a 6-opening press of a size which has a total pressing area about equal to that of the larger single-opening presses. This reduces the space requirements considerably, and this multi-opening press is not as complicated as those with many more openings. Indeed, simultaneous closing may be eliminated; but problems with blowing mats out of the press during closing may occur, depending upon the furnish type or whether prepressing is performed.

Single- and multi-opening presses are unproductive during the loading-unloading, closing, and opening part of the press cycle. This dead time becomes extremely important when pressing thin board. In broad terms, it is claimed that economic feasibility of a continuous press is limited to a process where the cycle time is one minute or less. It may be possible to go as high as three minutes in press time depending on the product. The reason three minutes is the cutoff point is that no big multi-opening press with 20 or 30 openings can charge the loader, insert the mats into the press, and close the press in less than three minutes on a reliable basis. The dead time in a single-opening press may be 15 to 20 seconds. Thin boards can be cured in less than 30 seconds, thus the dead time can be about 70% of the pressing time. The elimination of this dead time has led to the development of continuous presses for thin board.

A new system called the Mende process for producing a continuous thin board being used widely over the world. In this system a continuous steel belt runs through the forming area and partially around a 10-ft-diameter (3.05 m) heated pressing drum. This belt carries the formed mat through the continuous press. The machines are supplied in five widths, ranging from 4 to 8 ft (1300 mm–2500 mm).

Another design of continuous press has been developed by Washington Iron Works. It consists of two heated steel belts with a pressure-holding section about 11 m long. A set of two large nip rolls, located at the beginning of the pressure section, first presses the mat to nearly its final thickness. This quick impression of the mat is different from the Bartrev press developed in the 1950s which consolidated mats continuously into board, using a stainless steel band running over a caterpillar backing track. The nip roll pressure is approximately 100 to 3000 lbs/linear in. of width of the rolls (909–1364 kg/25.4 mm). Between 30

and 100 lbs of pressure/in.² (207 to 689 kPa) is then applied in the holding section which is backed up by lubricated slides. The mat is pressed and cured in less than 30 seconds depending upon the thickness of the board and the resin catalyst used. This is a flat straight-through press, and the board is cured in the flat position, whereas the panel in the Mende system is mostly cured as it passes around the 10-ft-diameter (3.05 m) heated pressing drum. The development stage for this newer press was completed, and it was ready for production application when this book was prepared for publication.

The advantage of crosscutting the endless board to any desired length is not agreed upon by all authorities. The possibilities of making boards more economically in a 16.4- to 24.6-ft (5–7.5 m) long multi-opening press or a single-opening press 45.9 to 49.2 ft (14–15 m) long, where cutting losses can be less than 10% on the full length, must be evaluated to determine whether the continuous press is indeed better for any installation.

Another pressing system which is producing thicker board makes a continuous panel employing a single-opening press to press board on a step basis. In this process, a mat of unlimited length is pressed one step at a time. A special heating arrangement in the press platens prevents the resin in the mat at the entrance of the hot press from curing. A number of these systems are in operation.

Presses are now run with automatic controls, although manual operation is possible. In this age of automation, programmed controls are common, and it is easy to change pressing cycles simply by changing the punched control card.

Press Heating Systems

The most common way of heating a press is to introduce some type of heating medium into the press platens. The most commonly used medium in the United States is steam because boilers can operate off plant residuals. Other systems widely used in the world are hot oil and hot water. There is some use of high-frequency pressing, and its popularity has gained in the last several years. With the exception of the high-frequency, the heat is applied to the mat in the hot press through conduction. With the high-frequency or, as this is sometimes called, radio-frequency type of heating, the mat is placed in an alternating electric field which is set up between press platens. In this field molecular vibration occurs, which leads to heat generation for curing the resin. A new system using electric heat has been recently announced, and a unique system using direct heating by gas flames has been used for many years.

Steam: In steam-heated presses, the steam as generated by boilers is run through a passageway in the press platens. The steam temperature is directly related to the steam pressure. Thus, pressure control valves are used for adjusting the press temperatures. These controllers are operated by air controllers, making it imperative to have clean, dry compressed air which is not contaminated by water or compressor oil. Otherwise the controllers will not function properly and the press temperature will be out of adjustment. In this system there must also be proper steam trap operation, and the strainers must be checked frequently to insure that they are not plugged with pipe scale or boiler water additives. There can be a difference in temperature between the top and the bottom of a press

platen, due to a film of condensate forming on the bottom of the passageway in the press platen. Condensate lines must be laid out properly so that they will drain properly.

Hot Water: Hot water systems have been popular because of the relative ease in controlling the heating of the water and the final water temperature; however, they are not normally used in the United States. A boiler is used to generate steam for heating the water in a hot water generator. The maximum press temperature that can be practically achieved with hot water is about 420°F (216°C). Hot water systems eliminate steam traps and their associated leakage problems. The heat transfer is uniform throughout the platen, varying only with flow velocity and temperature. More interest is being expressed in this heating medium nowadays when the fuel used is expensive fossil types because savings in fuel costs of more than 19% have been demonstrated in comparison with steam. Problems with hot water heating include the need for treating the water for pH and oxidizing problems and leakage. The main disadvantage is that the hot water has to be pumped through the system under very high pressure.

Hot Oil: When heating with hot oil, it is quite easy to go to relatively high temperatures such as 450 to 500°F (230–260°C) with the present heating systems. Higher temperatures are possible for special cases. Electrical means are used for heating and controlling the hot oil temperatures; however, recent developments have resulted in a way to use heat from wood waste incineration for heating the oil. The hot oil is pumped through the platens continuously. There must be sufficient flow of the hot oil to insure that enough heat is delivered to the platens, eliminating wide fluctuations in press temperatures. A big advantage with hot oil is that only the pressure necessary for pumping the oil is required. In the case of steam-heated platens it is necessary to treat them as pressure vessels. There is a fire danger with hot oil, however, in case of leaks; and it is important to keep the pressing area clean of wood particles, dust, and fiber which can easily catch on fire in case of an accident.

High Frequency: A number of advantages are possible with the use of high-frequency heating in pressing board, all of which have to be evaluated in the total concept of the plant before deciding whether or not to use it. Some of these advantages are: a short press time; press time is proportional to mass in the press, not the heat and vapor transfer properties of the mass as with conventional pressing; and low platen temperatures. Typically, during pressing ¾-in. (19 mm) boards, about half of the heat utilized is from the hot platens and about half from the high-frequency source. The heat from the high frequency appears immediately throughout the full thickness of the mats and results in faster cure cycles simply because the rate of energy input is greatly increased compared to hot plates. Other advantages when producing MDF include: the use of low-cost *in-situ* resins; the use of the same adhesive formulation, no matter what the thickness and density of the final board product; the elimination of board-cooling equipment after pressing, since the boards can be stacked immediately because of lower board temperatures; and a more uniform density profile in the board. Better overall physical properties are developed, particularly in the thicker fiberboards. The storage time between board pressing and finishing can be reduced, since the moisture content of the panels is more or less equilibrated as the board comes out of the press.

A number of improvements of the fiberboard properties and characteristics are claimed with the combination of contact and high-frequency heating. They include better machinability, better coatability, superior dimensional stability and higher internal bond, improved edge screwholding and edge hardness. Because the faces of the finished board will probably be lower in density than conventionally pressed boards, a slightly lower bending strength and stiffness can be expected. This is not true if the boards pressed with contact heating have soft surfaces.

A number of plants have been built in the medium-density fiberboard field using the high-frequency type of pressing. There also have been a number of plants built using only the conventional type of heating in the press platens. Both types of plants appear to be operating successfully in the marketplace. However, it does appear that the high-frequency type of resin curing is better for boards that are ¾ in. (19 mm) or over in thickness. It should be mentioned that a few small single-opening press lines producing "conventional" particleboard also use RF heating.

High-frequency heating has been finding more favor in the medium-density fiberboard lines because of the speed of curing the resin during pressing, particularly with thicker boards over ¾ in. (19 mm). High frequency assists in producing thicker boards with good hard surfaces. It has been difficult to do this with conventional platen heating systems because of precure or overcure of the surfaces. Figure 17.6 shows production versus generator power output at four levels.

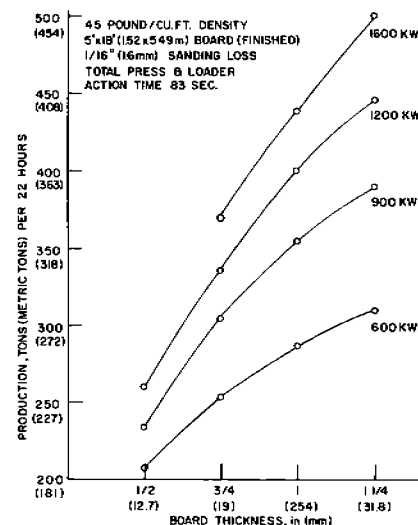


Figure 17.6. Production vs generator power output levels in a six-opening press. (Courtesy Votator Division, Chemetron Corp.)

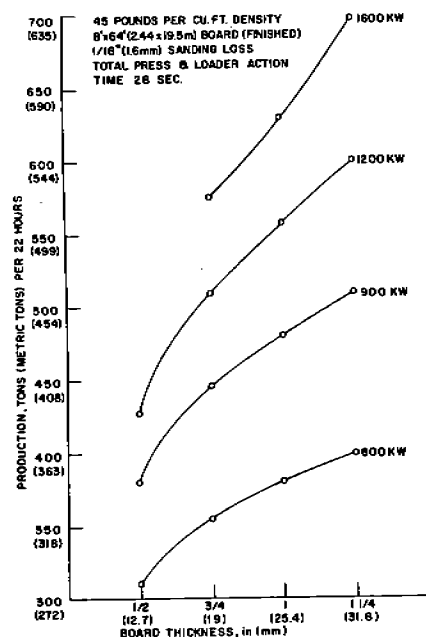


Figure 17.7. Production vs board thickness at four high-frequency power levels in a single-opening press. (Courtesy Votator Division, Chemetron Corp.)

Figure 17.7 indicates the increased production that can be expected when making boards using either 600, 900, 1200, or 1600 kW high-frequency power levels. This information is based on *in situ* UF resins. The heat cycle includes time necessary to cure the resin which is not a function of RF power input. Thus, if other types of UF or PF resins are used—types which cure slower or require higher temperatures—the heat cycle will be longer and the production less than that shown in the figures. A large single-opening press is in operation producing boards 8 ft wide by 65 ft long (2.44x19.8 m) using high frequency (1600 kW) as part of the curing system. Multi-opening presses, however, to date have been limited to eight openings at 5x24 ft (1.52x7.32 m).

High-frequency units are used in conjunction with platen heating systems because, if the platens are not heated, heat generated in the mat during pressing will rapidly move to the cold platens, thus insufficient heat will be in the mat surface for cure of the resin. A hot platen also prevents the moisture from moving to the cold surfaces where it would condense and cause wet, soft surfaces as well as possible rusting of the platen and mottling of the board surface. When pressing, the high-frequency power is not turned on until the mat has been compressed to approximately the final board thickness.

With high-frequency heating, the particles are uniformly heated. Unless the mat surfaces are in contact with a hot platen, they lose heat to the platen. The moisture in the wood aids heating and, when vaporized, is dispersed throughout the mat. This can wet the particle surfaces and further improve the distribution of the resin as well as assist with the plasticization of the wood furnish.

As is well known, wood is a poor conductor of electricity. However, the moisture in the mat, which ranges from about 8 to 13%, assists with the absorption of the high-frequency energy during pressing. The system is based on the absorption of energy by the mat when it is placed in an alternating electrical field. At frequencies of about 6¹⁰ hertz, molecular vibration occurs, which leads to the heat generation within the mat. This power comes from oscillator tubes which are self-excited. This power is transmitted via conventional hot press platens, which form electrodes, to the mat or mats in the press.

The heating of wood with high frequency takes from about 1.2 to 2.5 kW minutes of RF power per 2.2 lbs (1 kg) of wood depending on the temperature rise.

A single-opening press requires insulation of one of the platens. The multi-opening presses with intermediate pressing platens require insulation of the guides and hangers on these platens. If the number of openings is even, it is not necessary to insulate either the top or the bottom platen. Figure 17.8 illustrates these layouts. Figure 17.9 shows the connection of a 900-kW generator to a multi-opening press.

Since it is necessary to insulate presses that are using high frequency, it is difficult to use high frequency on continuous presses except as a source of heat for preheating the mat. Such preheating can speed up the pressing time in a conventional system and has been used for many years with the Bartrev system. Newer systems are also using high frequency for preheating the mat before it enters the hot press.

Complete closure, or shielding of the high-frequency system inside the press, is necessary because the platens can serve as a radio frequency transmitter. Thus, without shielding, radio and television transmission could be interrupted. Figure 17.10 shows a typical arrangement for shielding the press. It is nothing more than a thin sheet of sheet metal which serves to confine the electric energy. This means doors for loading and unloading the press must be used to seal off the press after loading the mats.

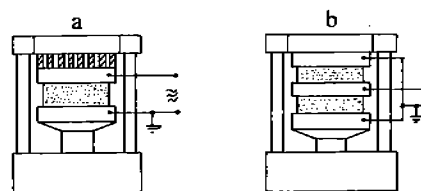


Figure 17.8. Schematic diagram of the connections for a single- or two-daylight press from the HF generator. One side of the single-daylight press (a) must be insulated from the HF energy, whereas the two-daylight unit (b) only needs insulation for the guides of the middle plate (Hafner 1964. Courtesy Brown Boveri Corp.)

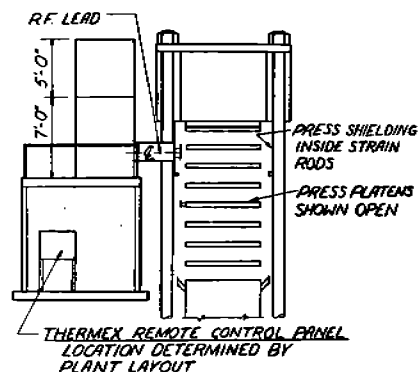


Figure 17.9. End view of a 900-kW generator and press (Hopkins 1970).

It is also necessary to insulate the pipe connections for the platen heating medium on all ungrounded platens with a high-frequency generator. This can be done with insulated hoses or metal pipe which is wound into a spiral. This spiral acts as a choke coil which prevents the escape of high-frequency signals. Platens connected to ground do not need such insulation. If stops are required between the press platens to control board thickness, they must be made of material other than metal. Suitable plastic materials can be recommended by manufacturers of the high-frequency units. Also, all metal parts involved in the actual electrical field should have the sharp edges rounded off to prevent corona and random arcing at these points. A serious problem occurs if any metal gets into the mats since an arc can be created that pits the faces of the platens. This can eventually require the removal and resurfacing of the platens. At last one supplier has a device, called an

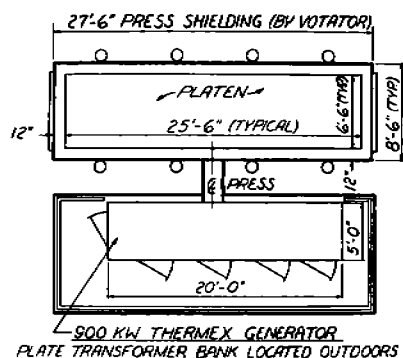


Figure 17.10. Plan view of a 900-kW generator and press (Hopkins 1970).

arcex, which senses the arc and stops the generator before such damage can occur.

According to the rules and regulations of the Federal Communications Commission, each high-frequency installation has to be measured for spurious radiation. The field strength limit has been set at 10 microvolts per meter measured at one mile from the equipment, which has not been difficult to achieve with proper press shield design.

With high-frequency generators, more than the rated power can be delivered because the generator only delivers power during the curing time of the press cycle. During press loading and unloading the generator does not deliver power and is thus able to cool down. However, there are limitations on how long the generator can deliver excess power, and the details must be worked out with the manufacturer to prevent damage to the equipment.

The oscillator tubes are cooled by a closed-loop system, using distilled water. The heat exchanger, which is cooled by plant water, is included (as is the storage tank) to maintain the cooling water at the proper temperature. Figure 17.11 is a photograph of such an installation.

There are many safety provisions for such equipment both for the personnel and for component protection. Safety grounding devices are used where lethal voltages exist. Interlock switches are used both for personnel protection and to provide proper sequencing of operations. For example, the use of interlocks in the generator circuit insures press closing and high-frequency application in the proper sequence. Pilot lights are also usually used to indicate whether control, filament, and plate circuit functions are in operation. They also indicate operation of crowbar and other protective devices. A bank of small indicator lights is used by one manufacturer to locate trouble spots such as open doors (there are 15 in this system), unactuated flow switches, actuated temperature switches, and so forth. For component protection, rapid-acting vacuum switches de-energize the plate transformer primaries within 10 ms after operation of the electric crowbar.

The so-called crowbar has as its principal purpose the prevention of an oscillator tube from being destroyed when internal arcs occur during operation. In addition to this, the crowbar also provides protection for other components in the high-frequency section of the equipment, especially the vacuum condensers.

The crowbar is a brute-force device. When the oscillator is operating correctly, an ignitron, which is connected across the DC supply terminals, acts like an open circuit (Figure 17.12). When an arc occurs in the high-frequency section, the ignitron is fired by the crowbar control circuits and shorts the DC supply within microseconds of the occurrence. This diverts the electrical energy from the fault location to the ignitron and prevents damage to the component in which the arc occurred. The crowbar firing circuit is a single-pulse device. Its fault-sending circuit utilizes several relays to make sure the crowbar is ready to operate before the high frequency is turned on. Failure of any crowbar relay to close its contacts will prevent operation of a high-voltage power supply. In addition to the fail-safe relay, a test button for checking the crowbar firing circuit is provided.

Each manufacturer is cognizant of the potential problems with safety and has taken precautionary steps, such as described here for one manufacturer, to eliminate the hazards of using high-frequency generators.

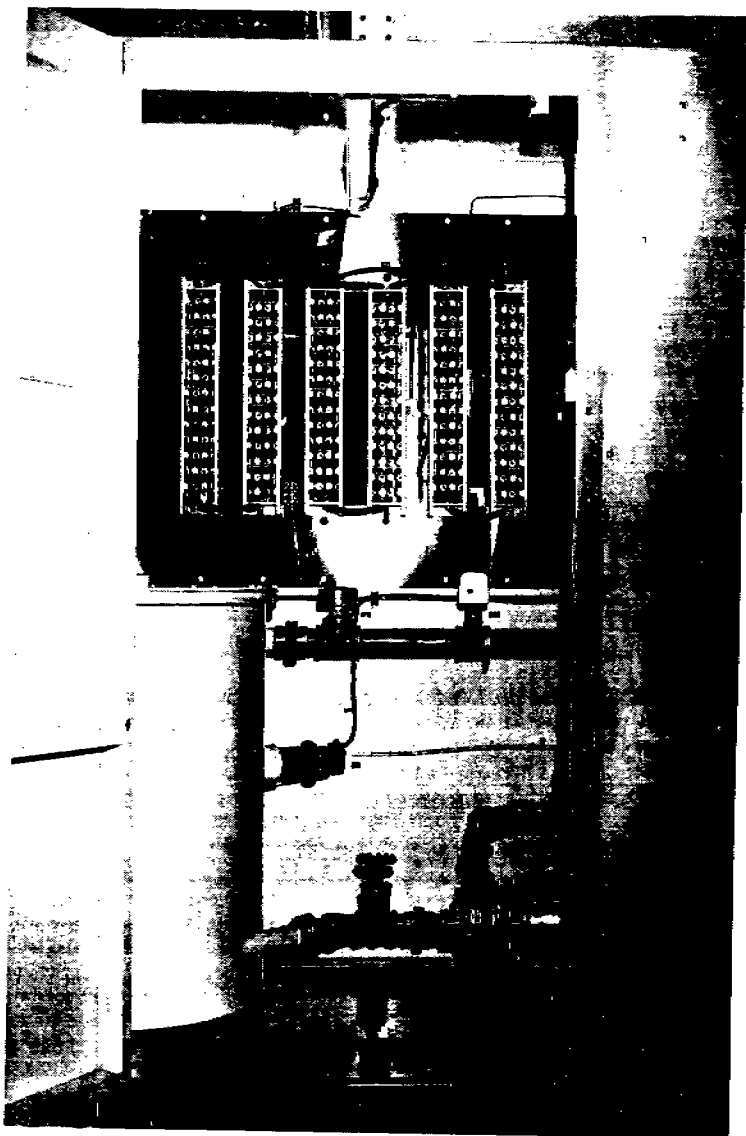


Figure 17.11. Thermex generator (250 kW) with a solid-state rectifier. It has a distilled water to plant water heat exchanger (Hopkins 1970).

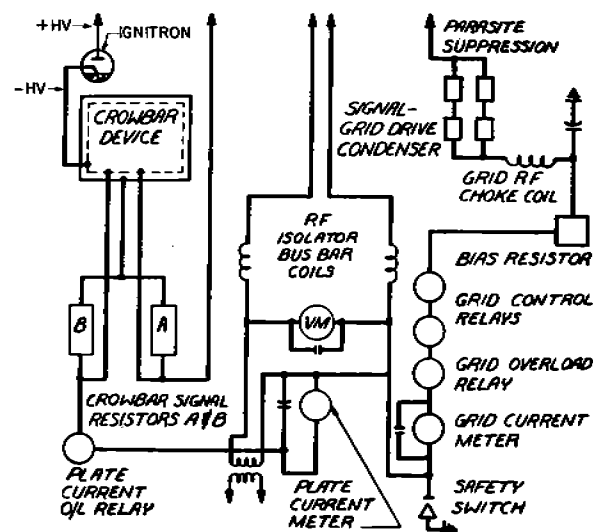


Figure 17.12. Diagram of the crowbar installation (Hopkins 1970).

At least one manufacturer provides door interlocks and high-voltage grounding switches at all access panels and doors. These open the high-voltage circuit when the door is open and also ground the high-voltage circuit to further insure its safety. Such devices are normally sufficient for personal protection but can be disabled if sufficient efforts are made. Such practice should be highly discouraged as the voltages within a generator can be lethal.

Electric: Electricity is commonly used for heating small laboratory presses. Such energy is uncommon in production processes; however, a recently unveiled system uses electricity to heat special caul plates. The first plants are being proposed for producing thin board. Mats on special, thin caul plates are stacked one upon another and then inserted into a single-opening press. Electrodes are attached to the ends of the special cauls, and as soon as the press is closed, the electrical system is energized, heating the cauls and the mats. It is claimed that no low-density faces develop because heat is not applied until the mat has been subjected to maximum pressures. Thus, the soft surfaces found because of immediate contact between the mat surface and hot-press platens in conventional heating are eliminated. Near perfectly formed mats are needed, otherwise the boards do not have uniform thicknesses. At first it might be anticipated that higher pressing pressure would be needed since plasticizing of the wood by the steam formed would not occur until after the press was closed. This is not too different from some fast-closing standard presses, which close in about 20 seconds. However, consolidation of the mat to final caliper does not occur until heat is applied. Figure 17.13 illustrates this system.

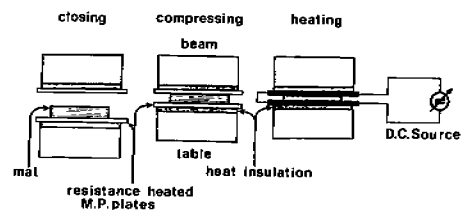


Figure 17.13. Electrical heating system for board (Axer 1975).

Gas Flame: As will be described later under "stack presses," heat is applied to platens in a press by direct gas flame. Continuous presses also use this heating system to heat the heavy links in the "caterpillar" tread which transmits the mat through the press. The heat stored in the links is used to heat the mat. This can be a hazardous operation unless care is taken to keep combustible material such as fine particles away from the open gas flame.

Thickness Measuring

An important measuring gauge of value to a press operator is a thickness gauge measuring board caliper out of the press. Excessive thickness is an indicator of low resin cure, shortage of resin, or moisture content that is out of control, etc. A continuous data reporting system allows the operator to adjust the blender, former, or press to possibly overcome the problem. Automatic marking of the thick panels allows for special handling of them later.

One version of a continuous thickness gauge is shown in Figure 17.14. The electronics are solid-state and use linear variable displacement transducers (LVDTs) or other electronic devices to determine thickness. The sensing wheels need to be held together with sufficient force to overcome any warp. All components must be dirtproof and waterproof.

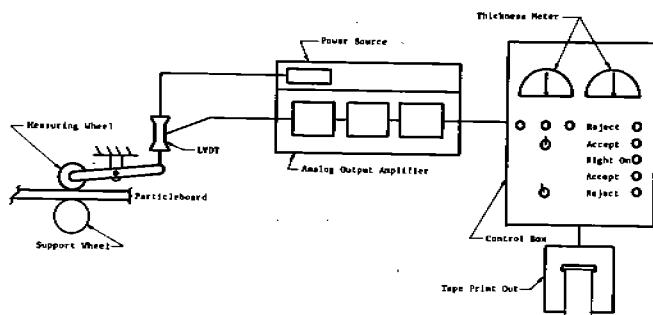


Figure 17.14. Schematic drawing of an out-of-press thickness gauge (Carter 1969).

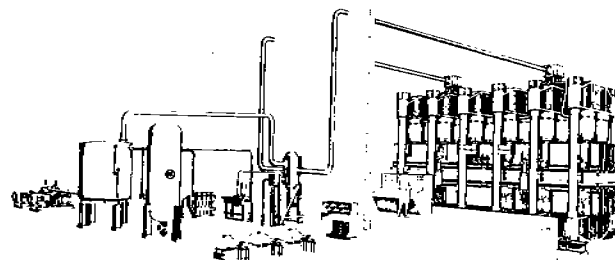


Figure 17.15. A single-opening press. (Courtesy AB Motalla Verkstad.)

Platen Presses

By far and away the most popular type of hot press used is of the platen type. A further breakdown is into multi-opening and single-opening (Figures 17.15 and 17.16 illustrate these two types of presses). Another type of platen press is what can be termed the stack, which will be dealt with separately at the end of this section. These types of presses are discontinuous in that the mats are introduced into the press and are held there during the pressing operation. The speedup systems in the mat formation line are needed in order to gain time for the actual

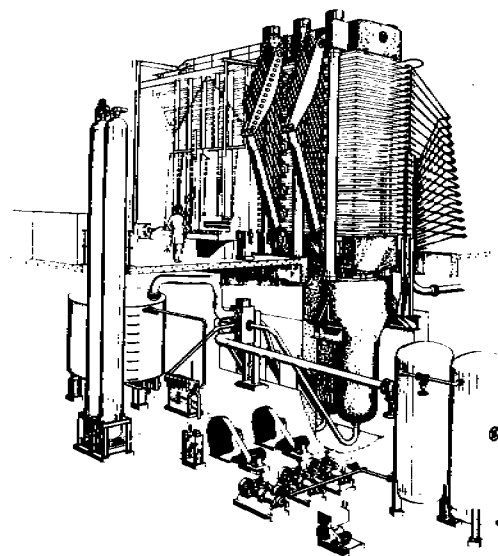


Figure 17.16. A multi-opening press. (Courtesy AB Motalla Verkstad.)

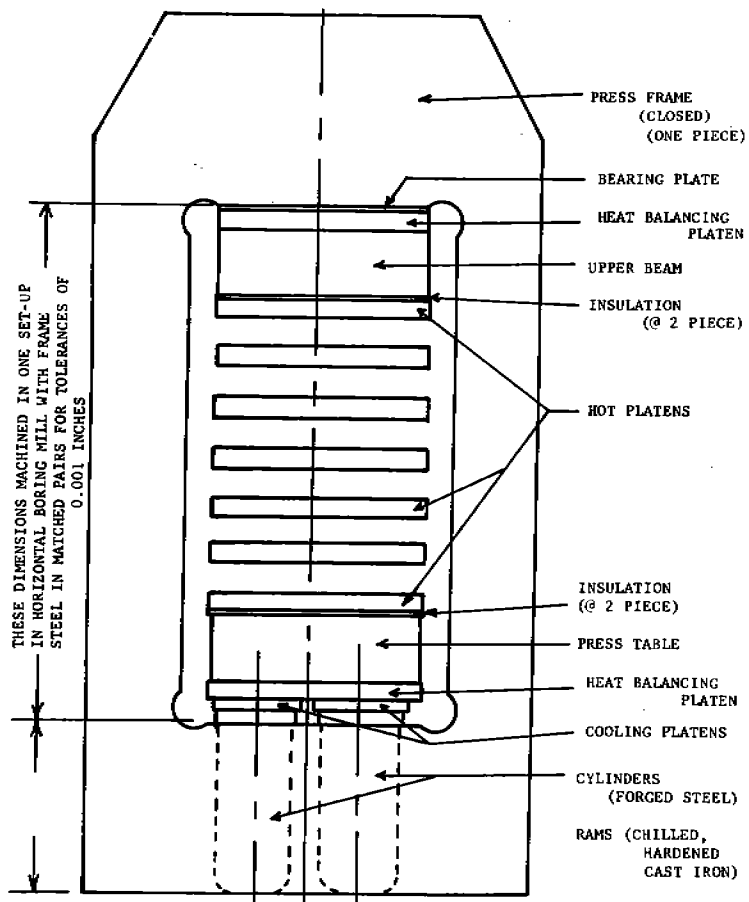


Figure 17.17. Schematic drawing of closed-frame press design (Ogran 1967).

pressing of the boards. For the most part, the multi-opening presses are upward-acting presses while the single-opening presses are downward-acting presses. In other words, the hydraulic system operates from either the bottom or the top of the press. Presses must be designed to handle the maximum bending moments, tensile forces, and shear forces which can occur in pressing.

Sophisticated press loaders have been developed for placing the mats into the multi-opening presses. A typical system was shown in Figure 17.15. With a downward-acting, single-opening press, it is not necessary to have any type of

press loader outside of the steel belt or wire mesh belt that brings the mat into place between the hot platens.

The optimum action of any platen press, of course, is one in which the horizontal members, the upper beam, bottom press table or platen and the intermediate hot platens all remain flat, level, and parallel throughout the complete press cycle. Smooth press travel, accelerating, and decelerating means minimum wear and maintenance and longer press life.

Press Type: Two different types of platen presses are produced: frame and column. Figure 17.17 shows a typical frame press and lists its parts. Other drawings of frame presses are shown in Figures 17.18 and 17.19, which also illustrate ways to install the cylinders. The frame for the presses is made of thick sheets of steel, out of which an opening is cut for the platen or platens. The best frames should be made from single plates and not welded from four strips. It is a simple operation to manufacture individual plate units, intersperse them with spacer-rings and clamp them together to form a press frame. Each frame is composed of two vertical pieces of steel plate matched in pairs with web plates between to form a rigid and stable component. When cutting the frame from the sheets of metal, it is important that rounded corners be cut in the plates to reduce the stress concentrations that would occur in a right-angle corner. It is desirable to round or chamfer the outside corners of the frames. Sometimes these frames are set close together as shown in Figure 17.18 for assembling a press. Because of the number of frames a heavy upper beam is not needed. However, because the frames are relatively close together, there is a somewhat crowded condition for attaching parts to the press platens and for general maintenance.

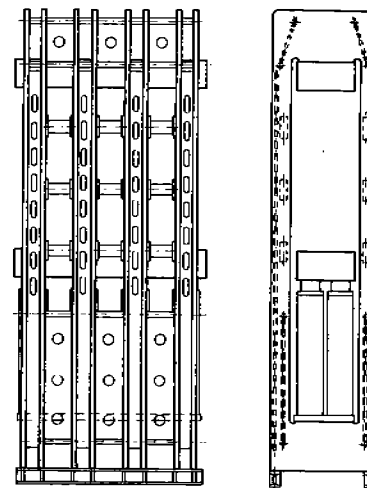


Figure 17.18. Frame press with eight independent cylinders on base plate. (Courtesy AB Motalla Verkstad.)

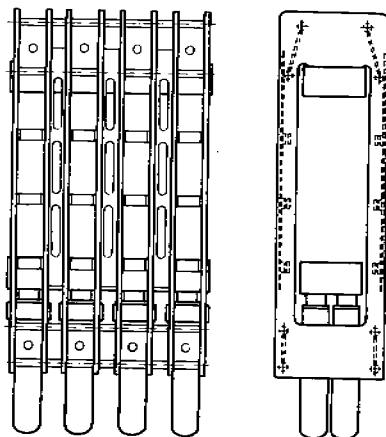


Figure 17.19. Frame press with eight suspended cylinder units. (Courtesy AB Motalla Verkstad.)

The number, size, and arrangement of the frame sections are dependent upon the platen length and width, the compression characteristics of the materials being pressed, the specific maximum pressure on the platen area, the hydraulic design requirements, the ram force distribution, the bending and stress analysis of the horizontal components, the press accessibility for operators and maintenance

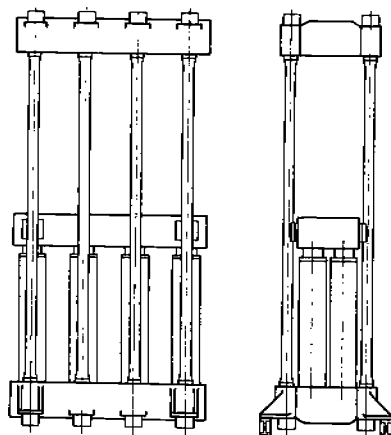


Figure 17.20. Column press with eight independent cylinders on base plate. (Courtesy AB Motalla Verkstad.)

personnel, the press auxiliary equipment which includes simultaneous closing units, and the material and fabrication utilization and economics. In the frame press it is normal to use a number of smaller rams, usually in pairs, rather than large rams. Two or more of the main rams are used as jackrams first and then as main rams. With these smaller rams, fast press closing can be accomplished without the need for jackrams or accumulators.

With column presses, as shown in Figures 17.20–17.22, the wider spacing between the columns and the heavier top platen or crown is shown. For example, one column press for producing 8x24-ft (2.44x7.32 m) boards has a crown that weighs 120 tons (109 mt). As can be seen, there is more space between the columns in this type of design. Columns can be cylindrically ground columns or welded frames. In column presses larger cylinders are used than in the frame presses and they are mounted as shown in Figures 17.20 and 17.21. The cylindrical columns are built with threaded ends. Large takeup nuts are screwed onto these threads, and it is important that the threaded area at the bottom of the screw area is not less than the diameter of the column proper; otherwise the column is weakened at this point and stress failures will occur. These columns are prestressed when put in place. After the installation is running, the columns are checked periodically and the nuts adjusted so that the proper stress is kept on the columns. Such presses are very rigid, whereas frame presses have more “give” in them when subjected to stresses that could occur from eccentric loads, such as unevenly formed mats.

With such large rams, fast closing of the press becomes a problem that must be solved. As shown in Figure 17.23, jackrams (fast-acting rams) can be used to close such a press at high speed while the main cylinders are opened to the tank for prefilling by gravity. The main rams are then used to apply the high pressure on the mats being consolidated into boards.

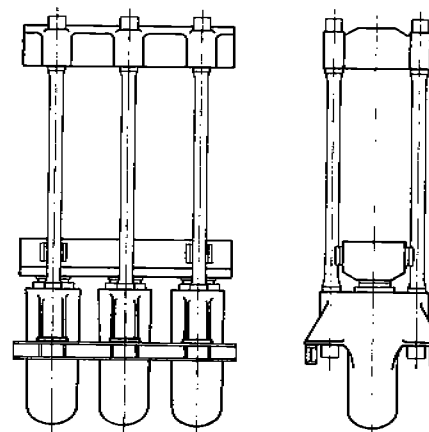


Figure 17.21. Column press with three cylinders directly connected to the columns. (Courtesy AB Motalla Verkstad.)

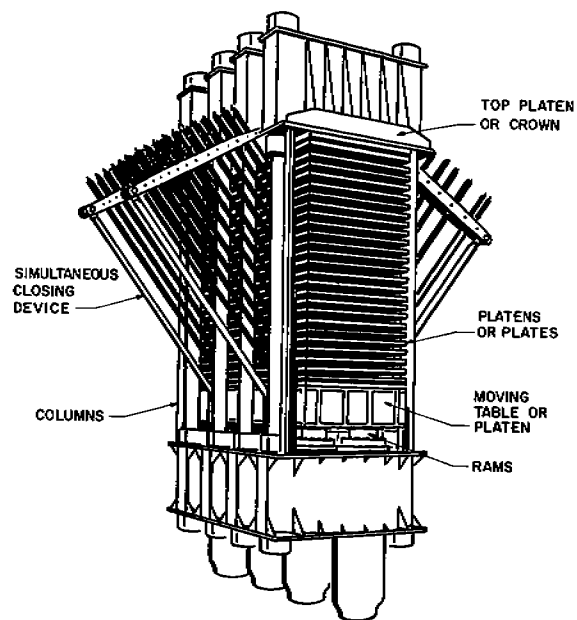


Figure 17.22. A 5x8-ft (1.52x5.48 m) hot press with simultaneous closing (Morse 1967).

Maloney (1977)

Another method of achieving fast closing is found with low-pressure accumulators which are capable of rapidly filling the main oil or water lines and raising the press at the required closing speed. The type of accumulator used on board presses is shown in Figure 17.24. It is not an accumulator in the true sense as a bladder or piston does not separate the gas and hydraulic fluid. The bottle is pressurized with compressed air for water systems. Nitrogen is used for oil systems to avoid explosion. Air or gas will be absorbed in the fluid and so refilling of the compressed air or nitrogen is required. As a simplified illustration, the pump first pumps the hydraulic fluid into the accumulator until the desired pressure is attained. For fast press closing, valves 1 and 2 (Figure 17.24) are opened, which relieves the pressure in the accumulator. The pressure built up in the bottle then rapidly forces the hydraulic fluid out of the accumulator and into the cylinder, thereby closing the press quickly. The pump then takes over, applying high pressure for final consolidation of the mat into a board. During the time pressing is taking place, the pump also recharges the accumulator with hydraulic fluid in preparation for the next press closing. Several accumulators can be used with a press, and a somewhat complicated valving system is needed.

High-pressure accumulators reduce the pump capacity required, but the direct high-pressure pump is less complicated and more reliable.

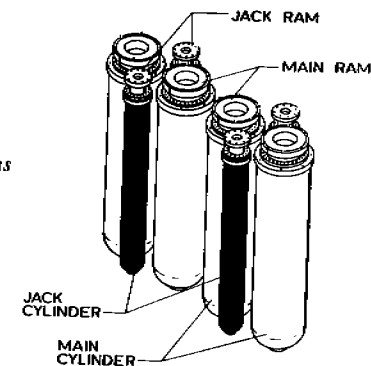


Figure 17.23. Illustration of main rams and jackrams (Morse 1967).

Hydraulic Fluids: Water can be, and is, used as the hydraulic fluid. It has long been used because large quantities can be made to flow quickly through small-diameter piping. The susceptibility of the system to corrosion has been overcome by using water softeners and additives such as soluble oil. It is low in cost and, if leaks occur, the water evaporates without leaving dirty residues. Additionally, there is not the fire hazard with water that there is with some oils.

Despite these advantages and the fact that nonflammable hydraulic oil is expensive, oil drives are now the most popular. Oil systems are capable of giving

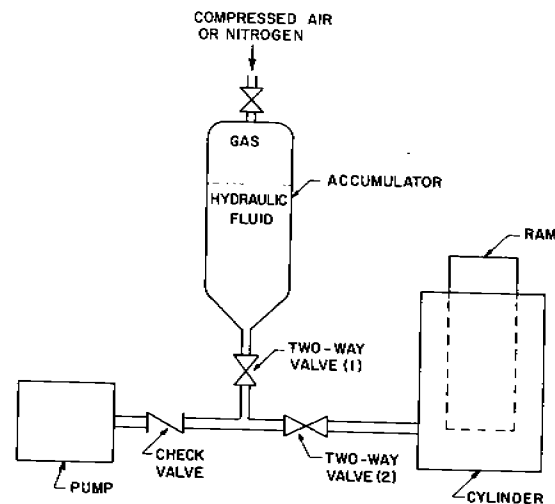
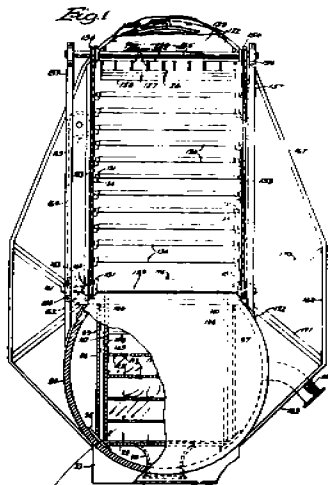


Figure 17.24. A bottle-type accumulator used in the board industry.

Figure 17.25. Design of a water hydraulic press for waferboard (Gunn 1972).



high outputs with relatively small tank and pump units compared to water hydraulic systems. Clean, acid-free machine oil used in these systems is the best preservative for metals, and its good lubricating properties minimize wear at seals and valves.

Normally, the diameter of the rams totals much less than the total surface area of the press platen. Advantage is taken of Pascal's principle that an increase in pressure at any point in a liquid results in a like increase at every other point in the liquid. Once the press has closed, it is possible for a large force exerted over a small distance (the rams) to be obtained by exerting a small force through a large distance (the pump). Thus relatively small rams in comparison to the total platen area can be used, and these are standard items. However, another approach has been taken on at least two presses. This design (Figure 17.25) has a large ram which is about the same size as the platen. At the top is a semicircular tank enclosed by the top member of the press which is pipe-connected to the lower tank holding the ram. The concept is that the pressure acting on the mats during the pressing cycle is equal and opposite at all times as the upper tank adjusts position to accommodate pressure differentials. Water is used for the hydraulic medium, and, since the ram is so large, only pressure slightly more than needed for consolidating the mat into a board on a one-to-one basis need be applied by the pump. Cost of the press is therefore claimed to be lower because of reduced costs for pumps, piping, and control valves. Furthermore, such a press is much lower in weight. Only two of this type are known to be in use in the industry.

Deflections: The press platens must be made to resist deflections under a number of cases. The deflection of the structural members of a press can never be totally eliminated, only minimized to acceptable limits. Figure 17.26 illustrates the type of deflections that can be found on hot presses. The main consideration of any press

design regarding deflection is to build into the members sufficient strength to limit the amount of deflection to certain specifications. The most common figure used is to limit the combined transverse and longitudinal deflection within the area of the hot platen size to 0.010 in. (0.25 mm) when the maximum rated pressure is applied to the largest mat size. If equal hydraulic pressure is applied to mats of smaller size, the deflection will increase as the load is distributed over a smaller area that is further away from the points of support for the platens. When mats smaller than maximum are pressed, it is possible to build up a higher than designed pressure upon the mat. Thus it is important to check and insure that such higher pressures are not applied to the smaller mat, as the press can be severely damaged.

Another cause of deflection in the press table and upper beam is the unequaled heating of these units causing more expansion in them. Cooling plates and a layer of thermal insulation material are used to minimize this deflection as shown in Figure 17.17.

Platen damage can be divided into two main types. The first is permanent bending of the platens that results from pressing to full pressure when a mat is missing from one or more openings. This applies only to presses that use thickness stops or gauge bars located at the outer edges of the hot plates as shown in Figure 17.27. Also, the narrower the mat, the more damage to the platens because the load becomes concentrated more in the center. The second type of damage is localized deformation of the surfaces caused by tramp metal such as bolts, nuts, wrenches, and so forth.

The repair of platens damaged by pressing without mats is done by using the press hydraulic system to bend the platen past its yield point in the opposite direction in order to flatten it. Perfect flatness is hard to achieve without removing the plate and having the surfaces remachined. In repairing small localized damage, the usual way is to build up the spot with welding rod and grind the excess weld off to give a smooth surface.

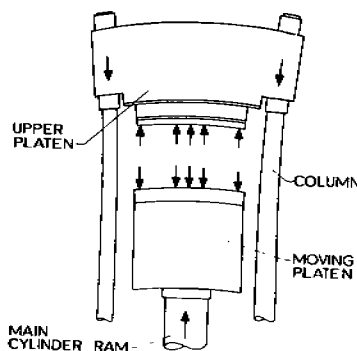


Figure 17.26. Some possible press deflections to be found on hot presses (Morse 1967).

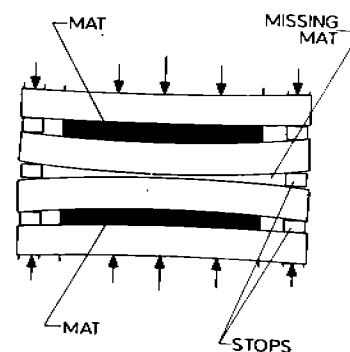


Figure 17.27. Platen deflection damage possible when a mat is missing (Morse 1967).

Proper maintenance of a press is very important, not only to prolong its useful life but to prevent major breakdowns. Periodic checks should be made by personnel who are well qualified and properly trained. These checks should locate loose bolts, improper lubrication, excess wear on parts, damaged platens, misadjustment of simultaneous closing units, hydraulic leaks, improper hydraulic cycles, and so forth.

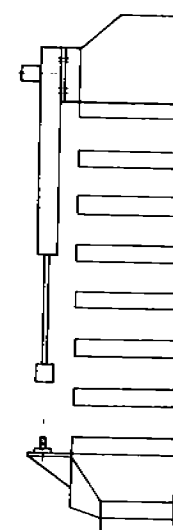
Stops: Some method of holding the press platens at the right spacing during the pressing period is necessary to insure that the finished boards are of the correct thickness. In a small laboratory-type press, this can be done in a relatively simple manner by using dial gauge indicators. However, no matter what the size of the press, uneven mat formation will make it difficult to hold the press opening at the correct or desired dimension over the entire area of the press platen.

The simplest means for controlling thickness is the placing of stops or gauge bars between the hot platens. Thus, once the platens are on position against the stops, the correct thickness of the final board is assured unless very poorly formed mats are used. In that case, there will be extreme springback in the areas of high density, and the final board will have a marked variation in thickness. Indeed, in some older presses in operation, some of the boards do come out wedge-shaped, either because of wear on the press or because the mat-formation systems are not as sophisticated as the newer ones. In operations using such stops, it is necessary to take into consideration the thickness of the caul plates being used, if cauls are used, and the amount of springback that can be expected in the board due to species, moisture, and particle geometry effects. Such stops are relatively simple to use but are subject to peening caused by pressure from the platen or from having foreign matter such as particles crushed between the stops and the platen. In a large, multi-opening press, the usual system in changing such stops is to have a number of the plant staff work together to quickly change the stops by hand; however, systems are available for automatically changing stops.

Some of the multi-opening presses use linear variable displacement transducers (LVDTs) to assist in controlling board thickness. The LVDT is used to generate a voltage signal in a secondary winding in proportion to the displacement of its core from center. This signal is used as a command to an electrohydraulic servo control. This control system adjusts the variable-volume hydraulic pumps so that just enough pressure is maintained in the hot press to keep the press on the stops; or if position control is being used (as will be discussed later), the platens maintain the proper opening for producing the boards desired. In the case of multi-opening presses using stops, this control is set for the entire package of boards. Figure 17.28 illustrates this type of control. Thus, when all the platens are set upon their stops, the LVDT will be in contact with a preset gauge bar. If the LVDT moves away from its contact point, a command will be sent to the pumps to supply more oil to the hydraulic cylinders until the LVDT is back in its proper position. Less pressure is needed at the ending of a press cycle because the resin is curing out in the board and holding it in its consolidated position. The LVDT system, therefore, automatically compensates for the need for less pressure at the end of the press time.

With the stop system used in multi-opening presses, extra space is needed to accommodate the stops. As a consequence, many tons of extra weight can be

Figure 17.28. Schematic drawing of an electronic position sensor (Strisch and van Hüllen 1969).



added to the press for the stop systems. Stops can also prevent proper venting of the steam or vapor coming from the edges of the boards being pressed. If the hydraulic system goes out of control, the stops between platens can cause severe deflection and possible damage to the platens.

Thus, it is of advantage in some cases to be able to press without stops, particularly with multi-opening presses. One such system utilizes what is called *four-point control*. It is necessary that the press table at the bottom of the hot press be held in a perfectly horizontal position during the closing process to avoid horizontal movement of the heating platens. A table rod guide is used by one company to accomplish this, and these guides insure parallel position of the pressing table and the head or crown of the press. The rods are fixed at the table and guided by the head and are made rigid enough to keep the table horizontal should it try to move to an inclined position. The rod is also resilient enough to yield to abnormal pressure, as illustrated in Figure 17.29. The table is measured at all four corners by electronic position sensors, such as shown in Figure 17.28. The values determined electrically are simultaneously transmitted to the hydraulic control of the press. The four corners of the press are guided by the four-point control acting on four independent hydraulic cylinder systems. These four hydraulic systems have their own decompression and compression valves and prefilling. All systems work jointly during the closing process until they reach their preselected nominal positions. At that point, a changeover takes place, and the individual systems operate independently and hold their positions in accordance with the individual electronic signals. Such pressing is not possible without precision in forming the mats.

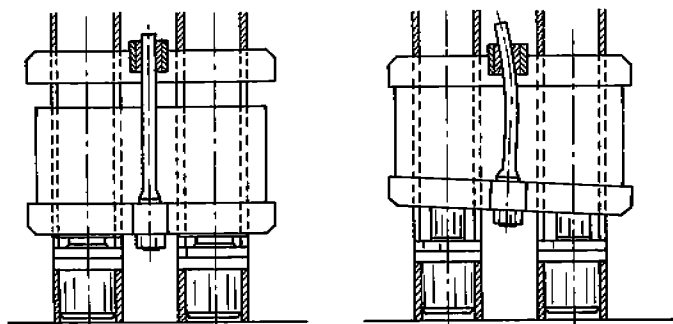


Figure 17.29. A schematic drawing of the action of the table rod guides (Strisch and van Hüllen 1969).

With single-opening presses, the use of stops has been popular, although position control is also in use. One system places the stops about 5 ft (1.52 m) on center on both sides of the press, but about 10 in. (254 mm) above the surfaces of the hot plates when the press is closed. Thus, they are not contaminated by blown-out particles from the mat and finished board. It is also possible to change the stops quickly, as they are readily accessible. Some feel that the thermal deflection of the top and bottom of the single-opening press is of such magnitude that thermal deflection takes place in spite of the best precautionary measures. While these variations are not of too great significance with multi-opening presses, they are magnified on single-opening press lines. Thus there is the possibility of major variations in the final board thickness.

One company uses spacer plates mounted on swiveling devices so they can be swung in between the table and head of the single-opening press outside of the actual area of the heating platen. These spacer plates, as with the previously mentioned system using gauge bars, do not lie on the pressing area. The swivel device makes it possible to change stops quickly.

However, a newer design has replaced the stop systems with a hydraulic thickness-control system. In this single-opening press, the press cylinders are controlled individually by direct-acting valves giving the desired thickness over the entire board area, irrespective of normal variations in the mat itself. The position valves control the hydraulic pressure in the cylinders so that the back pressure of the mat at the respective cylinder location is counterbalanced to give the correct thickness of the board. In areas of the mat where it has been evenly formed and has the desired moisture content, the thickness is achieved at the prescribed point in a press cycle; and pressure reduction commences. In areas of the mat which are unevenly formed or the moisture content is out of control, the hydraulic pressure required for proper consolidation is maintained for either a shorter or longer period until the desired board thickness has been achieved.

Steel stops cannot be used between platens when high-frequency heat is used. Special plastic stops or position control must be utilized.

Multi-Opening Presses

Sophisticated loaders for multi-opening presses have been discussed previously under prepressing. Some simply push the caul plate holding the mat into the hot press. Other systems used for caulless production lines deposit the prepressed mat directly on the hot platens by means of belt systems. For the Flexoplan system, a press loader can either carry the wire mesh screens holding the formed mats into the press, where the bars at the leading edge of the wire are engaged by a holding device after which the press loader is withdrawn from the press; or preferably a chain system engages the bars at the leading edge of the wire-mesh screen and pulls the entire assembly into the hot press.

It is imperative to use simultaneous closing with a multi-opening hot press with many openings. The early board presses were adapted from the plywood industry, where simultaneous closing is not needed. With this system, the bottom opening was closed before the top opening and the problems with variation in density profile occurred. Simultaneous closing devices have made it possible to close each opening or "daylight" at the same speed as any other. Thus the density profiles of each board are identical. In addition, simultaneous closing makes it possible to close the press far faster than previously. In one example, a 24-opening press with simultaneous closing will have the rams traveling at about 400 in. (10.2 m) per minute. However, this translates into about 17 in. (432 mm) per minute per opening. This type of operation enables modern multi-opening presses to close to final position within about 30 seconds for boards $\frac{5}{8}$ to $\frac{3}{4}$ in. (15.9–19 mm) thick. At first glance, it would seem that the simultaneous closing would not be necessary if the press would indeed close at 400 in. per minute. However, this rapid closing sets up tremendous wind forces around the mat because of the air being exhausted from the press openings. These forces would be so severe that the entire mat would be disrupted, making it impossible to press boards of any quality.

Figures 17.30 and 17.31 illustrate one approach for providing simultaneous closing. Figure 17.32 shows that not every opening has to be equipped with simultaneous closing but that they can be closed in pairs. Figure 17.33 illustrates

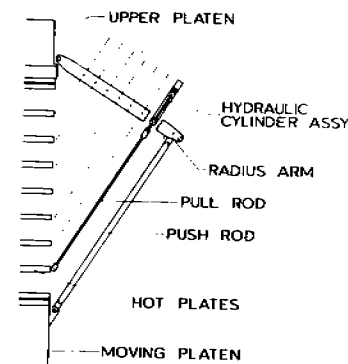


Figure 17.30. A simultaneous closing system (Morse 1967).

the comparison between an open and closed press equipped with simultaneous closing. Simultaneous closing is not used with some presses with a few openings because of well-prepressed mats or the type of furnish used.

The press unloaders are simply receiving elevators that take the finished boards and bring them to the level of the board finishing line (Figure 17.34). Boards can be pushed into the unloader by the nosepiece of the press loader. One system uses drive rolls located at the lead end of the unloader to remove the boards from the press once the unloader pushes them far enough out of the press for the rolls to engage. This enables the use of compressed air for blowing loose particles out of the press before the next press load is inserted.

Another system used with cauls has a draw-out beam which grips special notches in the lead end of the caul plates and pulls the cauls and boards out of the press into the unloader. The unloader itself can be equipped with belts or idler wheels to facilitate unloading.

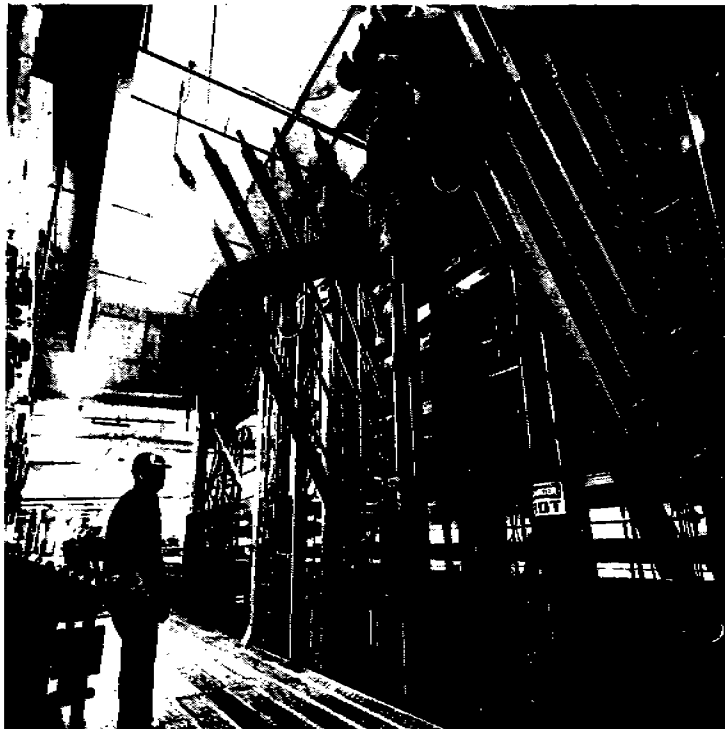


Figure 17.31. Simultaneous closing arrangement on a multi-opening press. (Courtesy Washington Iron Works.)

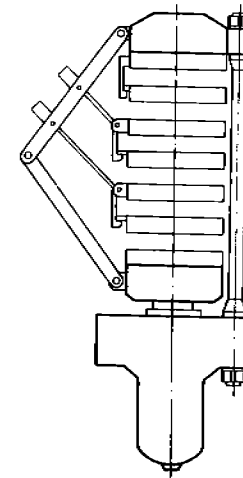


Figure 17.32. A simultaneous closing system for every two openings. (Courtesy AB Motalla Verkstad.)

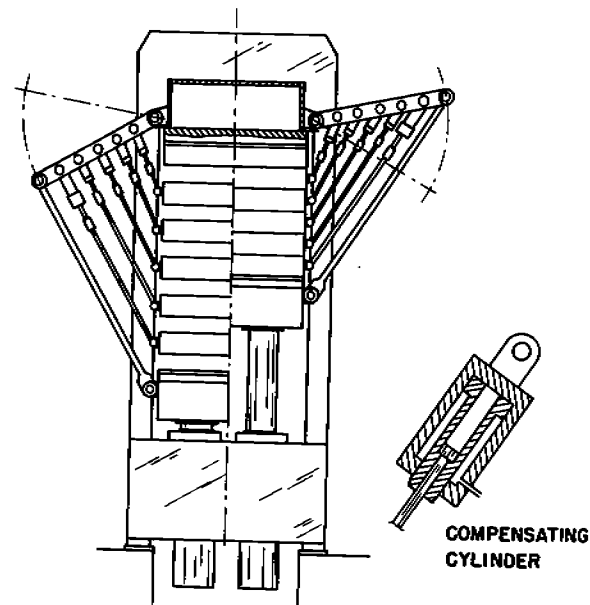


Figure 17.33. A simultaneous closing device for hydraulic presses (Strisch and van Hüllen 1969).

Because of the tremendous heat generated in a multi-opening press, heat shields are used to insulate the press loader and the mats it contains and the finished boards in the unloader from the press. These are simply large sheets of metal that are rolled into the space between the loader and unloader and the press during the pressing time. Such shields can also be used on the outfeed side of the press. Their main purpose is to keep the boards from "floating" out of the press when the press is opened. The vapor venting through the bottom face of the boards provides an air cushion on which the boards can easily move out of the press into the unloading elevator due to the forces of gravity. Unfortunately, the boards may enter the elevator improperly and jam the mechanism.

In the caul and caulless systems used with multi-opening presses, loose particles fall from the mats being inserted into the press or drop off the edges of finished boards being removed from the press. These particles can be between the stops (if they are used), and the press between the caul plate and the press platen, or between the surface of a freshly deposited mat and the press platen in the caulless system. All of these occurrences are troublesome. In presses using cauls, compressed air released through a manifold system can be used to blow these particles out of the press. In caulless systems, compressed air for blowing these particles out can be released through the nosebar of the press loader trays as they pass through the press openings carrying the new mats into position for deposition upon the press platens.

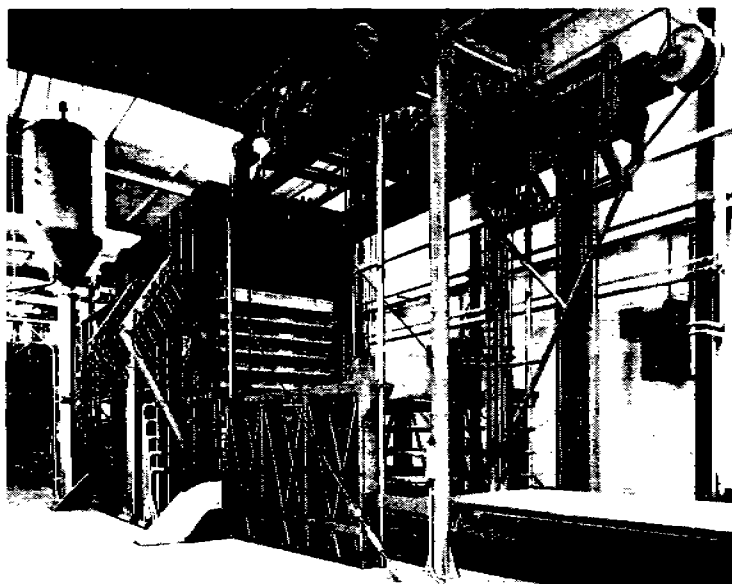
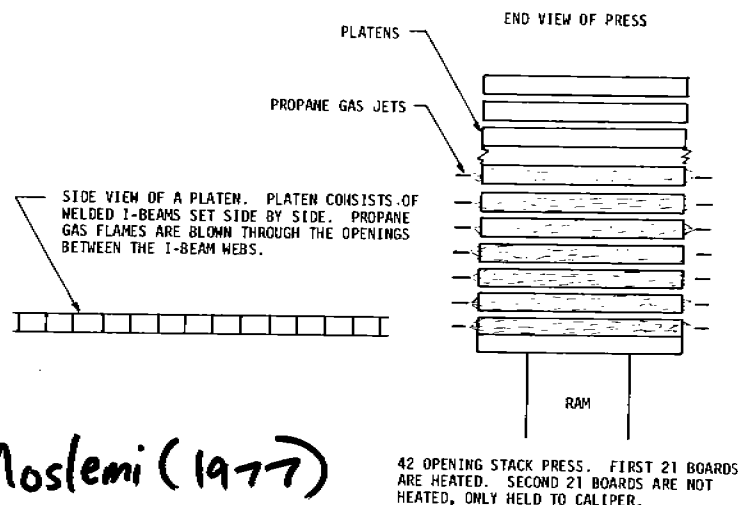


Figure 17.34. A Flexoplan press and unloader (Strisch and van Hüllen 1969).



Moslemi (1977)

Figure 17.35. Schematic drawing of the Chapwood stack press installed at the Philomath, Oregon, plant (now out of business).

Stack Presses

A particularly interesting press that has been used for many years in the industry is a stack press as shown in Figure 17.35. The concept is illustrated in a 42-opening press as described in the following paragraphs.

The particular board is made with wet-lap fiber faces and a shavings core. Drying and pressing of the board takes place simultaneously. The formed mat on a caul plate is first placed on a *platen* as illustrated in Figure 17.35 and the entire package is inserted into the bottom of the press. Then the ram drives the package upwards until it is held in place by catches or dogs. At that time all of the 41 packages of platens, caul plates, and boards above are resting on the newly inserted mat. This dead weight supplies the pressing pressure, although the total weight can be adjusted by using dogs for each platen. As one package is inserted into the bottom of the press, another is taken off of the top and brought down to floor level by means of an elevator.

A temperature of more than 400°F (204°C) is held throughout the first half of the cycle. The heat is introduced in a unique way by means of gas jets, set in manifolds along the sides of the press, that blow flames through the entire width of the platens. The platens themselves are made of I beams welded side by side. The gas flames go through the openings between the I-beam web. One-half the jets operate from one side and one-half from the opposite side of the press. No heat is applied in the upper half of the press. The final board is quite dry at the time it leaves the press.

Single-Opening Presses

Multi-opening presses have been the most popular for board pressing because of their high productivity. Increased production can be had by increasing the number of openings in the press. This also allows for some flexibility in production, such as increasing press time without a great loss in production. The larger presses, however, require sophisticated loading systems such as a preloader for the press loader in order to have sufficient mats ready for injection into the press. The forming line also has to run at a high speed in order to lay down a sufficient number of mats. Such speed lends itself to poorly formed mats. In such cases, it is advisable to determine whether two press lines are advisable. The addition of a single-opening line can provide the extra capacity that is needed for quality board manufacture.

Because of their massive size (one company offers presses 8 ft 9 in. wide up to 100 ft long (2.67x30.48 m), metal caul plates are not used in single-opening presses. The tremendous expansion and contraction of such large pieces of metal plus the difficulty in handling them, along with the massive caul return lines that would be required, make them uneconomical. The single-opening presses use either thin, steel belts or woven wire mesh for the carrier system.

① For those presses using the thin, steel belts, two variations are available. In the first one, the belt extends under a form station through the prepress (if one is used), through the hot press, and back around beneath these stations on the production line to the head of the form station. The mat is formed by a traveling former, which is unlike the conventional multi-opening system. While one mat is being consolidated into a board in the hot press, the traveling form station lays down a new mat upon the section of the steel belt beneath it. In this type of system, the mat forming is therefore discontinuous. When the press opens after consolidating the board, the steel belt moves forward, ejecting the finished board and moving the freshly formed mat into the hot press.

A platen-type heated prepress is now used with some of the single-opening operations. The advantage of such prepressing is that the press time is significantly reduced. In the normal single-opening press line, without the prepress, a certain dead time is required for heating up the bottom steel belt when it carries a fresh mat into the press. The top platen should not be brought in contact with the mat surface until this heating is accomplished. Now, by controlling the bottom platen temperature in the prepress at a different level than the top platen, this dead time can be eliminated. To further balance the application of heat in this system, a top rotating steel belt is used in the press itself. This belt is three times the length of the press and moves one length at a time in sequence with the movement of the bottom steel belt as it removes the finished board from the press and moves a new mat into the press. The bottom of a mat inserted into a press has heat applied to it immediately. In this press it is also possible to have different heat levels in the top and bottom press platens for applying the heat in a precisely balanced manner to the mat undergoing consolidation into a board, resulting in a perfectly symmetrical density profile in the board. One of these press lines is shown in Figure 17.36.

② The second type of single-opening press line, as shown in Figure 17.37, utilizes three different belts in the forming and press line. The mat is first formed upon a

wide belt conveyor using a stationary former. The mat then passes through a meter detector and a 600-lb/linear-in. (10.7 kg/linear mm) continuous prepress to a cutoff saw at the end of the forming conveyor. There the mat is transferred to a second wide belt conveyor. When the length of mat transferred to the second conveyor corresponds to the press length, a cutoff saw is activated and trims off a section of the continuously formed mat. The cutoff mat is then accelerated ahead and transferred to the steel belt conveyor that runs through the hot press. The steel belt carries the mat into the press and positions it for final pressing, as with the system utilizing a continuous belt throughout the entire system. After pressing, the board is moved out onto a roller conveyor by the steel belts, while another mat is simultaneously being carried into the press.

Prepresses were initially installed to allow for a faster closing of the hot press without blowing off the top surface layer of the mat; however, they were found to have other advantages. It has been found that the prepressed mat has less resistance to compression in the hot press. Thus, as soon as the press platens touch the mats, it is possible to build up the pressure much faster. It is also claimed that the prepressed board, as such, ends up with a better internal bond with this system of pressing, because the mat is compressed to thickness quickly and the high-temperature platens provide heat rapidly to the board core, resulting in a density profile that is relatively even throughout the board cross section as compared to boards pressed at lower temperatures.

The advantages of keeping the steel belt that passes through the hot press warm is twofold: less time is needed in the hot press to cure the board, since the steel belt is already partially hot, and the thermal stresses in the steel belt that occur during the hot pressing are reduced. In extreme cases, the belt itself can be folded if some part of the mat was formed too thin by accident.

The use of a heated prepress has already been mentioned. Another technique for speeding press curing is to heat the mat by means of a high-frequency-heated

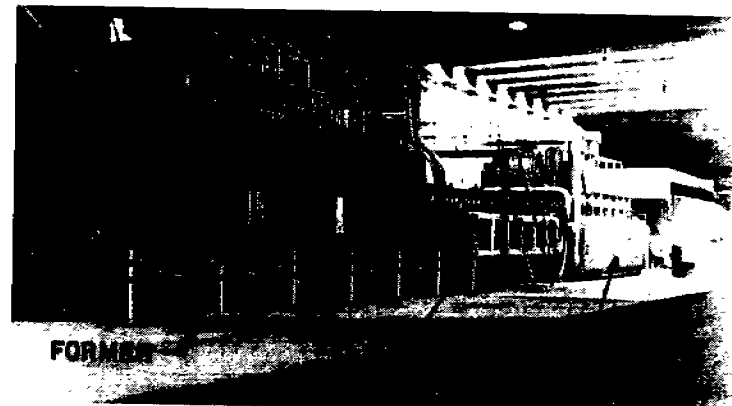


Figure 17.36. A single-opening press line with a heated prepress (Bucking 1974).

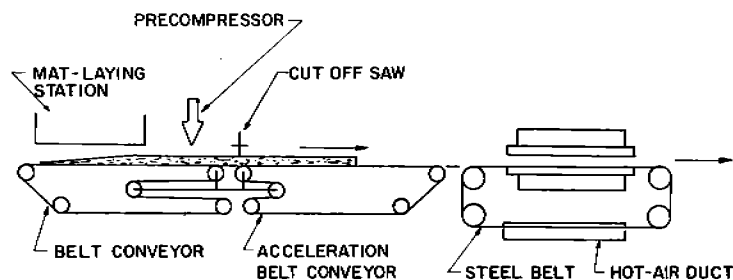


Figure 17.37. Three-belt feeding system for the single-opening press line (Carlsson 1973).

tunnel (Figure 17.38). This type of heating has been used for many years in the continuous Bartrev pressing system. It is now being introduced with single-opening press lines for heating the prepressed mat from approximately 80° to 160°F (27°–71°C). Thus, the required temperature increase in the board core to 212°F (100°C) is reduced to about 50°F (10°C) from 160°F (71°C).

The total length of this type of single-opening line is greater, as the preheater takes up about the same amount of space as the press. Conversely, the installed high-frequency power is less, as compared to using high frequency in the press, as the preheater is working continuously at a lower level and not intermittently at a higher level as it does in an RF-heated hot press. In addition, the shielding to prevent the electromagnetic radiation is less complicated and less expensive in the preheater. It is reported that a mat for conventional board about 5/8-in. (15.9 mm) thick, preheated to 160°F (71°C) requires about 50 seconds less time in the hot press than a mat that enters the press at room temperature. Since, in the single-opening press lines, preheated mats go into the press soon after preheating, such preheating should not cause problems with advancing the resin cure, as might be expected with multi-opening press lines where a number of mats are accumulated before they are inserted into the press.

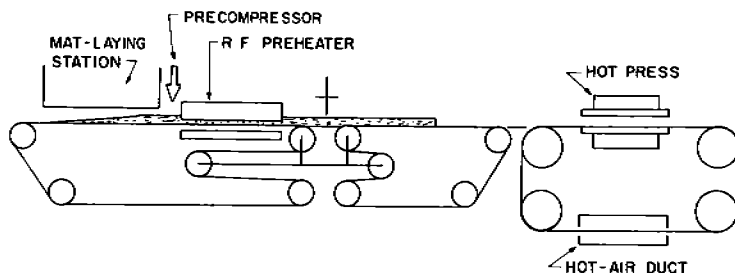


Figure 17.38. RF preheater installed on the press line (Carlsson 1973).

Single-opening press lines at present can produce up to 250 tons (227 mt) of 5/8-in.-thick (15.9 mm) board per day. Further improvements are expected to increase the production to about 350 tons (318 mt) a day. By using the preheating system, it is anticipated that capacities of upwards of 500 tons (454 mt) a day may be reached within a few years.

3 A third type of single-opening system uses the aforementioned woven wire mesh. This, in actuality, is a discontinuous pressing system that produces an endless board. It uses the same type of wire-mesh cloth as the Flexoplan system. This particular wire cloth has a good dimensional stability, with a maximum thickness variation of 0.004 in. (0.10 mm) over the full dimensions of the belt in use. Damage to this type of belt can usually be rectified easily within the production plant, whereas damage to the thin, steel belts used in other systems may be more difficult to repair. The wire cloth, however, has to be in perfect condition over its full length as it does not index to a given point each cycle. The steel belt is in sections and does index to a given point; so if damage occurs in an area, only the one-length section of the press size where the damage occurred need be replaced, instead of the whole belt. This type of metal cloth adapts itself to the temperatures and high pressures encountered in the hot press without developing particularly high stresses within itself.

In this system, the forming station is mobile and moves back and forth, forming the mat on the mesh cloth. The cloth carries the mat into the press and returns to the head of the forming station beneath the press and forming line after the board is pressed. Since the mat is not precut before it enters the hot press, the hot press itself has a special design to prevent precuring of the mat at the entry of the press. It is also necessary to have this hot press designed in such a way that the endless mat is not fractured at the juncture between the loosely spread mat and the finished board. A smooth transition from the mat to the finished board is produced by a combination of two techniques, as shown in Figure 17.39. In this figure, it is

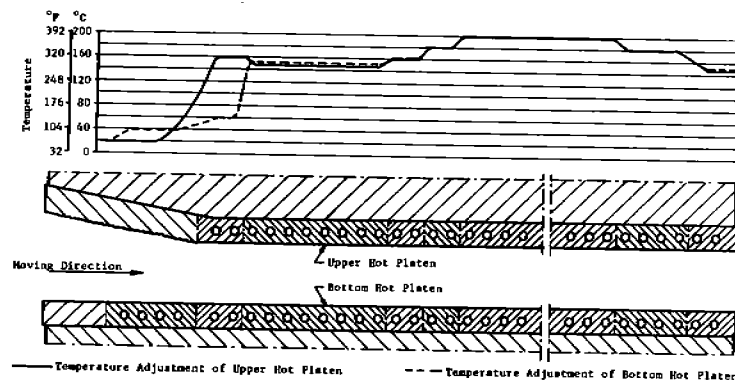


Figure 17.39. Diagram showing temperature adjustment of platens and wedge-shaped opening at the feed end of the press (Strisch and van Hüllen 1969).

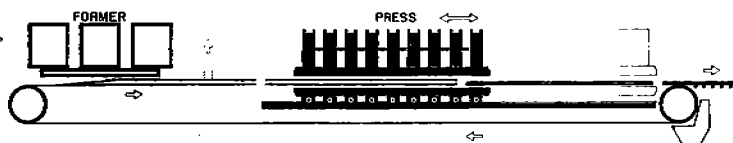


Figure 17.40. Moving single-opening press. (Courtesy Raute, Inc.)

shown that the temperatures in the hot press are not applied uniformly over the whole length of the heating platen, but that the temperatures are stepped down at the inlet and at the outlet of the hot press. The temperatures in the top and bottom platen are held at about the same level from one end to the other. The mat is stepped through the press in such a way that the part pressed first in the inlet zone of transition has final pressing accomplished in the outlet zone of transition. Thus, the mat is pressed twice in the zones of transition and with reduced temperature, which reportedly gives, in the end, the same quality of board as that pressed in the main temperature zone. At the inlet of the press, the temperature is slowly reduced in the critical stage below a temperature of 212°F (100°C); since at that temperature the resin is curing out, particularly in the case of urea, but final curing is not effected.

Another special feature of this press is that the top platen is not pressed perpendicularly on the mat at the infeed end of the press, but presses down in the shape of a wedge, as shown in Figure 17.39. To avoid shifting of the different layers of the mat with accompanying tearing, this wedge has a wavy surface on its bottom, where it contacts the top of the mat.

A fourth type of single-opening press developed in Finland is quite interesting in that the press moves back and forth, as illustrated in Figure 17.40. The mat is formed upon a continuous closed-mesh wire belt which moves at a constant speed. A section of the formed mat corresponding to the press length is next separated by a traveling cutoff saw. As soon as the mat is in the press, the press closes and consolidates the mat while traveling forward at the same speed as the wire belt. As soon as pressing is completed, the press opens and travels rapidly back toward the former as the next mat enters the press.

Continuous Pressing

Continuous presses have always captured the imagination of those in the industry. With continuous pressing, there is no need for handling much of the production line with batch processes. Quick acceleration of mats down forming lines, followed by deceleration as they are loaded either into press loaders or presses, is not needed. The discontinuous method has called for extensive and sophisticated engineering to overcome all of its problems. However, continuous pressing has its own problems, which have prevented its widespread use, except in manufacturing thin board.

Continuous presses for laminated lumber products, plywood, and composition board have been proposed and patented for at least 50 years. Conceptual feasibility, technical feasibility, and commercial feasibility are all interrelated. The

economics of making a profit with the system is the governing factor, determining whether a continuous pressing system can indeed be successful.

Almost every conceivable type of pressure backing—including direct steam pressure, direct fluid pressure, direct air pressure, rollers, circulating bearing balls, double bands, caterpillar sections, friction sections, nip rolls and combinations thereof—has been patented for continuous-band-type presses.

The first continuous press actually used in production was the Bartrev, which was developed in the United Kingdom over 25 years ago. This particular system produces 50-in.-wide (1.27 m) particleboard at standard thicknesses. A typical production press is shown schematically in Figure 17.41. The press itself, shown in Figure 17.42, is a massive piece of equipment. As the mat enters the press, it is first heated by high frequency which shortens the time necessary for complete curing of the resin in the press. Stainless steel bands run over the caterpillar backing track. The caterpillar tracks are heated by gas panels and the track links store the heat for use in curing the board.

In each one of the track links are special high-pressure bearings, which call for frequent greasing. There are also special high-pressure, heat-resistant roller bearings running on the guide rail inside the press, as shown in Figure 17.43. It is immediately apparent that the large number of bearings require an enormous amount of maintenance, and this was felt to be one of the difficulties with the original system. A few of these systems were built and some are still in operation. One has been particularly successful in Sweden and the maintenance cost has been much lower than anticipated. However, its use has not become widespread.

Recently a modernized version of this type of continuous pressing has been developed, using the caterpillar-type tread or lug prepress. The first system of this type is now in operation in the Federal Republic of Germany. Figure 17.44 is a drawing of this recent development.

In the 45-ft-long (13.7 m) press, the thin, steel belts go through the press at the same speed as the segmented platens. Indeed, the steel belt runs free except

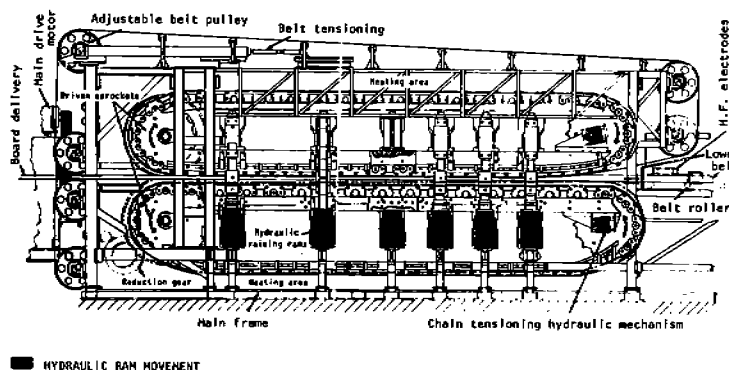


Figure 17.41. A Bartrev press 50 in. (1.27 m) wide (Knapp 1973).

where it is necessary to run the lower belt around a pulley to provide for transferring the mat as received from the former. Thus the platens and belts are not dragging against each other. The drive rolls are the small ones inside the press, which also control the board caliper. This contrasts with the large drive sprockets at the outfeed end of the Bartrev.

Both single- and multi-opening platen presses are unproductive during the loading-unloading-closing-opening part of the press cycle. This unproductive time becomes critical when pressing thin boards. In a large multi-platen press with 20 to 30 openings, experience has shown that a minimum of three minutes is required for charging, closing, opening and discharging the press. Since a thin board can be cured in less than a minute, a fraction of the total press cycle that a multi-platen press is unproductive becomes prohibitively large when producing thin boards.

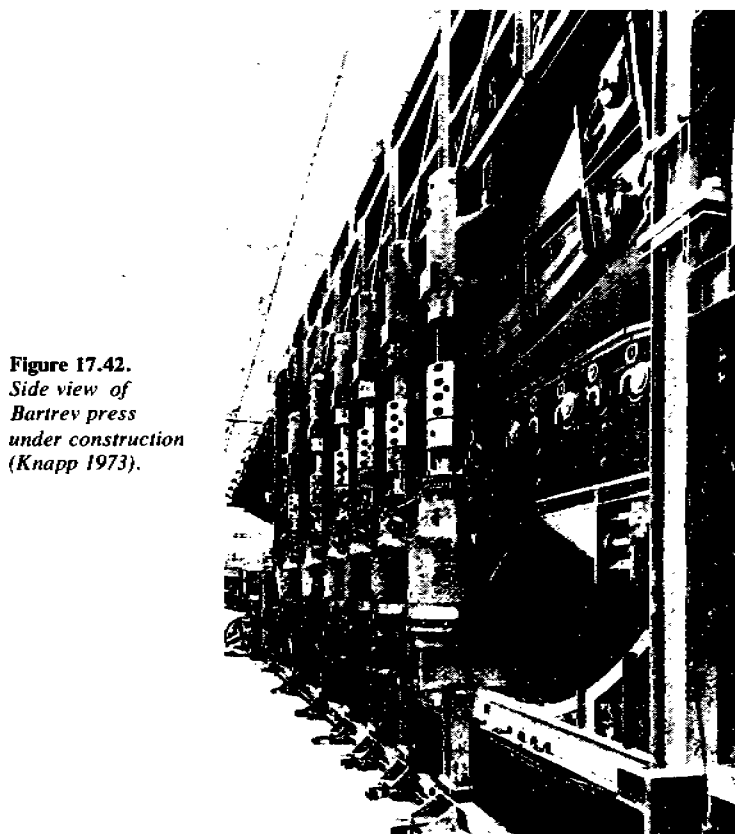
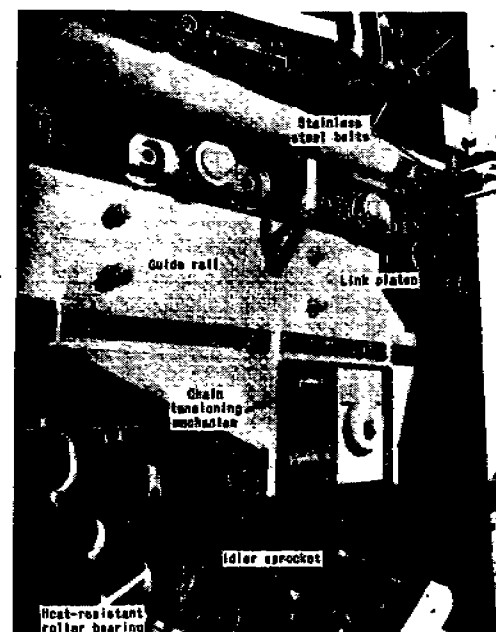


Figure 17.42. Side view of Bartrev press under construction (Knapp 1973).

Figure 17.43. A view of the track or chain-tightening mechanism (Knapp 1973).



This has been the impetus for developing the continuous thin board presses now in use in industry plants.

About 50 of the Mende type are now in operation. It is an outgrowth of a press developed initially for the continuous curing of rubber sheeting or laminating thermoplastic films. Other versions are also undergoing development with one ready now for the market.

Their capacity ranges up to about $\frac{1}{4}$ in. (6.4 mm) in thickness with widths between 4 and 8 ft (1.22 and 2.44 m). Line speeds can vary from 15 to 90 ft (4.6–27 m) per minute depending on board thickness. Resin levels can range from 5 to 12% depending upon the particle geometry and the board properties desired. When using particulate-type furnish, board densities of about 46 lbs/ft³ (0.74 sp gr) have been the maximum. However, experience now with pressure-refined fiber is showing that the easier-to-compress fiber allows compression of boards into final densities of about 55 lbs/ft³ (0.88 sp gr). It appears quite likely that boards made of fiber at these higher densities will meet minimum specifications for hardboard. Particle geometry is still an overriding factor in developing good bending and stiffness properties in composition board. Thus, the fibrous material enables the production of higher-strength boards; whereas the particulate-type furnish, such as planer shavings, results in boards with much lower bending and stiffness properties. As mentioned, it has not been possible to make higher-density boards out of

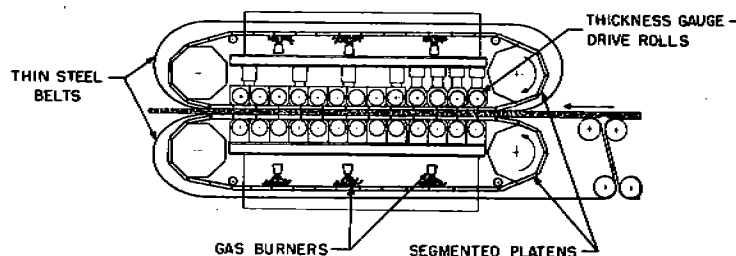


Figure 17.44. Continuous press employing gas flame to heat pressing treads. Note high-pressure section at entrance of press (Wentworth 1975).

Maloney (1977)

the shavings-type furnish in this system. Thus, density cannot be used to compensate for the lower physical properties of these boards. In some countries using flakes as part of the furnish, board properties intermediate between the shavings-type boards made in parts of the United States and the fiber-type boards are found.

The Mende press is shown in Figures 17.45 and 17.46. First there is a 10-ft-diameter (3.05 m) heated press drum and a heated pressure roll at the infeed, which holds the steel belt at a given distance from the press drum and establishes the caliper or thickness of the board. In essence, this roll operates as a nip roll. Calibrating rolls further along in the pressing section hold the steel belt at the proper distance from the heated press drum. The finished board passes out either back over the forming station (which is usual) or over the top of the press station itself. Infrared heaters are placed within the press assembly to assist in maintaining the press temperature on the outer side of the continuous belt.

A high-grade Swedish steel belt is normally used in this press; however, a stainless steel belt has been used recently with success. Belts can be changed in 24 hours. A length of new belt is first fed through the machine and then the two ends are welded in place. Wide belts such as needed for 8-ft (2.44 m) board must be welded together out of two narrower bands of steel at present because of the unavailability of wider material.

The 10-ft-diameter (3.05 m) press drum and the calibrating rolls are crowned. In initial designs, some problems were observed with boards thicker in the center

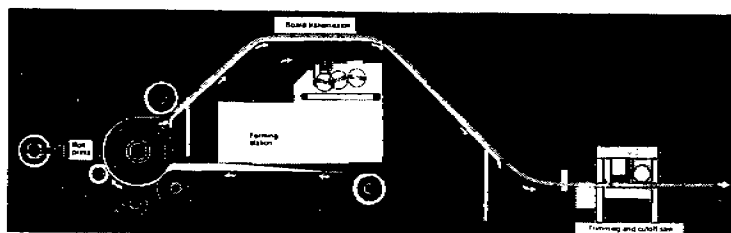


Figure 17.45. Schematic drawing of a Mende press. (Courtesy Bison-Werke.)

Maloney (1977)

than at the edges. By crowning the rolls (the infeed pressure roll is not crowned), this problem has been overcome.

As can be readily seen, the hot board leaving the press experiences a severe curvature. However, when all things are equalized and carefully controlled in the production process, it is possible to end up with flat board. The board is cut to length and trimmed to width within a short time after leaving the press. Thus, the final set of the hot board takes place in the flat position.

The heating medium for the drum in the system can be either hot water, hot oil, or steam. The manufacturer is suggesting that hot oil be used to provide the greatest flexibility in temperature adjustment for manufacturing either interior- or exterior-type products and to eliminate the boiler.

At the present time, the system is being refined to overlay the board simultaneously with thin plastic sheets. This will eliminate a separate step for doing such overlaying.

The other continuous-band-type press now ready for production application consists of two horizontal steel belts, which are arranged in close proximity for pressing the mat into the final thin board in the flat position. A drawing of this press is shown in Figure 17.47. A particle or fiber mat is fed continuously between these two steel belts and the initial rolls serve to nip or press the mat to its final caliper. A pressure of 2000 to 3000 lbs/linear in. of roll width (35.8–53.7 kg/linear mm) is maintained. The nip rolls compress the mat to a thickness which is within about 25% of the final thickness of the board. Initially, experimentation showed that the mat could be overcompressed so that it was thinner than desired.

The final compression is achieved by having the two steel belts and the compressed mat passed between two heated horizontal steel platens, as shown in Figure 17.48. This figure shows the basic concept of the press, in which the horizontal flow of the mat passes through the nip roll section for calipering and then into the holding section, which is 36 ft (11 m) long. The holding section consists of four subsections, the first two of which are 6 ft (1.83 m) long and the second two of which are 12 ft (3.66 m) long. Each one of these sections is heated.

in use?

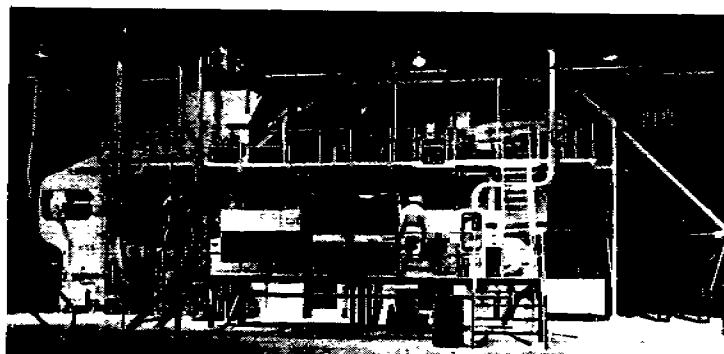


Figure 17.46. A continuous Mende press in operation. (Courtesy Bison-Werke.)

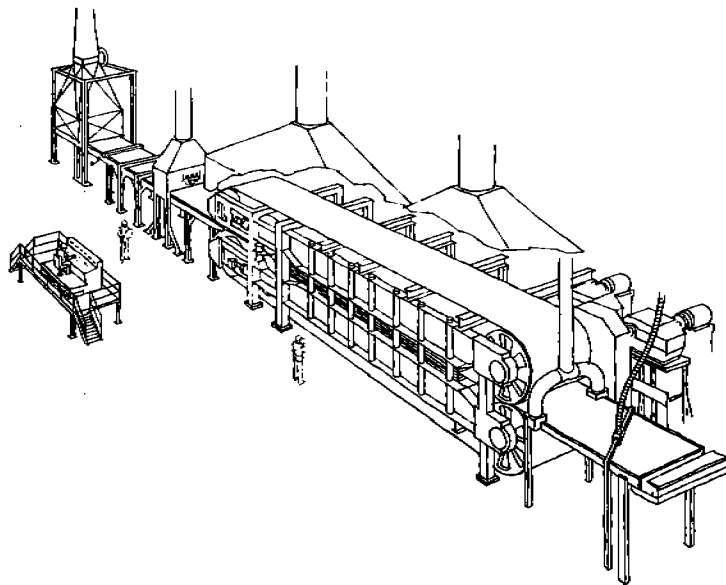


Figure 17.47. Continuous band hot press (Johnson and Martin 1975).

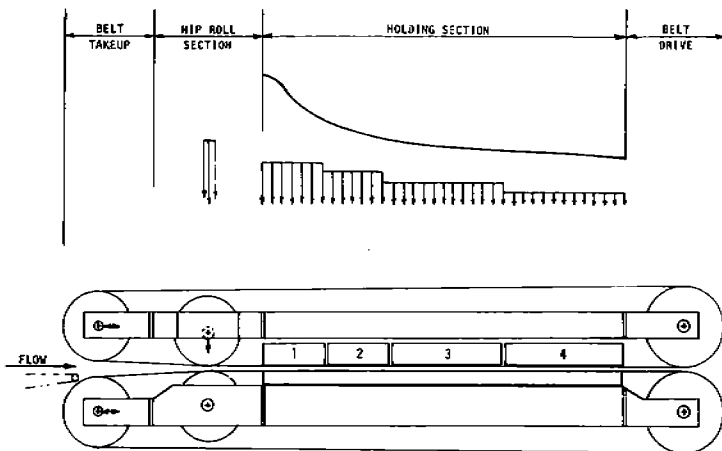


Figure 17.48. Continuous pressing concept (Johnson and Martin 1975).

The pressure to maintain board thickness does not exceed 100 lbs/in.² (689 kPa) on the mat. Depending on board thickness and resin, as well as press temperature, the resin sets in between 15 and 50 seconds.

It has been found that the preferred temperature ranges between 300° and 390°F (150–200°C), as the effective conditions of dynamic rolling are best within this press temperature range. The temperature and moisture conditions used in the high-pressure dynamic rolling operation are for the purpose of causing the plastic flow and compression of the fibers to take place without setting up or curing the resin to any appreciable extent. The fibers are compressed quickly and continuously to the required density and thickness. It has been found that the holding section of a press provides the cure at a relatively low pressure of about 50 psi (345 kPa) and at a press temperature of 350°F (176°C).

Figure 17.49 shows a pilot plant model and Figure 17.50 shows a cross section of the holding section of this press. The section works against a stop beam to guarantee the thickness of the final board, although it is felt that this may not be necessary. On the top of the stop itself is a cooling plate and then a course of insulation between the cooling plate and the hot plate. The antifriction shoes are located between the hot plate and the steel belt which runs on top of the shoes. The upper belt is separated from the upper hot plate by another layer of antifriction shoes. Another course of insulation separates this hot plate from a cooling plate and the pressure section. The antifriction shoes consist of a metal backing plate with an antifriction material applied to the top of it. This is a dry lubricant which has the proper coefficient of friction for correct operation of the continuous press. However, in experimentation to date there has been shown a tendency for the shoe surface to glaze over, because of contamination. This problem has been eliminated by the introduction of a small amount of liquid lubricant for the purpose of purging the shoes and keeping them clean.

Continuous band

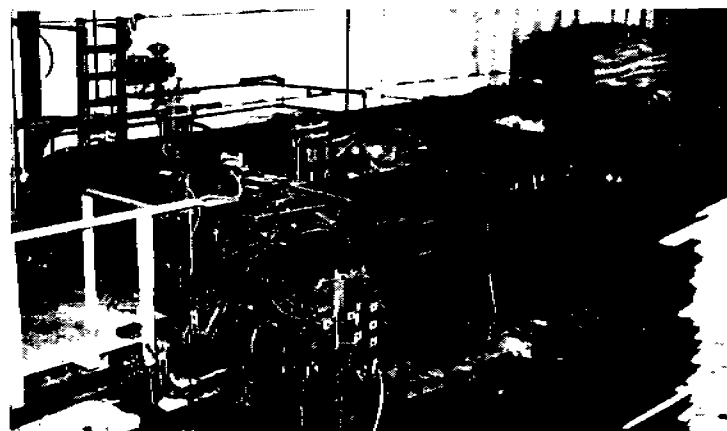


Figure 17.49. Pilot plant model of continuous band press (Raddin and Wood 1973).

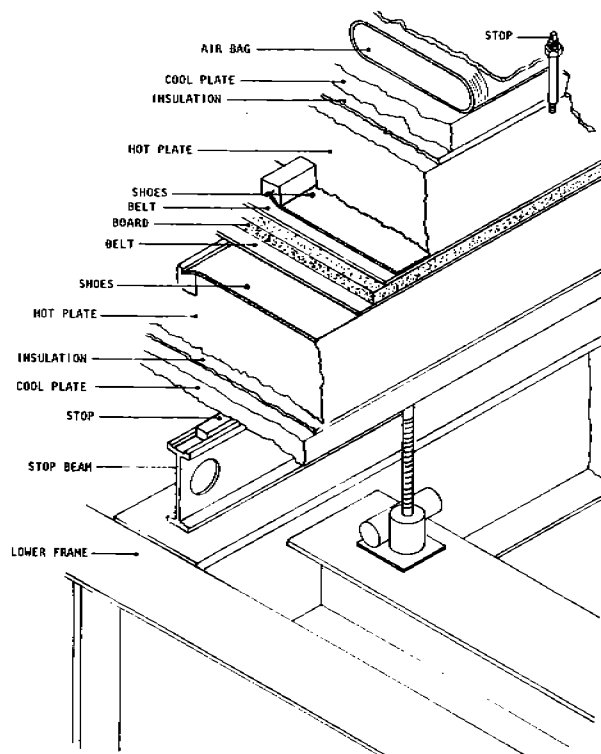


Figure 17.50. Cross section of holding section (Johnson and Martin 1975).

With any type of belt press, there are a number of problems of maintenance. A system has been devised for changing both belts in an eight-hour period on this particular press. Experimentation has also determined a belt that has the necessary properties to withstand the stress required of it as it is wrapped around the driving drum and pulled through the pressure section. All calculations show that the belt has sufficient yield strength and fatigue resistance to operate for a long time without a need for changing.

The initial press is to produce a 4-ft-wide (1.22 m) panel. This press is designed for producing 100 tons (91 mt) of 1/8-in.-thick (3.2 mm) board per day, at a line speed of 66 ft (20.1 m) per minute and a maximum horsepower of 220 (164 kW) per belt for a grand total of 440 HP (329 kW).

On experimentation to date, the density profile of the thin boards produced is relatively uniform throughout the cross section of the board. Figure 17.51 shows the density profile of boards made with hardwood fiber and softwood fiber.

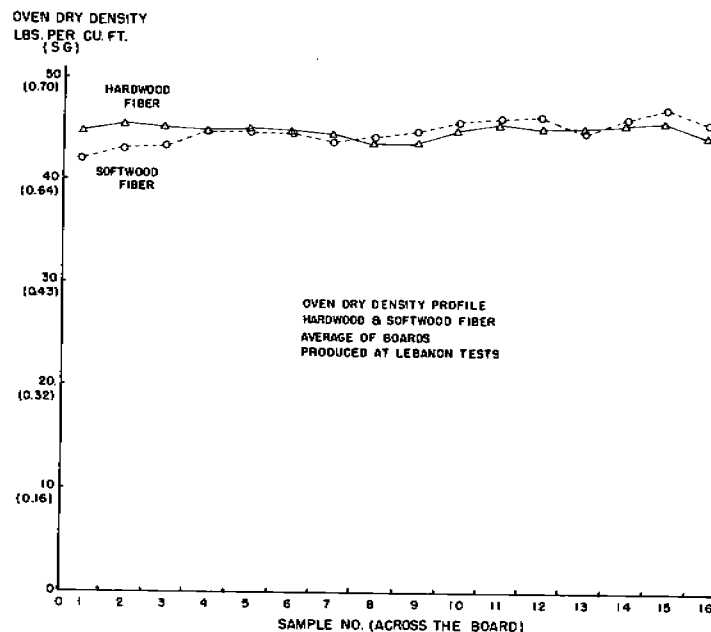


Figure 17.51. Density profile of fiberboards made on a continuous band hot press (Johnson and Martin 1975).

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18.

FINISHING BOARD

For this discussion finishing is being separated into primary and secondary. Primary will cover the cooling, sanding, grading, cutting, and shipping of the raw board. Secondary will briefly discuss filling, painting, laminating, and edge finishing of board. However, this is a lengthy subject and space will not allow a full discussion. Much finishing is done elsewhere, such as in special finishing plants or in furniture factories. However, more and more finishing is taking place in board plants to add value to the product, which hopefully increases the profit.

PRIMARY FINISHING

Cooling

Immediately upon leaving the press, the board is hot and will not reach its maximum properties until it has cooled. High-density hardboards usually are quite dry and have to be humidified to adjust their moisture contents before finishing. Particleboard is not normally humidified. Medium-density fiberboard may or may not be humidified.

Most board, because it is urea-bonded, is cooled upon leaving the press. The familiar *star* or wicket cooler shown in Figure 18.1 has been used for many years. These coolers hold about two press loads of board, and heat is dissipated from the boards while they are in the cooler. With urea-bonded board such cooling reduces the board temperatures to about 130°F (54°C). Such temperature reduction is necessary to keep the urea resin from breaking down. A hot-stacked pile of boards can maintain a much higher temperature for days because of wood's good insulating property.

Newer types of coolers are enclosed chambers such as shown in Figure 18.2, where the boards are transported on edge through the cooler. Air of controlled temperatures can be passed through these coolers to assist with the lowering of the board temperatures. Coolers can be massive pieces of equipment holding several press loads of board, some of which are 8 ft (2.44 m) wide and over 25 ft (7.62 m) long. With adequate cooling, sanding can be done immediately without tearing out the surfaces, which can occur when sanding "hot" boards.

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18.

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Most all board is cooled; however, it can be advantageous to hot stack phenolic-bonded board to complete the resin cure. Some urea-bonded board is also

hot stacked when the urea resin system is so formulated as to benefit from hot stacking. Some plants also find improved resistance to water absorption and thickness swell in boards where the hot stacking assists with the distribution and flow of the wax in the boards.

Hot stacking assists with final curing of phenolic resins and this has been a common practice with such boards. Retail yards have reported that packages of phenolic-bonded boards are still warm upon receipt, illustrating the insulation found with wood.

Cooling is needed to prevent hydrolysis from occurring in the board. Hydrolysis has already been mentioned as a problem in hot pressing. The temperature of the board, the moisture distribution with the board, and the vapor pressure are constantly changing during the pressing operation. This dynamic situation continues until the board cools after leaving the press. Asymmetrical stress changes consequently can occur, resulting in warping of the panel. Cooling is designed to provide symmetrical cooling of the panel and therefore balanced stresses from face to face, as well as to prevent hydrolysis.

Panels can be stacked by automatic stackers before further processing or they can go directly to sanding, trimming-to-size, and on to cut-to-size sawing.

Sanding

Panels should be relatively cool for sanding and final trimming to size. Hot panels have not achieved their full strength, and sanding such panels may not result in the best finish. The same is true with trimming-to-size, and some plants trim the panels to a rough size followed by a final trimming later on.



Figure 18.1. Board turner and cooler. (Courtesy Washington Iron Works.)

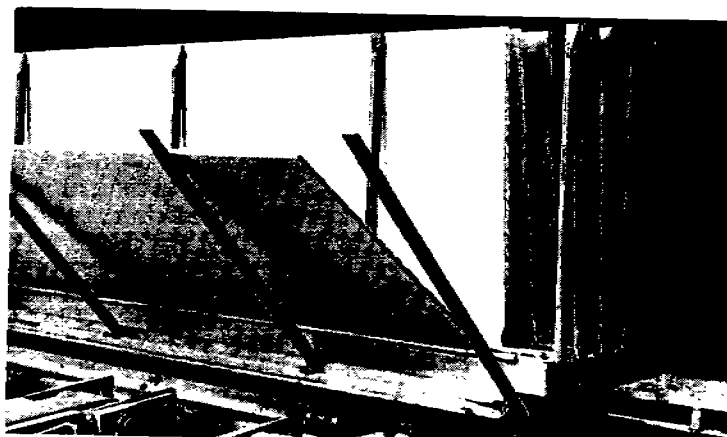


Figure 18.2. Boards leaving an enclosed board cooler. (Courtesy Washington State Univ.)

In the early days of the industry, drum sanders were used since they were about all that was available. These sanders consist of a number of sandpaper-wrapped drums which, because of their limited contact with the panel, tend to leave *chatter* marks (slightly corrugated surface) which is poor for overlaying and surface finishing. Some of these sanders are still in use. A narrow-belt sander traversing across the panel is used to try to minimize the chatter marks.

The development of the wide-belt sander, however, has made it possible to quickly dimension particleboard and develop a fine finish in the same machine. Modern sanders fall into two basic types: high-speed, multiple-head machines and slow-speed, single-head machines. Sanders will now sand panels up to 8 ft 5 in. (2.57 m) wide at line speeds to about 170 ft (52 m) per minute. Modern boards do not require as much sanding as some of the pioneer boards. Cases are known of having to sand off about 0.125 in. (3.2 mm) of surface because of poor soft surfaces and poor dimension control at the press.

The high-speed multiple-head machines can range from a two-head dimensioning machine to a six-head machine that will abrasively plane the panel to dimension with the first two heads and put on a fine finish with the last four heads. Fine control can be exercised over each head. Such a machine is shown in Figure 18.3. The slow-speed single-head sander is used on finished lines for buffing or finishing cut-up stock and banded stock. Some sanders can be purchased in modules, for example, putting in four heads now and two more at some time in the future.

Figure 18.4 contains schematic drawings of some of the sanding-head configurations showing the basic parts. The opposed-head configuration is designed for maximum stock removal and dimensioning or sizing of the panel. The platen head or smoothing bar is used for finishing. As shown in the drawing, the sander belt in this case contacts the panel over a wide area. This removes the chatter marks that

occur from the dimensioning step. Also shown in Figure 18.4 are the combination head and combination four roll, both of which are designed for smoothing the final surface of the panel being sanded. Acceptable final board thickness after sanding is about ± 0.003 in. (0.08 mm).

Most sanders today have all of the sanding heads contained in one machine or in modules designed for close coupling. However, there are versions where the sanding heads are separated by several feet. With these sanders there is usually a brush before each sanding head to clean all debris from the surface being sanded. Brushes are also used in the close-coupled machines.

In a sander, the first heads are designated as primary. As mentioned, they are for sizing the panel to the desired thickness. The opposed-head configuration, with the top and bottom steel contact rolls directly opposing each other, provides the most accurate dimensioning. Secondary heads are usually of the combination type, using both a contact roll with a smooth surface or spiral serrations and a finishing platen or smoothing bar. The secondary head is used to dimension the board to final caliper and to remove any grit and rotation marks caused by the primary contact rolls. These secondary heads can be opposite each other, or opposite a platen or a back-up roll, which is called a *billy roll*. The finishing heads can be either a combination head or a platen only. The platen-type head consists of two belt carrier rolls and a pressure platen. This type of head removes very little stock but removes all of the imperfections developed by the primary and secondary heads, resulting in a very fine finish.

Single-head machines can be used for sanding on a production line. A few of these have been used, but they must run at slow speeds and the panels must pass through the sander several times.

Good feed systems have been developed for transporting the panel through these sanders. In earlier sanders this was quite a problem, resulting in poorly

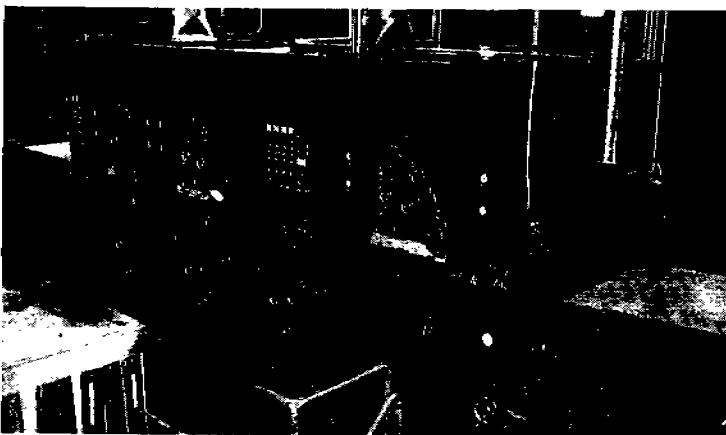


Figure 18.3. A six-head sander. (Courtesy The Coe Manufacturing Co.)

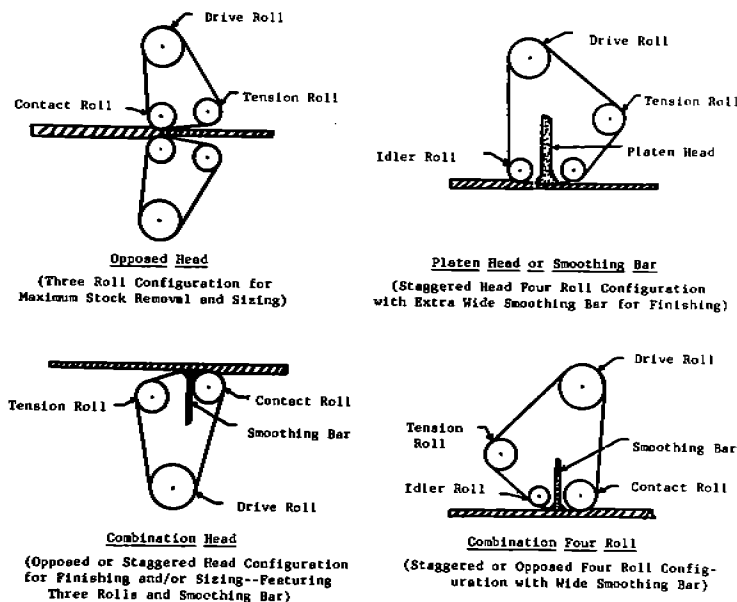


Figure 18.4. Some sanding-head configurations (Murdock 1968).

finished panels which would have end or edge snipe. In present-day sanders, the bottom feed rolls are the only ones driven and these rolls are covered with polyurethane to provide a good grip upon the panel. The upper or pinch rolls are usually equipped with soft rubber or polyurethane covers. Some operators like to use knurled steel feed rolls wherever possible. There apparently are more maintenance problems with the polyurethane-covered rolls, and these are used only where the conveying is critical. The billy rolls opposite the contact drums are either rubber-covered or smooth steel. Since these are powered feed rolls, the rubber-covered ones are superior in controlling the panel feed. The overhead or hold-down rolls are normally spring-loaded rather than driven as mentioned. Spring tension on these rolls must be sufficient to prevent slippage of the panels and to provide enough friction to the lower drive rolls to insure constant end-to-end feed. The contact drums can be either knurled steel or covered with rubber. Knurled-steel drums are relatively maintenance free. Rubber-covered contact drums have a maintenance problem from wear in the areas where the edges of the sander belts oscillate. This problem is enlarged in sanders which use both wide and narrow belts. Steel drums are utilized for an aggressive sanding operation.

The sander belts oscillate back and forth across the panel as sanding is accomplished. Consequently sophisticated sander belt tracking systems have been developed. Some of the techniques employed are: air jets against limit-switch

arms, electronic eye systems, and air jets from idler rolls. The air jets, when covered or uncovered, cause differential pressure in the instrumentation which controls the automatic belt oscillation. This method of signaling the instrumentation has provided excellent control of the oscillation.

It is important to have proper belt tensioning in a sander as the belts tend to stretch during their operating life. Pressure gauges are used to monitor the tension, and adjustments can be made by the operator.

The polishing platens require guides and adjusting mechanisms with close-fitting tolerances. Their end-to-end adjustment must be extremely accurate to prevent sanding a taper across the panel. Polishing platens have covering material, normally of polyurethane or hard-pressed felt covered with graphite cloth. Minor defects in this covering must be monitored and corrected, if they occur, since a poorly applied covering can cause streaks on the sanded panels. It may be necessary to have frequent maintenance and changes of the polishing platen material.

Large-capacity air systems are needed to remove the dust generated by the sanding heads. If this is not done properly, the dust can be left on the surface of the sanded panels and this dust can then contaminate the bearings, guides, motors, and controls. Thus, close-fitting hoods, large pipe sizes, and high-capacity fans are necessary for efficient cleaning of both the machine and product. A problem does occur with the dust-collecting system in that every once in a while a sander belt "explodes" or breaks apart in the machine. When this happens, it is very likely that a great number of sparks are generated; and these sparks can pass through the dust-collecting ducts into the dust-collecting system and baghouse, causing an explosion and fire. Explosion-suppression systems are therefore important in the sander dust collecting system.

Sander belts are usually the most expensive item in the finishing department. Many variables are involved in determining the life span of the sander belts. These conditions vary between plants in many ways, all of which affect the production and belt expense. Some of these conditions are: difference in species; panel temperature and panel size; variation in panel thickness, requiring different amounts of stock removal; density of panel surfaces; storage and handling of belts; maintenance of the equipment; and the experience of the sander operator (which is a very important factor).

The sequence of sandpaper grits and the type of sandpaper used varies between operations. Sander design dictates, in many cases, the use of high-cost belts rather than medium-cost belts and low-cost paper-backed belts. With few exceptions, silicone carbide grain is the abrasive material used to sand board. The toughest resin bonds and the strongest backings available are combined with the silicone carbide grain to produce these belts. Similar belts are used for cutting glass, plastics, leather, ceramics, and nonferrous metals. It has been noted that no material requires more horsepower per inch of belt width, more aggressive contact wheels, or more massive machine construction than does this particleboard sanding operation.

The type of grit used on sanders varies between the sander and the product being sanded. Underlayment, for example, might not require any finer grit than 80, since an extremely smooth finish is not needed. Furniture-type panels how-

ever, requiring finer finishes, can be sanded in sequences of 50 to 100, 60 to 100, and 20 or 80 to 150 grit. Prefinishing plants, however, may go as high as 400 grit with the sandpaper. With the coarser-grit paper, the belt speed can range from about 550 to 6500 ft (168–1981 m) per minute. When using finer-grit paper, slower speeds are found to be better for providing a better surface with speeds running in a range between 400 and 2000 ft (122–610 m) per minute.

Open-coat belts (determined by the amount of cutting grains glued to the belt) are used for heavy sanding, as the grain spacing minimizes the buildup of material on the belt. Open-coat belts will have about 50 to 60% of the belt covered with grains while close-coat belts will be completely covered with grains. Close-coat belts are appropriate for finish-type sanding.

Belt life can be shortened by high humidity; inadequate dust exhaust; a heavy rate of cutting; a high sander feed speed; a high board resin level (especially in the faces); high board specific gravity (as we have learned, faces are normally higher than the average board density); metal or impurities in the board; the wood species itself; and extractives such as resin in the wood.

Belts should be stored on special racks before use in a controlled atmosphere of 50% relative humidity and 70°F (21°C). With proper storage and prevention of mishandling, such as getting the belts wet, maximum belt life can be expected.

Grading

After the panels leave the sander, it is normal for a grader to check the board surfaces visually for imperfections. An oblique light is used to show up these imperfections. A board turner can also be placed in the line so that the operator can grade both sides. Figure 18.5 shows one of these turners in operation. An

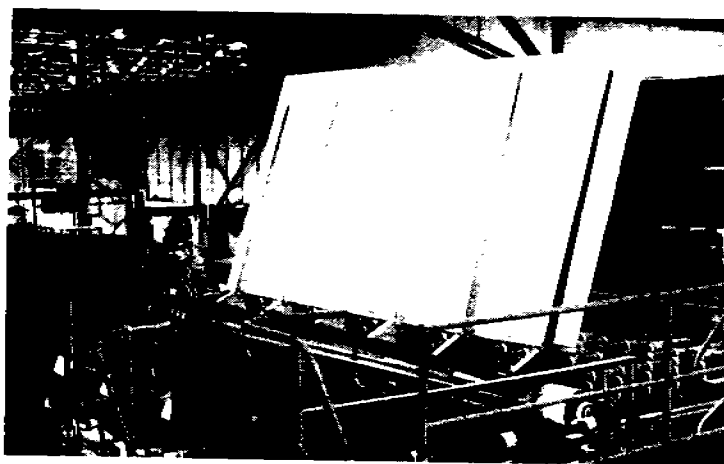
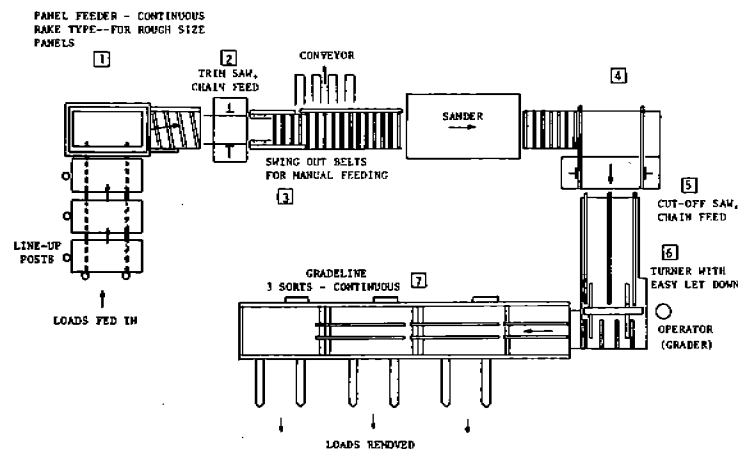


Figure 18.5. A board turner in operation. (Courtesy Washington State Univ.)



SPECIFICATIONS - FOR 4 FT BY 8 FT PANELS
(1220 MM BY 2440 MM)

1. FEEDER, HOOK TYPE, CONTINUOUS CYCLE NOT REQUIRING RELOAD DOWN-TIME. INCLUDES AN INFED BUNDLE CHAIN FOR LOAD STORAGE. INCLUDES AN OUTFEED ROLLCASE WITH A LINE-UP STRAIGHTEDGE.
2. SKINNER SAW.
3. ROLLCASE, POWERED ROLLS TO SEND PANELS FROM SAMS INTO SANDER.
4. PANEL TRANSFER, DESIGNED TO PUT PANELS ONTO CUT-OFF SAW CHAIN BEAMS.
5. CUT-OFF SAW.
6. POWER TURNER, FOR RAISING BOARDS TO VERTICAL POSITION FOR GRADING PURPOSES.
7. PANEL STACKERS WITH ACCUMULATORS FOR CONTINUOUS STACKING AND COUNTERS.

Figure 18.6. A typical grading, sorting, and stacking line. (Courtesy Keystone Machine Works Inc.)

automatic stacking system then follows so that several sorts of the material can be made. This is automatically controlled by the grader. Figure 18.6 illustrates a typical grading, sorting, and stacking line.

Cutting

Saws: A basic two-pass trimming system has been standard in the plywood and other panel industries right from the start. This consists of a first-pass or skinner saw unit with two side saws for edge trimming, a 90-degree corner transfer to a second-pass or trim saw with two saws as shown in Figure 18.7. The first evolutionary step for this system was to add one or more splitter saws for the first-pass saw and one or more saws for the second-pass unit. This was the beginning of the cut-to-size operation as illustrated in Figure 18.8. The primary and best use of this type of line is to break large panels down to sizes that are easier to handle and sand or cut up further. This is especially important with the monstrous-sized panels that are being produced today. From this line, which can be either in the board press line or in a separate line, the panels can be cut to order on a quick-set type island saw with either chain- or slat-bed feed. A slat-bed saw is shown in Figure 18.9.

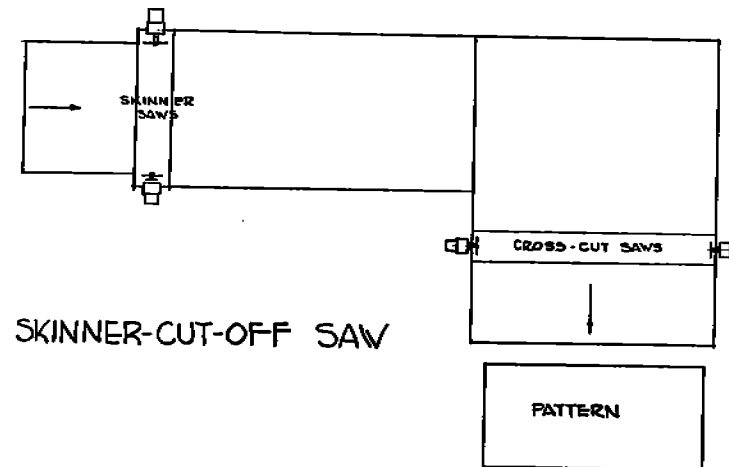


Figure 18.7. The basic two-pass cutting system (Murdock 1970).

The slat-bed saws come in two types with the most common one using a wooden bed into which the saw cuts. This bed is a replaceable item, and how often it is replaced depends on the number of size changes. The other type uses an aluminum slat with a replaceable neoprene-covered slat. On this type the bed dips under the saw line so that the bed is not cut.

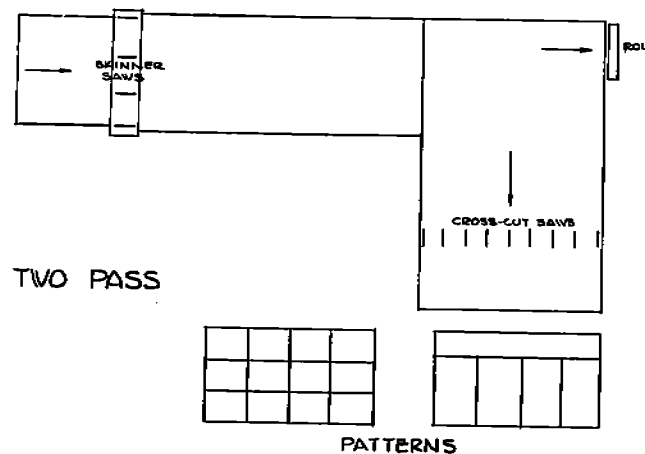


Figure 18.8. The basic cut-to-size operation (Murdock 1970).

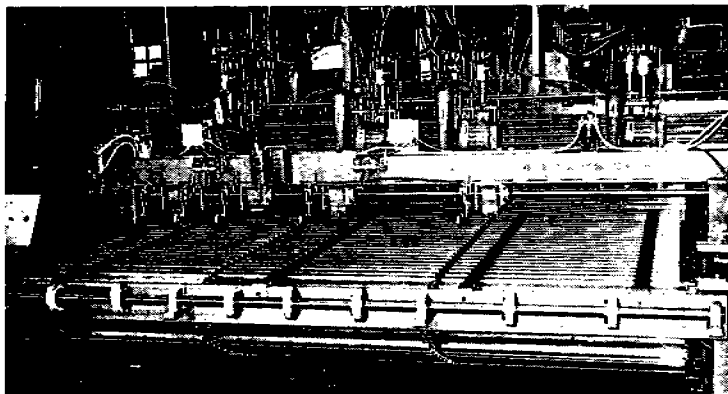


Figure 18.9. Dip chain slat bed with overhead aligning devices (Murdock 1970).

An interesting new saw has been developed for cutting to length the continuously pressed board as it leaves the press or the very long boards while they are traveling down the production line. The saw traverses at an angle across the moving board at a synchronized speed so that the board is cut off square to the edges. One of these saws is shown in Figure 18.10. Other saws cutting the thin, continuously pressed board momentarily stop the board with clamps so the cutoff can be made. The thin board continuously coming from the press buckles up for an

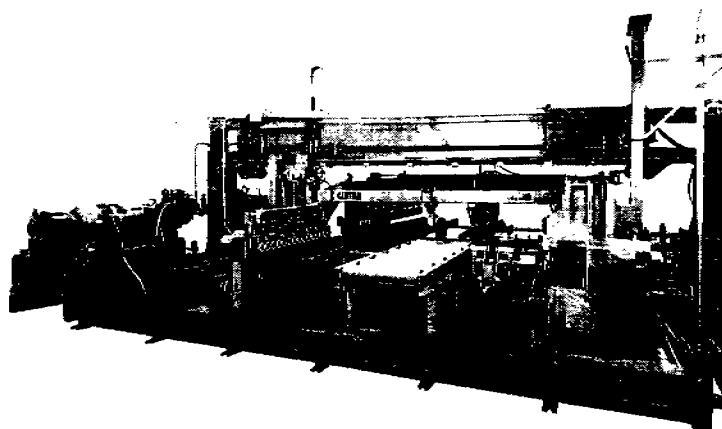


Figure 18.10. A trim/crosscut/splitting unit for continuously pressed or very large boards cut while moving. (Courtesy Mereen Johnson Machine Co.)

instant against the clamp restraint while this cut is being made. A clipper- or guillotine-type saw has also been used with thin board.

If further breakdown is needed for drawer parts and so forth, rip saws and double end machines are used for ripping, bullnosing, grooving, and sanding of these parts. These machines can be connected together for high production or fed individually.

The current trend is to more sophisticated systems using punch cards or tapes to control the saw. With these systems orders can be programmed at some central location and transmitted to plants where tapes are punched, inserted in the machine, and the order cut utilizing the best pattern for the primary board size. Large companies are doing their own programming, but there are independent firms also offering this service.

The new sawing systems are of three types. The first uses multiple-panel feeding with the panel stack initially moving into position and being clamped. The cuts are then made by traveling saws for both the rip and crosscuts. The second type uses a combination of the traveling saw and positioned saw arrangements. Here the multiple-panel stack is moved into position, clamped, and a rip cut made by a traveling saw as shown in Figure 18.11. After this rip cut is made, the stack is indexed for the next rip cut. The previous rip-cut stack is moved into a conventional-type crosscut saw with saws positioned for a desired length and cut. These units can be fully automatic with tape record control or they can be manually controlled.

The third type of sawing system is called the three-pass. This system for a high-speed, accurate cut-up operation uses a normal skinner-splitter saw and two crosscut saw assemblies arranged side by side with a residual off-bearing assembly at the third saw as shown in Figure 18.12. One system of this type can be tape controlled so that a complete change in setup can be made in 1¼ minutes while making 33 changes in the line. The large amount of electronics required for the

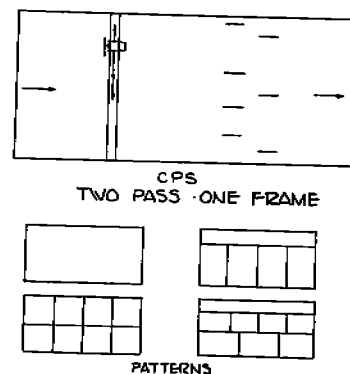


Figure 18.11. Combination cutting with a traveling saw and positioned saws (Murdock 1970).

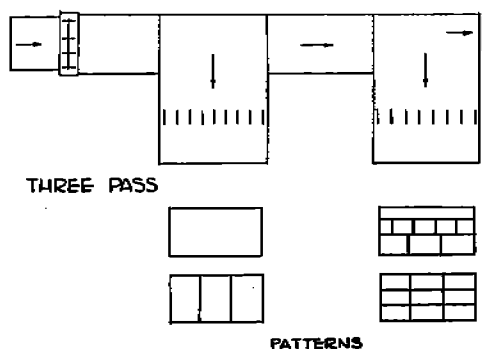


Figure 18.12. The three-pass cut-to-size arrangement (Murdock 1970).

three-pass system is of course expensive. A more practical approach is a combination of manual set and tape control. This consists of zero saw, stops and guides being manually controlled, and 17 saws, chain beams and hold-downs being tape controlled. This cuts the cost substantially but still allows the normal setups in a very short time. A completely manual networks depending upon the skill of the operator, would take 10 to 15 minutes for a 17-saw setup to be adjusted. This time interval includes the time it takes the operator to measure and check the size of the parts being cut.

The higher-production panel saws cut the material to size for the customer from large panels, either directly out of the press or later from panel storage. The scheduling task in a cut-to-size operation is a very complex and difficult one because of the interactions between all of the factors involved. However, the computer is presently being used successfully in two areas: daily scheduling and planning. By using a systematic method of cutting, the plant can consistently meet its cutting schedules and shipping dates. This method assures that orders will be continuously completed and shipped throughout the week. Orders may be changed, added, or deleted up to one day before the cutoff date for each period. One of the most powerful features of the computer scheduling service is its consistency, since the computer can analyze and solve the problems quickly and is never forced to take short-cut approaches to meet the deadlines, which manual schedulers often must do. Historically, a computer service can improve board yield over those prepared manually by 3 to 10%. As a result, primary board utilization can be maintained at 91 to 93%, leaving 7 to 9% incurred off-fall in wastage. Since it is usually possible to recover about 1 to 2 percentage points of the off-fall, the system can come within 2 to 4 percentage points of the perfect 97% utilization (considering saw kerf).

The cost of a computer scheduling service is low in view of the benefits mentioned. Considering board yield alone, computer scheduling should save the user more than three times the cost of the service. For example, \$1 spent for the service saves \$3 on material costs alone. The highly sophisticated new saws can

cost up to \$1 million, which is far more than the basic skinner-type saws initially used in the industry.

Board breakers are used to break the trim into small pieces. These are refined further for reuse as furnish or as fuel.

Sawblades: It has not been possible to use conventional cutting tools for particleboard and fiberboard. Tools employing tungsten carbide or modified grades of tungsten carbide for the cutting edges have become the best way to cut composition board. High-speed steel has not been successful because the resin in the board, the natural resins in some of the wood species, and the high silica content in some of the wood species (because of their geographic location) have made the board extremely abrasive. The use of high- and low-pressure overlays, vinyl coverings, fillers, and base coats has further complicated the cutting practices required for composition board.

The selection of the proper grade of carbide is a matter of careful analysis. It is necessary to obtain the most wear-resistant grade of carbide that will do the cutting job without causing chipping or flaking away of the carbide. The correct grade selection is most often made from experience. A grade of carbide must be hard enough for the material being cut but must also have the characteristic or property in its makeup to withstand the shock of impact when cutting. Usually a non-alloyed grade of tungsten carbide will give the longest tool life. In some instances a micro-grain grade (a finer grain) of tungsten carbide is used, particularly for high-density particleboards. Using proper tool design will allow a reduction in cutting pressures, which aids in optimizing the economy of operation.

There have been many recent developments in the style and configuration clearance angles of sawblades and in the grades of carbide required for the various jobs. The combination of these advances has provided the best cutting tools yet for cutting or machining board. The selection of sawblades for cutting the board can usually be determined by the density of the board. The coarseness of grain, particle size, and geometry, must also be considered in a sawblade selection to insure the most effective results. Ideally the design of the sawblade must match its rpm with the feed rate of the material through the cut, so that the desired chipload per cutting tooth will be maintained. If this is not done chip-out, fiber tear-out, and a decrease in the length of tool life will occur.

The end use of the material will determine the order of importance for the quality of the cut or life of the cutting tool. Both factors are vital points to consider in the selection of sawblades. The use of carbide-tipped sawblades is a must in order to achieve even moderate tool life when cutting. Sawblades with maximum shear and sufficient teeth, exerting the least possible pressure on the board as it is being cut, will assure the most effective results.

No matter what type of cutting is being done, the material must be supported properly, right up to the edge of the cut. This will help to avoid edge chipping or chip-out. In some cases special devices must be designed to provide proper material support. However, there are some applications where full support is not possible. An example of this is found when cutting against the feed on slat-bed machines (Figure 18.13). Cutting forces tend to lift the material away from the machine bed and hold-downs cannot be set close enough to the sawblade. Reversing tool rotation to a climb-cutting configuration improves the edge finish (Figure

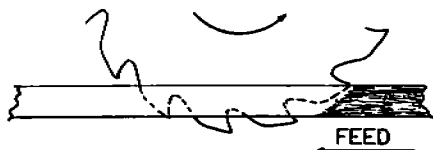


Figure 18.13. Cutting a panel from above with a power cut (Jones 1968).

18.14). If tool rotation cannot be reversed, the cutting should be performed as close as possible to the hold-downs and a zero or positive five-degree hook angle sawblade used to reduce the lifting force on the material. Cutting pressure can also be reduced by adding more teeth. Also, greater shear angles can be designed into the tooling to change the cutting force direction.

As the board becomes more dense, the leaving edge becomes more likely to chip or break out. The use of an alternate top bevel tooth form (Figure 18.15) can provide enough shear for a good top and bottom edge finish as well as good leaving end cuts that do not have breakout. The addition of alternate face bevel added to the alternate top bevel design will help avoid any leaving end breakout that still may occur (Figure 18.15). The alternate face bevel acts as a shearing tooth delivering a slicing movement to the cut, which reduces the cutting pressure.

As mentioned, a factor to consider when cutting board is tool life. The alternate top bevel design features a sharp point that dulls easily because it is subjected to high impacts as it enters the material first. In this case shorter tool life results. The use of a triple-chip grind design will give added tool life over the sharp alternate top bevel design. A tooth with 45-degree corner angles opens a path through the hard abrasive board as shown in Figure 18.16 (1). It is followed by a flat tooth which takes a light finishing cut on the sides of the material, shown in Figure 18.16 (2). Since the 45-degree tooth opens the path in the cut, the regular tooth only has to make the smooth side cut. The 45-degree "lead-tooth" is also extended so that it always cuts deeper than the raker tooth, thus protecting the sharp corners of the raker tooth and extending tool life. Such a cutting action is not only beneficial in producing longer tool life, but also produces a fine side finish.

Some very dense, hard panels are so brittle that the raker tooth chips the edges of the material. When this occurs an alternate face angle is sometimes added to the raker teeth to provide a slicing, shearing, side-cutting action which will not chip the side (Figure 18.17). This then changes the standard two-tooth design to a three-tooth design pattern.

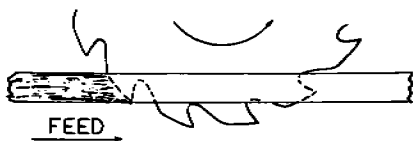


Figure 18.14. Cutting a panel from above with a climb cut (Jones 1968).



Figure 18.15. The alternate top bevel and face bevel tooth form used to prevent edge breakout (Kovich 1972).

In addition to the triple-chip design with alternating face bevel, there are other modifications to the standard alternate top bevel design which, in specific applications, help increase the tool life while still maintaining the sharp cutting point. One of these is the use of a raker tooth along with the alternate top bevel teeth, which helps increase the tool life (Figure 18.18). By adding alternate face bevels to

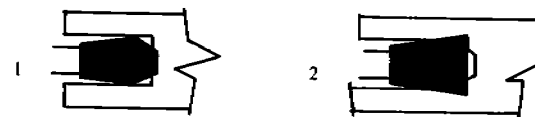


Figure 18.16. The triple-chip grind with flat raker tooth design (Kovich 1972).

alternate top bevels, the leaving edge breakout can also be avoided. This combination will provide a finer finish with a reasonably extended tool life. However, the triple-chip design with alternate face bevel on the raker teeth will generally provide the longest tool life.

There are five more important design features to consider, when cutting board, which directly affect any tooth style used. These factors are: clearance angles,

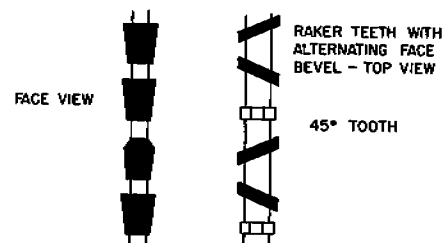
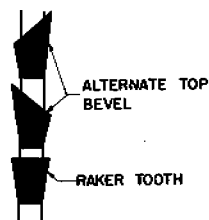


Figure 18.17. Forty-five-degree bevel tooth with raker teeth having alternating face bevel design (Kovich 1972).

Figure 18.18. A raker tooth added to the alternate top bevel tooth design (Kovich 1972).



hook angles, tooth approach angle, body thickness, and tensioning. Clearance angles have an important effect on blade design. In cutting board, high clearance angles are needed due to the abrasiveness of the resin binders. Also, some wood species are more abrasive due to the higher silica content in the wood fiber. One of these, southern pine, is used extensively for producing particleboard.

The resin binder tends to build up rapidly on the cutting teeth, resulting in dulling of the cutting edge and shorter tool life. Increased tip-to-body-clearance, side or back clearance, a radial clearance, and an outside-diameter clearance (Figure 18.19) must be designed into the sawblade. These increased clearance angles must be incorporated into the design of the cutting tool to allow for the *flow-back* of the material being cut. The flow-back of the material is the degree to which a material will compress before penetration of the tooth occurs. Low-density fiberboards will compress and bend ahead of the tooth (Figure 18.20). When the bent fibers are cut, the sudden release of pressure causes the fibers to flow back in a wave on either side of the tooth. If this wave contacts the sides of the tooth because of insufficient angular clearance, frictional heat develops, not only producing drag on the blade, but also burn marks on the board.

The *hook* or *rake* angle of a cutting tooth affects the ease in which the tooth penetrates the work being cut. The greater the hook or rake angle, the less power required, and the greater the shearing action. However, tool life is shortened decidedly. The less the hook or rake angle, the more power required. Consequently, a loss of shearing action occurs but the tool life is substantially increased. There are three basic hook or rake angles to consider in sawblade selection as shown in Figure 18.21.

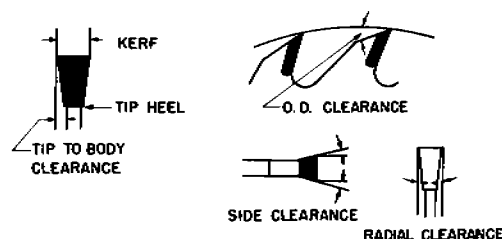


Figure 18.19. Clearance angles considered for sawblade design (Kovich 1972).

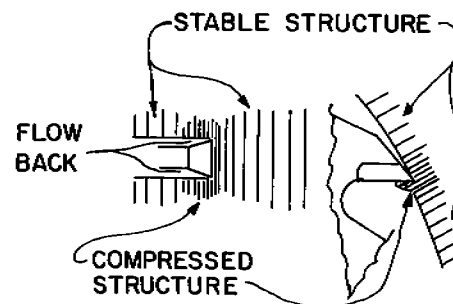


Figure 18.20. Illustration of compression of fibers in a low-density fiberboard being cut. (Courtesy North American Products Corp.)

To understand the importance of each hook angle, it is first important to consider the tooth approach angle that the sawblade is under in its cutting application. The relation of the blade position to the work affects the tooth approach angle. This in turn affects leaving-end breakout, edge chipping or chip-out, and thin panel cutting. There is a direct relationship between hook angles and tooth approach angles. The basic importance of tooth approach angles is in the control of cutting force direction. In thin panels, the sawblade should run low in the cut and barely project through the material being cut (Figure 18.22, Position 1). This directs the cutting force as nearly parallel to the plane of the material as possible; thus, the uncut portion acts as a support and edge chipping is controlled.

When work is fed into the saw or cutter near the centerline of the arbor (Figure 18.22, Position 2) there is more of a tendency to have a pounding effect resulting in more chipping.

On machines where climb cutting is necessary, the hook angles of the tool must be reduced so that the teeth do not grab the material and whip the sawblade across the table. The reduced hook angle will resist the tendency of the tool to cause chip-out and also resist the tendency of the tool to pull into the work. This can occur with such force that the tool will lunge forward, causing damage to both the tool and machine (Figure 18.22, Position 3).

The body thickness of a sawblade is another important factor for careful evaluation. The cutting width of a sawblade, as well as tooth form, hook angle, and size of chipload taken by each tooth, influences the cutting pressure. In general,

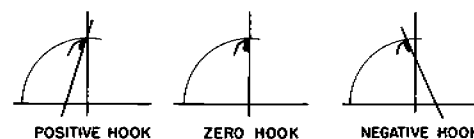
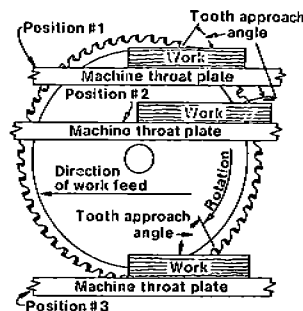


Figure 18.21. The three basic hook or rake angles (Kovich 1972).

Figure 18.22. Three blade positions for cutting board (Kovich 1972).



the thinner the kerf width of the saw, the lower the cutting pressure. However, as the kerf is decreased, the saw body must be made thinner and therefore becomes weaker. The sawblade body thickness is related to the diameter and, therefore, it is advisable to select the smallest-diameter blade commensurate with the thickness of the material being cut and the number of teeth and the tooth spacing required for the feed rate. For fixed-speed direct-drive saws, the rim speed of the blade and, therefore, both the aerodynamic noise and blade body vibration increase as the blade diameter is increased. On fixed-arbor machines where the blade cannot be raised or lowered, large-diameter blades should be equipped with supporting collars as large in diameter as possible. Saw collars should be of the hollow ground design and equal in diameter to provide equal support on both sides of the blade at the outer edge of the collars.

The use of a thin-rim-body sawblade is not always the answer to solving a quality or cutting pressure problem. At today's higher rpm, various sawblade applications, and increased feed rates, the stronger the saw body, the longer the saw life will be, and the more stable it will be (i.e., true running or body run-out) under full cutting load. In more operations, thin-rim sawblades will not be stable and run true when cutting particleboard. Therefore, the use of a stronger, heavier saw body is recommended. However, the use of thin-rim sawblades definitely has its application in cutting particleboard.

Proper tensioning is extremely important not only for the quality of the cut but also for blade stability and life as well. A properly tensioned sawblade for the correct rpm is very critical in controlling noise as well. The rim speed of a sawblade at 3600 rpm is approximately 180 to 200 (290-322 km) miles per hour. The centrifugal force acting on the thin-blade body is very large at such speeds and the internal stresses, due to heat treating, are very sensitive in the thin-sawblade body to such a force. During the processing of the sawblade, the body is straightened and tensioned by means of pressure rolls or saw hammers so that the steel in the blade body is uniformly stretched in a manner that will allow the blade body to retain its true circular shape at running speed.

Three or four equally spaced expansion slots, usually about one-sixth of the blade radius, are cut into the rim of the blade body at the bottom of the saw gullet as an aid to obtaining the proper straightening and tensioning of the blade body.

These slots permit the metal of the steel body in the rim area where the stresses are greatest, to be stretched in a more uniform manner.

Since the centrifugal force acting on the blade body is related to the rim speed and blade body thickness, the amount of tension must be adjusted to these two factors. Large-diameter thin-body saws require more tensioning than small-diameter thick-body saws.

Improper tensioning can cause severe vibration resonance in the blade body. This, in turn, will not only cause the blade to cut much wider than it should, but will also cause the blade to develop a great deal more noise. Sawblades that have too much tension will eventually produce cracks in the gullet and expansion slots of the blade; in severe cases, they may cause cracks in the collar area.

It is important to note that sawblade body cracks, excessive saw noise, and poor surface finish can also result from running a blade that is misaligned with the feed direction of the material. This latter condition is all too prevalent in machines where preventive maintenance is not a part of the company procedure.

Too many expansion slots can prevent the blade from running true under cutting conditions. As a result the saw will generate noise as well as yield poor-quality cuts. Therefore, it is very important for the proper number of expansion slots to be designed and engineered into a sawblade. Too many expansion slots only try to cover up problems due to improper tensioning. There are other factors that can cause a sawblade to scream. Sometimes, regardless of how much care is taken in tensioning properly, the problem can be built in at the time of manufacturing the steel blank itself (i.e., uneven cooling of the steel). To insure continued proper tensioning, the sawblade must be checked each time it comes in for servicing and maintenance.

In general, any sawblade, regardless of tooth form, can be made to cut. However, the blade may only cut for a short time before a complete breakdown, or it may leave a very poor finished cut. The reason one should understand the limitations and advantages of tooth form, hook angles, chipload, and the other factors covered here is that these basic factors can be put together into various combinations to achieve the desired results. Since the success of these combinations is dependent upon the type of machine used, work support provided, size of machine collars supporting the blade, saw tensioning, and the type, thickness, and density of the board as well as the kind of cut being made, it is obvious that it takes a combination of these factors to insure the best possible cutting results.

Recently, because of the limitations placed on saw noise by the federal government and administered under the Occupational Safety and Health Act (OSHA), the factor of noise has had to be considered with saws. It is not that noise problems did not exist before but that they have increased directly with the demands of the industry for faster production. Saw and cutting tool manufacturers have been able to do a commendable job with noise reduction on the rigid-body type of cutting tools. The development of spiral-tooth and staggered-tooth cutters in several design styles, which replace the simple, solid straight-tooth cutterheads, has provided good results. These tools are more expensive, however. More work has to be done for some of the very high-speed operations in meeting acceptable sound levels along with maintaining long tool life and appropriate surface finish requirements.

There have been many research studies conducted on the various types of sawblades used throughout the woodworking industry. This has been an extremely difficult problem to solve, particularly in meeting the proposed OSHA maximum allowable noise levels. It has been very difficult, because of the complex data developed, to come up with clear-cut solutions to circular saw noise. Great strides have taken place but much more work has to be done. There has also been a great deal of trial and error work performed by the industry in attempting to solve this relatively new problem.

It has been pointed out, however, that saws must be made to very close specifications and that manufacturing quality control must be high. In addition, the saws must be used as designed and the servicing of the saws must be done promptly and correctly.

Different types of saws have been evaluated, particularly those of the laminated type. With this sandwich-plate construction, two plates of equal thickness are laminated together with a viscoelastic material in between to make up the sawblade body. When either system undergoes flexure in the dynamic condition, the interface is subject to differential stress that converts some of the mechanical energy into strain energy which is finally dissipated as heat. This serves as a damping mechanism which suppresses some of the saw noise.

It is expected that the saw itself is operating properly in order to suppress whatever noise is being generated. Other techniques to assist in decreasing the noise level are coating the inside of the saw hood with sound-dampening material, enclosing all openings around the hold-down devices between the blade guard and the panel being cut, and using as large a saw collar as possible. A plastic polymer has also been used as a damping medium between the saw collars and the blade.

Much additional work will have to be done to meet the proposed OSHA standards as shown in Figure 18.23. A firm has been engaged to perform research on this subject. Its area of expertise is in aerodynamics and the researchers are to develop new blade designs (if possible) and to develop a system to absorb sound generated. They are to perform their research in six steps.

1. Identify the most used blade configuration, so when the noise is quieted, the most significant impact in the workplace will be possible.
2. Seek out the predominant noise sources, especially the aerodynamic ones, and attack them where they originate.
3. Use analytical noise-prediction models so they can look at their models and ask what effect they will get if they make a certain change.
4. Identify various possible noise-control methods both by making modification to blades, and by designing retrofit packages to absorb sound already generated. This phase will include cost/performance studies.
5. Prepare comprehensive design manuals to help reduce noise, predict how much reduction, and forecast the cost/performance impact.
6. Write a final report with all the technical information of the study and make it available.

Since this is a very difficult problem, it probably will take several years to solve to everyone's satisfaction.

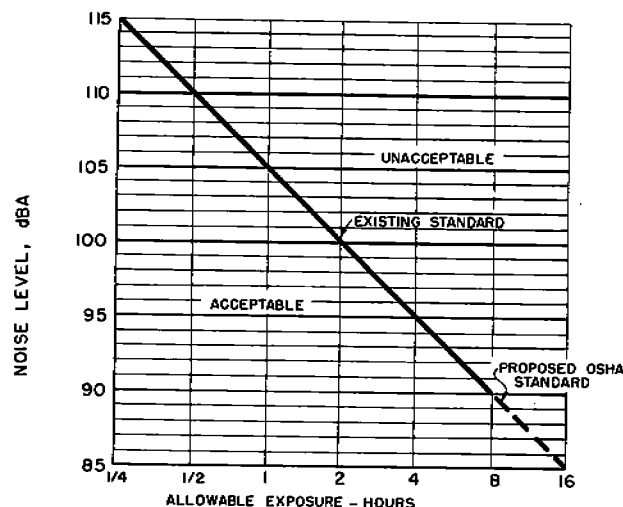


Figure 18.23. Noise exposure limit (Crawford 1975).

Shipping

Shipping composition board is an important facet of the industry. It is the last time the product is inspected prior to being used by the consumer. The shipping department of any plant assumes the position of being the "unseen salesman" and is a behind-the-scenes partner of the sales department. It is responsible for providing shipments of board to the customer, which are perfect in appearance, free of damage and which are easily unloaded. This calls for careful preplanning, packaging, tallying, and proper preparation of the boxcars or flatcars for loading and shipping. Truck loading is not as complicated but care must also be exercised here; otherwise the product will be damaged.

The preplanning for loading a boxcar becomes an intricate process when the multitude of small, cut-to-size pieces that can be shipped are taken into consideration. Standard sizes such as 4x8-ft (1.22x2.44 m) panels do not require extensive preplanning. However, with complex cut-to-size pieces and larger panels, detailed diagramming of the boxcar in preparation for loading must be performed. Indeed, it has been found that a single diagrammer may take up to one full working day in preparing his diagrams. Computer programs have also been developed for determining how a car should be loaded for a certain order. It is important that the final load is relatively level within the car and the units are tight together, which insures that the panels will not work loose and become damaged in transit.

The diagramming, whether done manually or by a computer, is the initial step when an order is received at a plant. This is done prior to cutting to size and unitizing, as the loading diagram for level, tight loading indicates the unit sizes and

Flatcar loading of composition board is especially attractive when long lengths of 12 ft (3.66 m) or longer are shipped. The flatcars used must be sufficiently long to contain a load as in boxcar loading, and the bulkheads on the ends of the cars must be of sufficient height to support all units in the end tiers. The bulkheads are first covered with a 6-mil (0.15 mm) vinyl sheet before any units are placed on the car. Preparation of a flatcar for loading is similar to that of a boxcar in that nails, sharp objects, and other foreign objects must be removed.

Following the loading of the units on the flatcar, the bottom units across the car are strapped to the center units and, in turn, the center units are strapped to the top units of the load, producing one solid package of board across the length and height of the load. The center block is applied as in boxcar loading, and the entire load is covered with another 6-mil vinyl sheet. This vinyl sheet and the vinyl sheet on the bulkheads are then joined together at the end of the car using a wraparound method on two 2x4s. Then the 2x4s are nailed to the bulkhead, and a similar installation is made along the bottom edge of the length of the load. All joints, seams, or holes in the vinyl are taped to prevent air from entering and causing ballooning of the vinyl in transit, which can cause tears and removal of the covering.

Hazards of wind and mechanical damage, as well as vandalism, cause transient removal of vinyl in flatcar shipping. Of course at any time that the covering is damaged, the product is subjected to whatever the weather conditions are at the particular time of transit.

Truck shipments of board are popular, both for short local hauls and for long cross-country hauls when shorter transit times are important. Such hauling provides for more convenient unloadings, especially with small consumers of board who do not have railroad facilities of their own. The trucking firm normally supplies the cables, corner protectors, and tarpaulins as needed to hold the load in place and protect it from the elements.

SECONDARY FINISHING

Composition board products can be sold in the raw state, primed or completely finished with some type of overlay and edge finish. Surface finishing ranges in quality from a simple paint finish to high-density plastic laminates. Edge finishing is necessary for most particleboard furniture-type applications; while, as already mentioned, one of the virtues of the medium-density fiberboard is the minimizing or complete elimination of the edge treatment. Tempering is practiced with thin hardboard by dipping it in oil and then heating in ovens to polymerize the oil. Oil-tempered hardboard consequently has excellent dimensional stability and resistance to weathering and the pickup of water. It is also possible to apply the oil to the fibers during the board-making process and to polymerize the oil during hot pressing. Oil tempering, however, will not be dealt with in this discussion, as surface and edge treatment, not complete treating of the panel, is the subject.

Surface and edge finishing or overlaying panels improves their appearance and properties, resulting in high-value products. Overlays can be printed with various wood grains or other designs for top-quality applications. Some overlays, such as those of resin-treated fiber, serve as a substrate for providing an excellent paint

finish. It is possible to eliminate painting by using pigmented acrylic films combined with resin-treated paper. Resin-treated paper overlays enable the use of some panel products for exterior applications, because the faces are protected. Particleboard, for example, tends to surface-roughen even though an excellent paint film is applied. Such roughening can provide a decorative effect; but, if a smooth surface is desired, overlays eliminate this particular problem.

In addition to providing satisfactory appearance qualities, protection for the substrate and, in some cases, upgrading low-quality surfaces, overlays offer a means for providing a number of specific characteristics beneficial for various end uses. Durable, hard, abrasion-resistant, and smooth surfaces can be developed. In the extreme cases, for very high-quality faces, fiber glass or metal can be used for the overlay.

Figure 18.32 from Guss (1975) shows the relative amount of the various types of finishing done in 1972 and the predicted amounts for 1977. These pie charts show the dominance of laminated-type finishes.

Surface finishes, classified as wet or laminated, consist of a variety of different types of paint, wood veneer, high-pressure decorative laminates, plasticized polyvinyl chloride film or foil, unplasticized polyvinyl film, melamine-resin-saturated paper, polyester-saturated paper (the last two are both low-pressure systems), resin-treated fiber overlays, polyvinyl fluoride film, vulcanized fiber, fiber glass reinforced plastic overlays, and metal. A variety of techniques is used for applying these finishes. Some of the pieces of equipment used are roller coaters, curtain coaters, roll printers, roll laminators, platen presses (hot and cold), pinch or nip rollers, postformers, and vacuum formers. Various means of curing liquid finishes, including ovens, ultraviolet light (UV), and irradiation are used. Microwaves, high frequency, and plasma arc are also suggested for curing purposes.

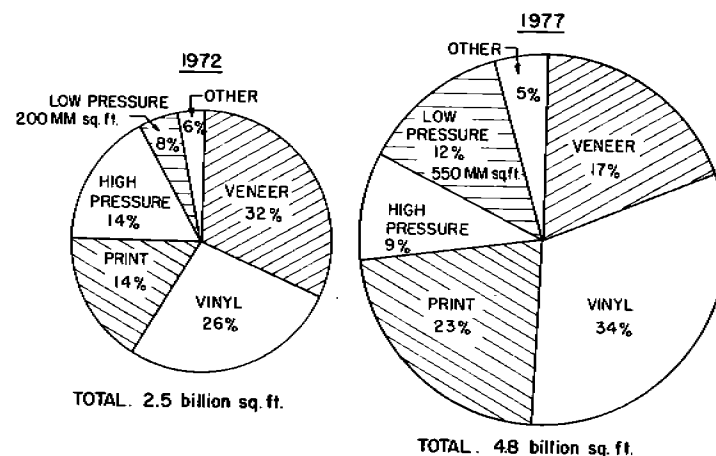


Figure 18.32. Finishes used over particleboard (Guss 1975).

An interesting surface coating originally designed for use with particleboard floor underlayment is a hot-melt wax-polymer. This coating provides a moisture barrier that improves the underlayment quality. However, a good market for this product is industrial shelving, where the wax finish makes it easy for workers to slide boxes.

Wet Finishing

The basic requirements for wet finishing composition board consist of three elements: coating equipment, drying equipment, and auxiliary machinery. The coating equipment can apply the finish by spray coating, curtain coating, direct-roll coating, knife coating, or reverse-roll coating. The drying ovens can operate as convection ovens using hot air, infrared ovens that are gas fired or electric, and the newly developed ultraviolet radiation-type drying equipment. The auxiliary equipment consists of panel feeders, brushes, sanders, burnishers, stackers, and conveying means for transporting the board panels through the finishing process. The importance of these auxiliary elements, particularly sanders and burnishers, for proper substrate preparation prior to coating cannot be ignored. Various types of finishing schemes for particleboard are shown in Figure 18.33. Many modern finishing lines now use ultraviolet for curing the filler and topcoat.

Face finish material now is far more sophisticated than that of just a few years ago. It ranges over solvent-free liquids, chemically cross-linked resins, water-base finishes, and irradiation-cured polymer systems. It is anticipated that greater advances are to come through research and development by the suppliers.

High-density hardboard can be finished directly with wet finishes, because of its dense, smooth surface. However, particleboard and medium-density fiberboard will normally need some type of preparation for final finishing, because of the voids between particles on the surfaces. Recently, more very fine material has been used on the faces of the boards that will receive high-quality finishes. This reduces the need for filling. However, with the wet finishes, some type of filling will usually have to be done. Boards over 45 lbs/ft³ density (0.72 sp gr) are recommended.

A typical wet system for treating particleboard or fiberboard is: first fill the surface; then apply a base coat; print on the highlights of a pattern with a gravure press; print on the final design; and apply a top coat.

The filler is the foundation of the coating system. In addition to uniforming the surface, it must have excellent adhesion, be hard and tough, and hold out the subsequent coats so that a deep, full appearance can be obtained.

Solvent-based fillers used include lacquer, vinyl, water emulsion, alkyd, polyurethane, and urea-alkyd. Lacquer or vinyl-based fillers have good adhesion to the substrate, excellent sanding, very fast drying by conventional oven systems, excellent recoating characteristics, and they may be pigmented to give excellent hiding properties. They have a lower volume solids, however, resulting in lower filling action, higher cost, and only fair chemical resistance.

Water-emulsion fillers have high-volume solids, good adhesion to most substrates, excellent sanding, relatively fast drying with conventional oven heating, good chemical resistance, and they may be pigmented for hiding. They are usually

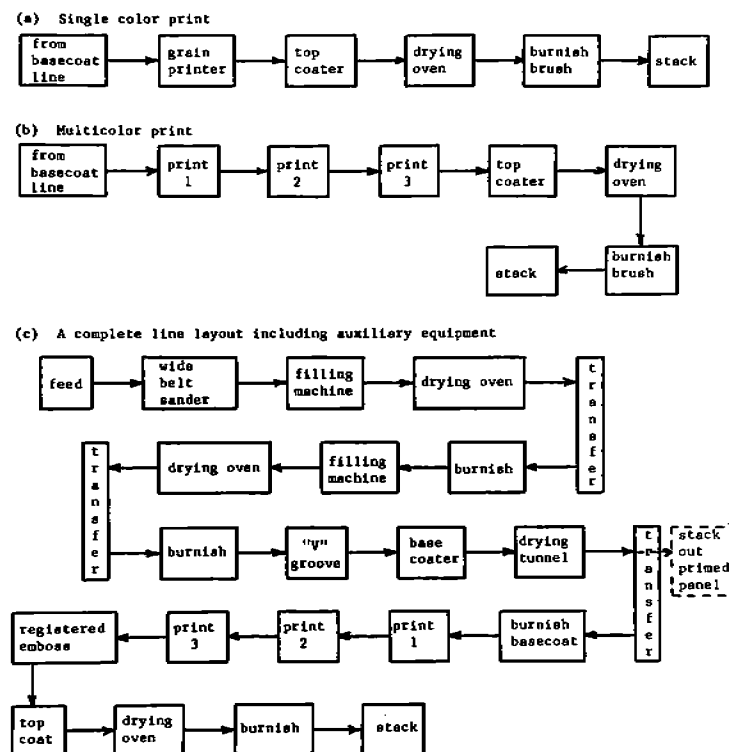


Figure 18.33. Typical particleboard grain printing (Knapp 1968).

sanded to smooth the surface before the next finishing coats are applied. They should receive at least one coat of a solvent-based material (e.g., basecoat, sealer, or topcoat) which will act as a moisture-vapor barrier. This will control flake swelling during the service life of the panel. Water-based fillers are a satisfactory means of reducing the air-polluting effluents on existing finishing lines.

Polyurethane and alkyd-based fillers have a high-volume solids level, good adhesion to most substrates, good sanding after curing, and excellent recoating characteristics. They have the disadvantage of relatively slow drying speeds.

Urea-alkyd fillers have high-volume solids, good adhesion, good sanding and recoating characteristics, and fast drying. However, they have limited pot life.

In the past few years, new fillers have been developed, based on photochemically reactive resins, primarily polyesters and acrylates. In place of a volatile solvent, they use reactive monomers (e.g., styrene, vinyl toluene, ethyl acrylate, methyl methacrylate) which become a part of the filler during curing.

A number of benefits are obtained with these ultraviolet light-curable systems:

1. Cure time is reduced by one-half or more compared with alkyd or polyurethane fillers.
2. Immediately out of the oven, the boards can be sanded to give a smooth, uniform surface suitable for printing.
3. Since there is no loss of volatile material, film shrinkage is much less than with conventional fillers. One coat of UV-curable filler will usually give a completely smooth surface.
4. Cost per square foot of polyester filler compares very favorably with alkyd and polyurethane fillers.
5. Since there is virtually no loss of volatile material to the atmosphere during the curing process, air-pollution problems are greatly reduced.

The UV energy is normally supplied by multiple groups of high-pressure mercury-vapor lamps. Each lamp consists of a quartz tube containing small amounts of liquid mercury. Upon striking an arc, the liquid mercury is vaporized by a rapid increase in temperature within the tube. The mercury vapor then emits specific wavelengths in the ultraviolet region, and this radiation provides sufficient energy to cause a rapid reaction of the photoinitiators in the coatings. The lamps also emit energy in the infrared region of the radiation spectrum, thus producing heat and speeding the reaction of the polyesters.

Ultraviolet radiation is hazardous, and direct exposure to the lamps can cause severe skin burns and eye damage. Thus, the units are shielded and equipped with electrical interlocks to prevent accidental opening while the lamps are burning. These units do have a good safety record.

There are two types of filling machines in use. They are the bottom-knife coater and the reverse-roller coater (Figures 18.34 and 18.35). The coating is applied to the bottom of the board in knife coatings. The filler is contained in a reservoir and is transferred to the board by a roller. The excess of coating on the surface of the board is removed by the knife, and this material flows back into the reservoir.

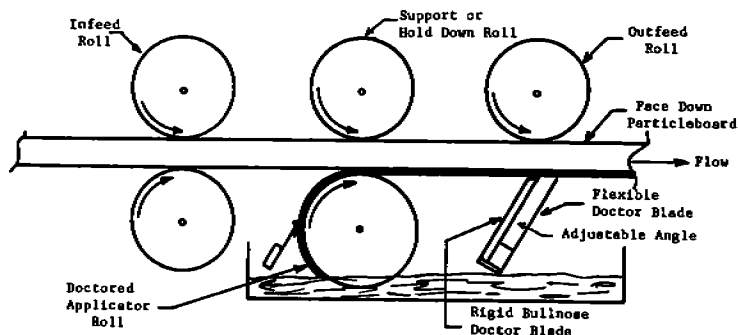


Figure 18.34. Schematic drawing of a knife coater (Knapp 1968).

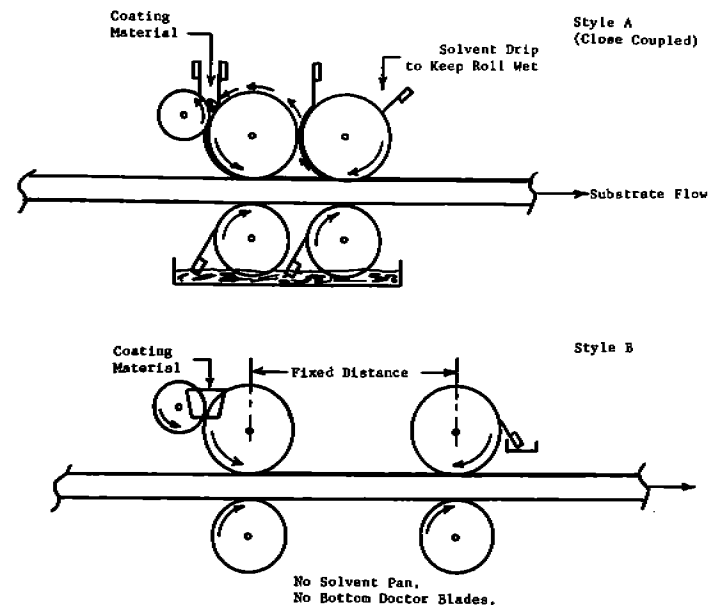


Figure 18.35. Schematic drawings of two styles of reverse coaters (Knapp 1968).

Normally, a knife coater is operated at comparatively low throughput speeds and with a high knife pressure. Because the knife is flexible enough to follow small variations in the board surface, there is very little surface buildup of the coating, while complete filling of the voids is achieved.

The upside-down operation makes it a little difficult for in-line inspection of the filling operation. Also, the possibility of damage to the filled surface is much greater than with the top side coating; so careful cleaning of conveyors and transfers is essential. Nevertheless, knife coaters are very effective where good filling with minimal surface build of the coating is required.

The reverse-roller coater is much more commonly used. The first section is essentially a direct-roller coater, followed by a doctor or metering roll. Support rolls are below the upper rolls (Figure 18.35). A controlled excess of coating is applied to the board by the application roll. The wiping roll is adjusted so that there is a snug fit between it and the pressure roll. As the board passes under the wiping roll, excess material is wiped from the surface and is removed from the roll by the scraper blade. The amount of material left on the surface can be controlled by varying the relative speeds of the application and reverse-wiping rolls. The faster the wiping roll speed, the less the amount of material left on the surface.

In newer machines the two rolls are closely coupled, so that the excess material is transferred directly from the wiping roll back to the application roll. There is

essentially no change in the coating composition from the beginning of the run to the end of the run, and there is no concentration of contaminants.

After filling and curing, the fillers are often sanded with a fine-grit belt or a flap-wheel unit, which is a slotted aluminum hub into which coated abrasive segments are loaded. These flaps of sandpaper can be used as is, or they can be partially cut into narrow strips which provide extra flexibility. These flaps or strips then whip over the panel during sanding and are particularly effective in obtaining abrasive contact with out-of-level surfaces. The panels are then brushed or blown clean and proceed to the basecoating step. Some board plants ship filled panels for final finishing by the consumer.

The basecoat or ground coat is then applied over the filled surface with a direct-roller coater, precision coater, or curtain coater. A curtain coater is shown in Figure 18.36. Precision coaters are similar to direct-roller coaters, but they can also control the texture of the coating.

Basecoats are high-solids-pigmented materials that form an opaque film. These are usually lacquer- or vinyl-based, though water-reduced basecoats are finding increased use. It should be mentioned that such coating can also be done on paper-overlaid board, veneer-overlaid particleboard, low-pressure-laminated particleboard, or composition board that does not require filling. Several coats of the basecoat may be applied. The basecoat is cured in an oven before passing through a buffer which can be a sander or a nylon mesh roll impregnated with abrasive grains. This scuff sanding can improve the quality of the print by removing high spots. All dust must be removed from the panel after buffing.

The basecoat supplies the initial undertone color for the final finish. A grain print is then applied by engraved rollers. The printing can be done in several colors with each print keyed in register to introduce an interplay of color and create the illusion of depth, wood texture, and figure highlighting. The engraved rollers are usually steel with a copper engraving which is chrome-plated to resist scraping wear. Its design is based on the principle of using many small, etched wells in various depths to hold and deposit ink. Deep wells produce dark tones and shallow wells, light tones. Each additional color requires a separate cylinder. Triple printing is necessary for high-quality prints. Machines may run with a number of cylinders, or they may be ganged up to permit multicolor to be printed in a single pass. Combination top and bottom printers are available, which print grain on

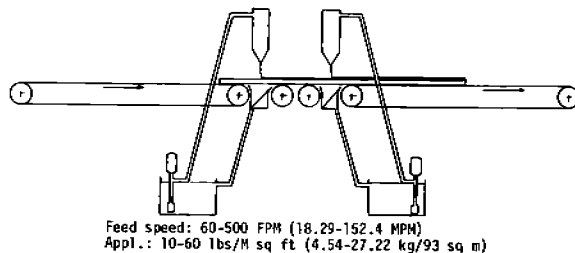


Figure 18.36. Double-head curtain coater (NPA Bulletin 10).

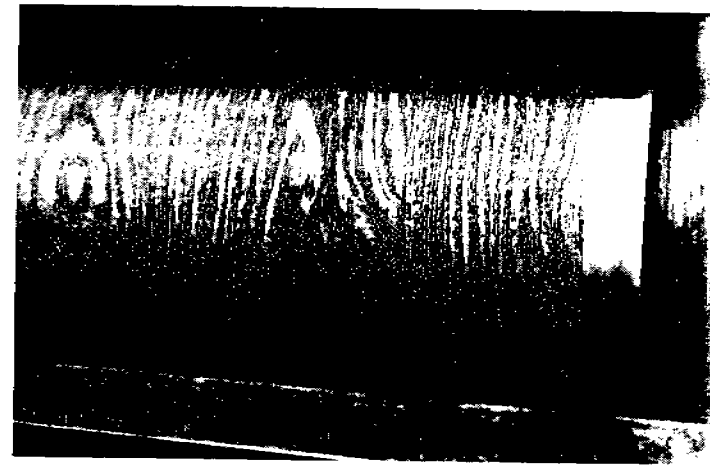
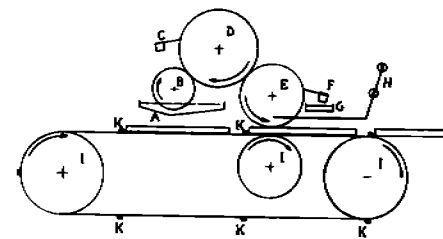


Figure 18.37. An embossing roll. (Courtesy Washington State Univ.)

both sides of the board with their cylinders synchronized to make the grain appear to show completely through. The surface can be embossed to accentuate the grain design. An embossing roll is shown in Figure 18.37. Such a roll also is used to apply ink at the bottom of the grain impressions simultaneously with the embossing. This is followed by the normal printing.

Figure 18.38 shows a one-roll printer. The ink container (A) keeps ink at constant level. The rubber application roll (B) covers the engraved print roll (I) uniformly with ink. An oscillating doctor blade (C) removes the excess ink and ink remains only in the depressions of the print roll. The rubber-covered transfer roll (E) picks up the ink in pattern form and transfers it to the panel.



Feed speed: 30-150 FPM
(9.14-45.72 MPM)
Appl.: <1 lb/M sq ft (0.45 kg/93 sq m)

Figure 18.38. One-roll printing machine (NPA Bulletin 10).

An open conveyor can be used to insure that the drying-type inks are dry before sealing. Nondrying inks must pass through a dryer. The sealer or topcoat is then applied by roller coater, precision coater, or curtain coater. A sealer is used to protect the print of panels for furniture manufacture, where additional finishing steps are to be applied. Sealers are usually nitrocellulose- or vinyl-based. If the completed composition board panel is used as is, generally a heavier coating of a more abrasion- and stain-resistant topcoat is applied as the last step. Alkyd-ureas are most frequently used, combining high build and abrasion resistance, rapid cure response, good chemical resistance, and low cost. Nitrocellulose, catalyzed nitrocellulose, vinyl, and cellulose acetate butyrate (CAB) are also used.

Fairly recently, UV-curable polyesters and acrylics have been introduced, utilizing similar technology and curing systems to the UV-curable fillers. Another recent addition is the water-reducible topcoats based on acrylic or polyester resins, cross-linked with urea- or melamine-formaldehyde resins. Both UV-curable and water-reducible topcoats will see increased use in the future as the industry moves to improve its environmental impact.

Laminating

When it comes to laminates for overlaying board substrates, there are two types: self-bonding and adhesive-bonded. Adhesive-bonded laminates include wood veneer, the familiar high-pressure plastic laminate used for many years, paper with precondensed amino and phenolic resins, film underlays with phenolic resin or amino resin impregnation and coatings, vulcanized fiber with amino resin coatings, and thermal plastic films such as polyvinyl chloride. The self-bonding laminates are newer and include melamine and polyester resin-impregnated paper. Diethyl-phthalate-(DAP) impregnated paper is another but is not used in the United States.

For successful laminating with thin films, it is important to have very fine particles on the faces of the board panel. Very fine material, previously thought to be a resin hog in board manufacture, is being used more and more for achieving smooth surfaces. The smooth surfaces, as mentioned, are needed for preventing show-through of irregularities through the thin surface in papers. It appears that more attention must also be paid to the particle size and geometry in the board core to insure a high-quality end product. If a high gloss on a film is used, irregularities are highlighted. However, most of the thin films are matte, satin or "furniture" finished, which tends to diminish this problem. Particleboard with large particles on the faces needs some type of "barrier," "cushion," or underlayment sheet underneath the film surfaces, such as phenolic- or polyester-impregnated paper (kraft). The use of panels without faces of fine particles is highly unusual in the United States.

A very low moisture content of the board can cause difficulties when the board and surface film are combined. Too high a moisture content causes stains due to the increased vaporization and also runs the risk of a poorly closed surface. Moreover, such a condition can cause overlay "blisters" and an undue shrinkage in thickness. The optimum moisture content for good bonding ranges between 6 and 7.5%.

Dense panel faces can give problems with adhesion to the films. Poorly cured adhesive joints can let go because of high tensile and shearing forces developed in the laminate. Because most particleboard has a low surface density on the outermost faces, problems can occur because of the lower strength associated with lower density. It has been found that 0.8 to 0.9 sp gr on the panel surface appears satisfactory. Thus, low-density faces must be sanded off, particularly if this has not been accomplished on the regular production line. These faces were mentioned in the discussion of density profile. The density of board for conventional laminating normally exceeds 45 lbs/ft³ (0.72 sp gr). Boards of lower densities have reportedly been used in short-cycle laminating but this is unusual in the United States.

Variations in specific gravity with thin boards are superimposed upon stresses generated by the laminating pressure. These stresses can become of such magnitude as the board shrinks and swells, due to changes in humidity, that stress cracks form in the laminates. Thin boards surfaced with melamine-resin overlays, ultraviolet-cured polyester underlays, and hard urea resin coatings are particularly susceptible.

It is also possible to laminate some overlays onto particleboard during the actual pressing of the particleboard. This is becoming of more importance with the thinner boards that are now being produced, particularly the continuous type where surface layers can be rolled upon the formed mat as it enters the hot press. In this case, almost perfect forming of the mat is necessary to keep a uniform density over the entire area of the final board. Let us now turn to the major types of overlays and their applications.

Wood Veneer: High-quality wood veneer overlays, of course, are a premium product as far as quality is considered in the marketplace. Particleboard and medium-density fiberboard have become the premier substrates for use with quality wood veneer. In fact, core-type hardwood plywood, which is a major product, consists of the hardwood veneer over the particleboard or fiberboard substrate. Most of the volume of the material is composition board, not hardwood plywood.

Wood veneer is also used for crossbands over the composition board substrate before high-quality veneer is applied to reduce telegraphing problems. Wood veneers such as tupelo, maple, and birch are laminated onto board to provide a base for subsequent printing or film overlaying. Veneers are applied to the substrate by conventional hot- or cold-pressing means developed over many years, and much experience has been gained in this type of laminating. Care must be taken to equilibrate the veneer and substrate to about 7% moisture content before gluing to minimize checking problems. Telegraphing is a problem with veneer laminating; consequently, exposing the substrate to high humidities before gluing and the use of glues with high water content should be avoided.

High-Pressure Decorative Laminates: High-pressure decorative laminates have been around for many years. They consist of printed papers which have been saturated with thermosetting resin, generally of the melamine-formaldehyde type and bonded to multiple layers of phenolic-impregnated kraft paper under high heat and pressure. This is a high-cost product with excellent impact and abrasion resistance, good chemical resistance, and durability. It should be used where the

high-performance properties can be best utilized. These uses include tabletops and countertops and other horizontal surfaces on furniture, kitchen cabinets, and on bathroom walls.

The pattern sheet of the composite is a high-quality pigmented alpha-cellulose paper, which is printed generally in up to four additional colors for optimum appearance quality. The sheet is impregnated with melamine resin and a water-alcohol solution and then dried. A clean alpha-cellulose tissue highly impregnated with melamine is assembled over the dried patterned sheet, and these in turn are placed over several sheets of phenolic-impregnated kraft paper. The assembly is then bonded and cured in a press operating between about 250° and 280°F (120°–138°C). Pressing pressure ranges between 1100 and 1400 psi (7.58–9.65 MPa) for periods varying from 45 to 60 minutes and longer, depending on the type of material being made. These laminates must be cooled in the press and the cooling time may be as long as the heating period. The resultant high-pressure laminate is in turn bonded to the wood substrate using contact-type adhesives, polyvinyl acetate (white glues), hot melts, urea-formaldehyde adhesives, casein, etc., for interior or protected applications and resorcinol or similar waterproof adhesives for exterior use. Where high laminating pressures under heat are required, phenolic-bonded high-density board is normally used.

For interior-type applications, the contact-type adhesives offer an advantage which the others do not in that they are suitable for on-site installation and do not require clamping or platen pressing. They provide the most versatile means of installing decorative laminates and have been one of the major reasons for the use of laminates. These adhesives have also been the cause of many problems when they have been used improperly.

Polyvinyl Chloride: One of the best-known overlay materials is polyvinyl chloride (PVC) film. There are two types: plasticized film and rigid. When applied in a plant, the film is usually in a pure form and is bonded to the substrate with an adhesive in a roll-laminating process. This film can be printed and embossed. Prints on the outside of the film can wear away in areas receiving severe abrasion. This has been overcome by printing the pattern on the reverse side of the film, which is placed next to the substrate. The back print is then covered with a ground coat or color coat which masks the substrate and adhesive. With wood grain printed pattern, the back printing technique has a degree of realism very difficult to attain otherwise. It is also possible to put a clear protective film over any of the films where face printing is desired, and this is a common practice.

It is reported that polyvinyl fluoride overlaid PVC film is nearly equal to ceramic tile in stain-resistance and cleanability. This two-sheet laminated overlay is valuable for the manufacturer of vinyl-clad panels which are folded for cabinet or furniture parts. This system is used for making finished products of square, rectangular, or polyhedral shape. The first step consists of lamination of the board with the flexible plastic sheet. Then accurate miter-grooves are cut through the substrate in the desired locations. Adhesive is then metered into the grooves and the panel is folded into the desired shape, using the flexible plastic sheet as hinges. Figure 18.39 shows some typical configurations that are possible. When back-printed film is used, cutting into the film results in an undesirable and distinct white line. But, by using face-printed film (usually with a protective film on top),

overcutting to a considerable depth is possible before it is visible from the face.

The back- or reverse-printed film is normally about 3 mils (0.08 mm) thick. The volume market for the face-printed film, which has a clear film laminated to the top, calls for 6-mil (0.15 mm) material (commonly 4-mil [0.10 mm] film for printing with a 2-mil [0.05 mm] overlay or a 3-mil [0.08 mm] film for printing with a 3-mil overlay).

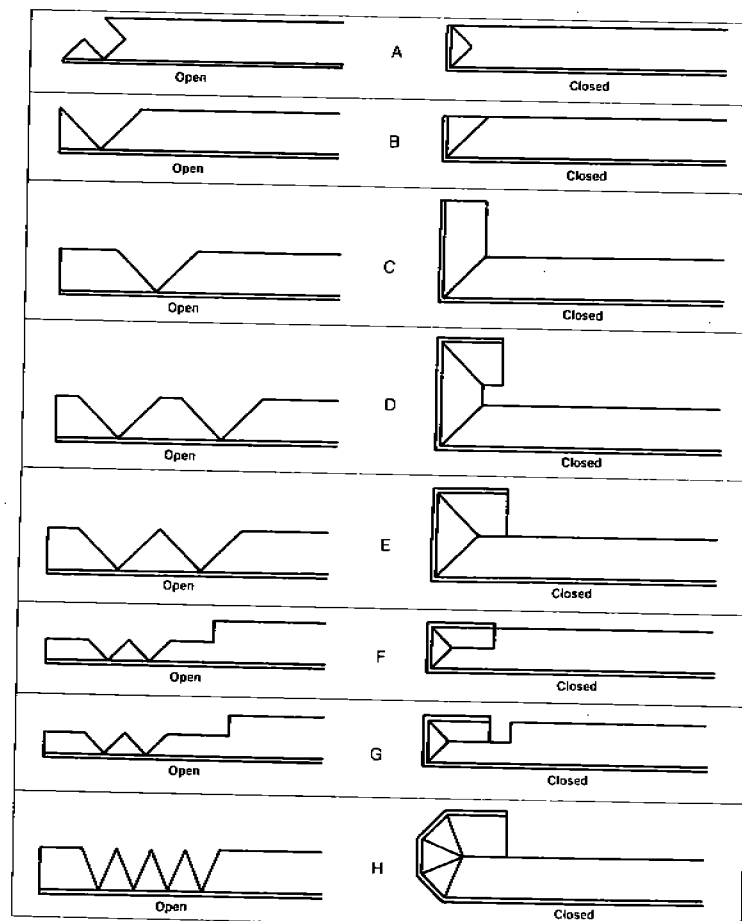


Figure 18.39. V-grooving process permits many simple as well as complex forms to be accomplished in uncomplicated grooving, folding, and gluing procedures (NPA Bulletin 13).

Adhesives are necessary for bonding vinyl film to wood-based panels and generally are of two classes: water-based (polyvinyl acetate) and solvent (polyester or polyurethane) which are applied to the substrate. Epoxy is being used more and more and has the advantage of being 100% solids, thus, there is not any solvent to evaporate. The solvent-based systems are two-part materials and are considered to produce the maximum overlay bond strength. The water systems are usually thermoplastic and are the types most commonly used. Whichever system is used, the adhesive must be resistant to the plasticizers that can migrate from the PVC film. The bond of the film to the panel should be sufficiently strong to resist film creep or shrinking away from the panel edges.

Application equipment for this system can be relatively simple (Figure 18.40). The essential parts consist of rolls to tension the vinyl sheet, a heating unit to soften the film and make it easier to handle, an adhesive applicator roll to apply the adhesive to the film, a heater to flash off the water and also soften the film, and nip or pressure rolls to provide intimate contact between the film and the panel substrate. In some cases, the adhesives may be applied to the panel substrate rather than to the film. Folding and tucking rolls may be used for the edge wrapping of the panel, as pointed out earlier. An embossing roll is normally used to emboss a realistic wood grain effect. Figure 18.41 shows a laminated panel leaving the press.

Vinyl films can also be applied to wood substrates, particularly those with three-dimensional characteristics, by vacuum lamination. The substrate material should be between 6 and 10% in moisture content. It is first shaped for profile to desired contours. The curves and corners are rounded, avoiding 90-degree angles.

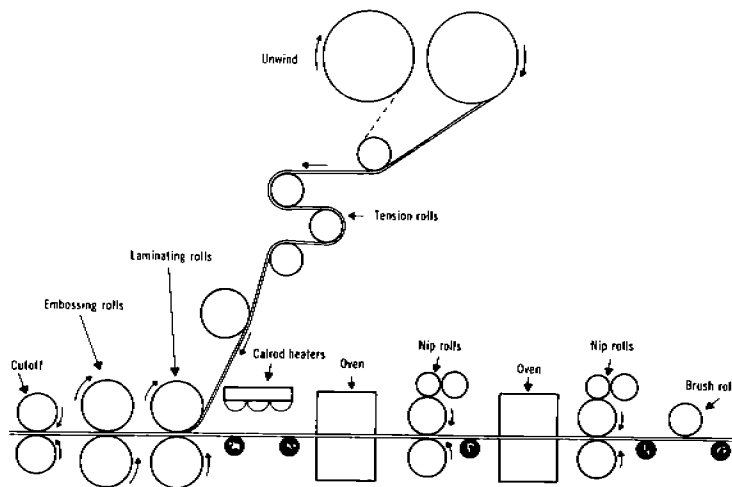


Figure 18.40. A typical direct-roll coating system for application of vinyl film to particleboard (Using Particleboard 1972).

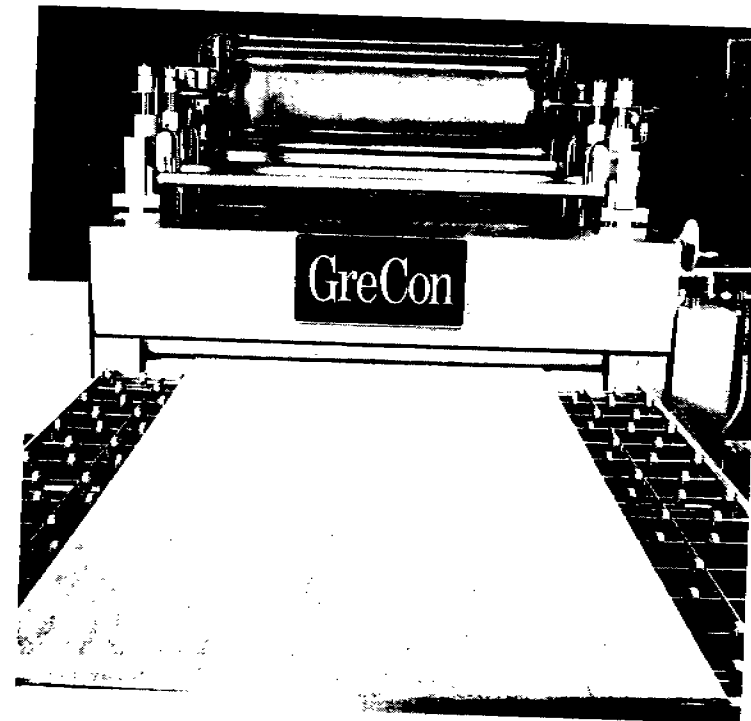


Figure 18.41. A vinyl overlaid panel leaving the press (Wentworth 1972).

Next, the part is spray-coated with a thermosetting resin. Only one coat of adhesive is necessary on dense substrate surfaces, whereas two coats may be necessary on low-density surfaces and edges. A part or a number of parts are then placed on the platen of a vacuum-forming machine. This platen is perforated with holes. Next, the vinyl film is placed in position above the workpiece and clamped into position. The film is then heated from above, while air is forced up from below, relaxing the film. The air trapped under the film is then evacuated to a reserve tank below the assembly, creating a vacuum below the film. Next, the film is drawn down to cover the part's surface and edges. More heat is then applied to the film until the glue line is activated. The heat is then removed and the part cooled while still under vacuum. Cycle times for this system are about four to five minutes in duration. The plasticized PVC film used on wood substrates is restricted to interior applications such as for wall paneling and furniture.

Fabric-backed or supported vinyl film, which is used in field applications, can be used for special cases in a plant because the greater thickness lends itself to deep embossing. Textured wood pattern is one example.

Unplasticized polyvinyl chloride film (rigid PVC) is formulated without a plasticizer and is normally thinner than the plasticized material. Thicknesses of 10 mils (0.25 mm) or more are known; however, 1.7- to 1.8-mil (0.04–0.05 mm) film is the volume market. The material is roll-laminated to board substrates. It is reported that a great market potential for this material is in residential siding products, where the chemical resistance, color durability, and low maintenance qualities of the exterior weatherable PVC can be utilized.

Low-Pressure Decorative Overlays: Of great importance in the industry today are the low-pressure decorative overlays. The first was diallyl phthalate (DAP) which was first developed (in the United States) about 1960. By 1964, an overlay material had been developed in straight polyester or melamine systems or combinations of the two.

Polyesters were most popular through the 1960s. Later on, European melamine-resin manufacturers came out with hot press and treating equipment packages for producing melamine-faced board panels in short cycles. A single-opening, fast-cycle system for 5x18-ft (1.52x5.49 m) panels was introduced in the United States around 1970, and several of these plants are operating or about to start operations. One will produce 8x24-ft (2.44x7.32 m) overlaid particleboards in one minute or less. These overlays can contain a decorative pattern or they can serve as a paint substrate.

Before pressing, polyester overlays are flexible and virtually tack free. Melamines are also quite tack free but are more brittle and may fracture if not handled carefully. Polyesters have a longer shelf life and can be successfully stored for six months or more at 65° to 70°F (18°–21°C). Melamines, however, slowly become more brittle and should be used within 30 to 60 days provided they are kept at 65° to 70°F (18°–21°C). Less advanced resins can be used in melamines to prolong their storage life in cases such as overseas shipments. Longer press times, however, are required.

The polyester-type overlay is alpha-cellulose paper treated with polyester resins ranging in resin content from about 52 to 62%. Most of the pressing at present is done in multi-opening presses at specific pressures of about 150 to 250 psi (1.03–1.72 MPa) and temperatures between 270° and 350°F (132°–177°C) at the board surface. In overlaying with both polyesters and melamines, press pads can be used between the press platens and pressing plates which are in contact with the overlays. West Coast U.S. plants, however, are mostly operating without press pads. Press or cushion pads tend to distribute the pressure uniformly over the panel being laminated and are particularly useful with panels of uneven dimension. Release papers are normally used to prevent sticking to the press platens and to provide the type of finish desired (smooth or textured). Pressing time in these presses is about one to two minutes for single-opening presses and five to eight minutes for multi-opening presses. This is time under pressure and does not include loading, unloading, press opening, and closing. The overlaid panels are hot when pulled from the press.

These polyester overlays are nonshrinking while curing and are consequently stress-free and nonwarping if cooled flat. Polyester is tougher and more resilient than melamine. In addition, polyester overlays exhibit less checking, greater impact resistance, and superior machinability.

The production of the overlays based on melamine-resin-saturated alpha-cellulose paper is rapidly growing in importance. The melamine-formaldehyde resin used has modifiers added to it to enhance the elasticity of the hardened melamine resins. Other materials are added to the resin solution, which later on improves the impregnation of the paper and helps prevent films from sticking to the platens.

The base papers for the decorative films are alpha-cellulose papers, which are used almost exclusively. For impregnation, these papers must have a high wet strength and the right porosity to accept the proper amount of resin. The board laminate consists of one to three papers: an overlay sheet, a decorative sheet and a barrier (or base) sheet. Barrier sheets are not known to be used in the United States. Most U.S. board has very smooth surfaces, eliminating the need for such sheets, which are used to cover porous surfaces. It should be mentioned that balancing papers are also normally used on the back of the board so that, after it is laminated, warping will not occur. In some cases, the same type of melamine overlay is used on both sides of the panel. In this way, if some minor defect happens to occur on one side, the other side is still perfectly acceptable for a top-grade face, and warping problems are minimized with identical papers on both sides.

The melamine-saturated papers usually contain 50 to 55% resin. The overlay or cap paper is an unfilled alpha-cellulose paper which, upon pressing, becomes transparent and protects the decorative paper lying underneath, particularly against wear and tear. The use of a cap sheet is popular in the United States on the wear side of panels. To improve abrasion resistance such cap sheets can also be used on polyesters. It has already been mentioned that the decorative papers are either pigmented solid colors or pigmented sheets with a wood grain or random design in one color or multi-color prints. It should be mentioned that these colors must be fade-resistant and compatible with polyester resins and solvents used in polyester and melamine resins.

Not much melamine overlay is applied in multi-opening presses in the United States. Special handling is necessary to prevent precure of the resin when loading this type of press. In the instances where such laminating is done, press times between two and eight minutes are reported at temperatures ranging from 280° to 330°F (138°–166°C). Pressures are higher than used for polyester, being about 350 psi (2.41 MPa). Release papers can be used to give smooth or textured surfaces.

Melamines shrink slightly during curing; consequently, they must be handled carefully if laminated to thin substrates below ½ in. (12.7 mm) in thickness. Warp problems, which will be covered later, must be handled. In comparison to polyesters, the melamine surfaces have better scratch resistance at the same resin level.

Formerly, relatively long times were always necessary for applying these types of decorative surface laminates. However, there has been a clear move to high temperatures at relatively short pressing times, made possible by the development of better resin systems.

A great step forward in this type of laminating is the previously mentioned short-cycle process with single-opening presses where lamination is accomplished in about one minute. High-gloss finishes so far have not been possible with this type of finishing. For most applications in the United States, high-gloss finishes are not desirable because any slight imperfection in the overlay or substrate is shown up. Resins with very short cure times (from 20 to 30 seconds or

less) are now available; thus, very fast press times are possible. These fast-curing resins require, however, that the time between initial contact of the film with a hot heating platen or plate to the time it takes to reach a specific pressure of approximately 120 psi (0.83 MPa) must not exceed a value of 15 to 20% of the condensation time. This means that in the case of a condensation time of 30 seconds, loading of the press, closing of the press, and generating of sufficient pressure must not exceed a time of about 6 seconds. Therefore, once the board and overlays are inserted into the press, maximum pressure must be applied quickly or the fast-curing resin in the overlays will polymerize before good bonding to the substrate takes place (referred to as *precure*).

Polyester laminating is accomplished in about 1 minute (40 seconds for resin cure and 20 seconds for unloading and loading in the press). Pressures range from about 175 to 220 psi (1.21–1.52 MPa). Release papers are usually necessary.

Melamine laminating takes about 80 seconds (60 seconds for resin cure and 20 seconds for press unloading and loading). Pressing pressures range as high as 350 psi (2.41 MPa), and resin curing temperatures range from 310° to 350°F (154° to 177°C). Release papers may or may not be used. The use of polished chrome-plated pressing plates and melamine containing a release agent often eliminates the need for release papers.

It must be kept in mind that there are many variations of the low-pressure laminates available and that the figures given here are intended as guidelines.

Plants equipped to overlay with melamine can usually operate with polyesters, but the reverse may not be true because of the higher pressing pressures required.

One system in use loads the press by means of a tray-belt on which the composition board with top and bottom overlay is aligned, as shown in Figure 18.42. Unloading is done by a traveling vacuum lift, which travels into the open press and carries out the finished board; or the bottom caul travels out of the press and a vacuum lift behind the press carries the board via an intermediate storage station to the finished board stack. The press plates and press pads (if used) usually remain in the press. In case a vacuum lift is used for unloading a press, the bottom heating platen is usually controlled differently than the top heating platen with regard to temperature. This is necessary to avoid differential curing rates between the top and bottom overlays, as the bottom overlay is in contact with the heated platen longer than the top overlay.

Another type of short-cycle laminating which has been developed is a vertical laminator as illustrated in Figures 18.43 and 18.44. The substrate is cleaned and transferred to the vertical position by a special vacuum lift. The overlay papers are placed in positions and "tacked" there by means of a gluing process. The sandwich is then fed into the vertical press, and heat and pressure are applied simultaneously to both faces of the panel. In both systems the finished panel is then edge trimmed with conventional equipment.

Vulcanized Fiber: Vulcanized fiber has been successfully bonded to wood panel products for many years. It possesses some properties such as toughness not matched by the more common resin-treated fiber overlays, but it has not been able to compete economically with the medium-density overlay products. A paperlike sheet is made from chemically converted cotton cellulose generally treated with zinc chloride and is felted into a multi-layer product of whatever

thickness is desired. It is very tough and dense and has excellent electrical properties. Many of its properties, such as dimensional stability, are quite similar to those of wood. Modified polyvinyl acetate and resorcinol adhesives provide durable exterior quality bond on wood-based panel products. An important use for vulcanized fiber has been as crossbanding in the furniture industry under fine hardwood face veneers applied to plywood, particleboard, or lumber core panels. The sheet provides a stabilizing influence on the thin hardwood overlay and resists telegraphing from the core panel.

Resin-Treated Fiber Overlays: Resin-treated fiber overlays are another important surfacing for wood-based panel products. They consist of cellulose sheets or papers which may be plain, bleached, dyed, or printed, saturated with a resin such as phenol formaldehyde or polyester, and then hot-press-bonded to the wood substrate by heat and pressure. Some systems contain sufficient resin to be self-bonding, while others require secondary adhesive.

High-density overlays are described as a surfacing that is hard, smooth, and of such a character that further finishing by paint or varnish is not necessary. These overlays consist of a cellulose-fiber sheet or sheets containing not less than 45% resin solids based on a volatile-free weight of fiber and resin, with the resin being a thermal-setting phenol or melamine type.

Medium-density overlay is a resin-treated facing that presents a smooth, uniform surface intended for high-quality paint finishes. It consists of a cellulose fiber sheet containing not less than 17% resin solids for a beater-loaded sheet, or 22% for an impregnated sheet, both values based on the volatile free weight of resin and fiber exclusive of glue line. The resin can be a thermosetting phenol type, or a combination of polymers that will pass performance standards of U.S. Product Standard PS 1-74 for Construction and Industrial Plywood. Commercial production is usually hot press laminating, but roll laminating has been done.

A light-weight, medium-density type overlay is manufactured particularly for use with particleboard and insulation board. This phenolic resin-treated paper weighs approximately 33 pounds per thousand square feet without the glue line. When bonded with phenolic adhesives and finished with conventional paints, it performs very well on products for which it is designed. Considerable production of a fiberboard siding product overlaid with this type of material and preprimed and/or prefinished at the factory has been performing well for several years.

Polyvinyl Fluoride: Polyvinyl fluoride overlay is supplied in a variety of thicknesses, up to about 2 mils (0.051 mm). It is commonly roll laminated onto products such as hardboard, utilizing a modified epoxy adhesive. The adhesive is applied to the board, the solvent flashed off, and the film nip rolled to the substrate. The overlay possesses excellent color retention, good chemical resistance, and has good abrasion resistance. However, it is expensive, which limits its use. It has been used on some residential house siding (particularly plywood), where its weathering properties are excellent.

Specialized Overlays: Specialized overlays, such as fiber glass, reinforced plastic, and metal, have not found widespread use in the composition board industry as yet. However, their success with certain plywood products fore-shadows the possibility of more use of these types of products taking place in the future.

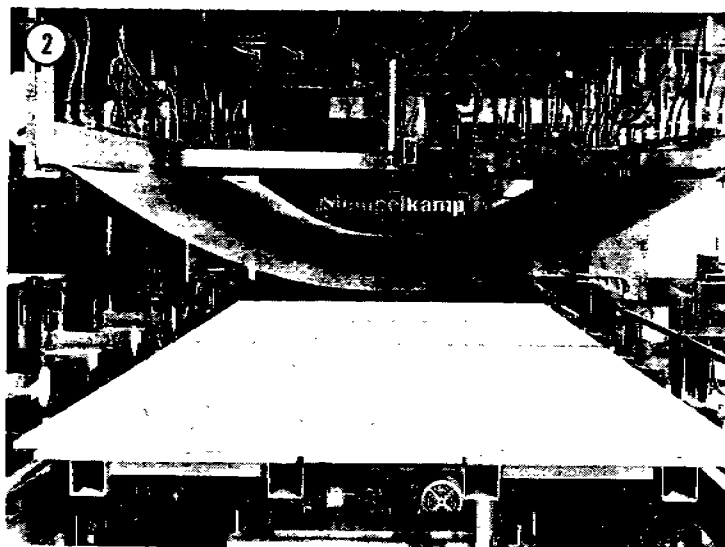
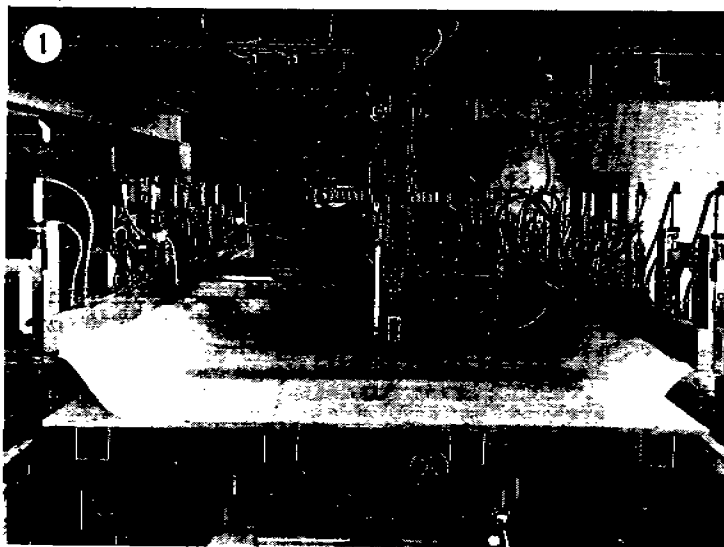
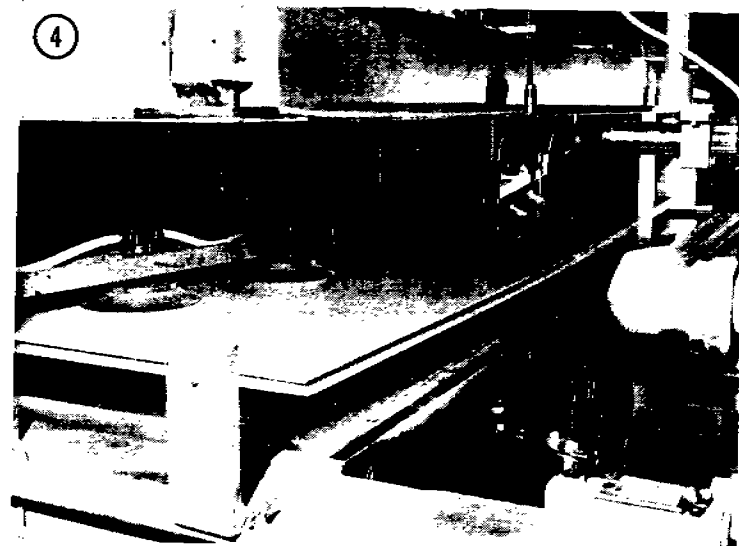
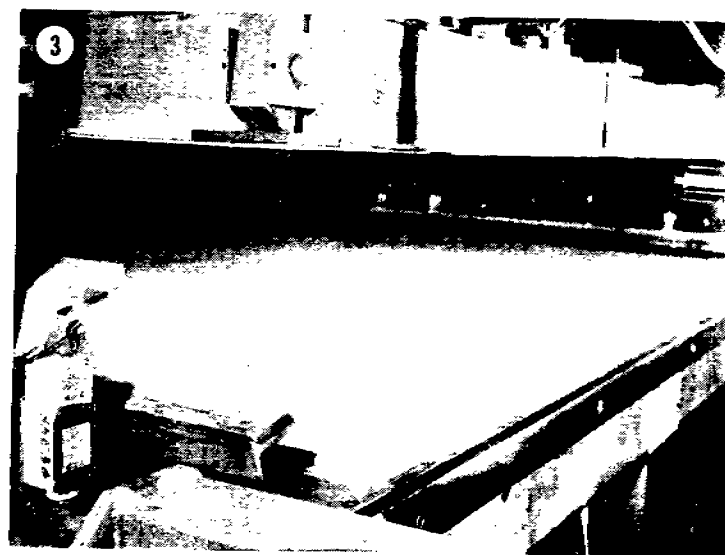


Figure 18.42. A short-cycle press line for overlaying. The four photos show assembly of resin-treated papers with board substrates and press loading. (1) Laydown and positioning of bottom surface papers. (2) The top papers are



positioned over the substrate. (3) The assembly is then clamped prior to being loaded into the press. (4) Finished board is ready for unloading. (Courtesy Siempelkamp Corp.)

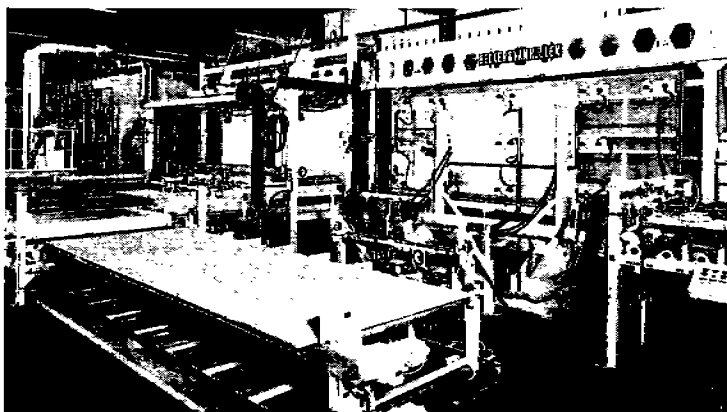


Figure 18.43. The panel in front is raised into vertical position by means of a movable vacuum table shown in rear. Resin-impregnated papers are then fixed to the panel. (Courtesy Becker & van Hüllen.)

Warp

Composition boards must stay flat in service conditions, particularly when they are unsupported in modes such as cabinet doors. Wood products have tendencies to warp because of unbalanced construction either from natural causes, such as differential shrinking and swelling between summerwood and springwood, or from man-made causes in panels, such as particleboard where a skewed density profile is developed. Nothing can be done about the natural causes of warping found in lumber and, to some extent, in plywood. If the composition board is produced properly, however, such sources of warp should not exist. However, the man-made causes of warp must be considered and handled. A secondary manufacturer is at the mercy of the board manufacturer in that he has no control over the way the board was produced. However, a secondary manufacturer can induce problems such as a skewed density profile in the panels by sanding only one side of a board he receives, which can result in warp problems.

The type of unbalanced construction developed by sanding can be handled by proper care. Such a panel should not warp when subjected to the forces induced by moisture changes. However, upon applying decorative plastic laminates and backing sheets, differentials in response to the changes in moisture content can cause an imbalance within the panel. These stresses caused by the differential movement are a major cause of warpage in the field. Much of the warpage is created because of different stresses within the materials which are originally bonded together into the laminated composition board final product. There can also be an unequal stress as exerted by the laminate material on opposite sides of the board. This can be caused by having unequal thicknesses of the sheets of material or by having different types of material.

Temporary unbalance can also be caused by unequal rates at which the laminates and backing sheets change dimensions. When decorative laminates and backing sheets are exposed to high relative humidities, backing sheets have been found to attain their maximum expansion in about one day and decorative laminates in about one week. When panels of unbalanced construction are exposed to such moisture conditions, it is common for the warp to occur in the opposite direction to that logically expected, based on the unrestrained dimensional characteristics of the panel components. This reverse movement can be misleading if conclusions about the warp proneness of a particular construction are based on too short an exposure to different humidities.

It is important to condition all the materials to the same relative humidity conditions before lamination takes place. It is recommended that exposure to about 40 to 45% relative humidity for seven days will accomplish this objective but local conditions must be considered. Ideally the backing sheets should exactly offset the longitudinal shrinking or swelling of the laminate on the opposite side in order to prevent warping. The ideal backing sheet not only responds to the moisture change just as the laminate does, but also transmits as much stress to the core as does the laminate. An ideally constructed panel would use the same laminate on both sides of the core. This may be feasible on thin boards that are exposed from both sides, such as used for cabinet doors. However, the laminate is more expensive than backing sheets and, whenever possible, backing sheets are used, running the risk of differential characteristics between the laminate and the backing sheet.

It should also be pointed out that laminates and backing sheets may have a machine direction and exhibit very different expansion and contraction rates in response to changes in moisture content. It may be found that linear movement across the machine direction of the sheets is twice as much as that in the machine direction. This must be taken into account when laying up the package of materials prior to final laminating. It has also been found that the elastic-type adhesives such as rubber-base contact cements reduce somewhat the amount of stress transferred to the substrate by the face laminate, which reduces the tendency for warping.

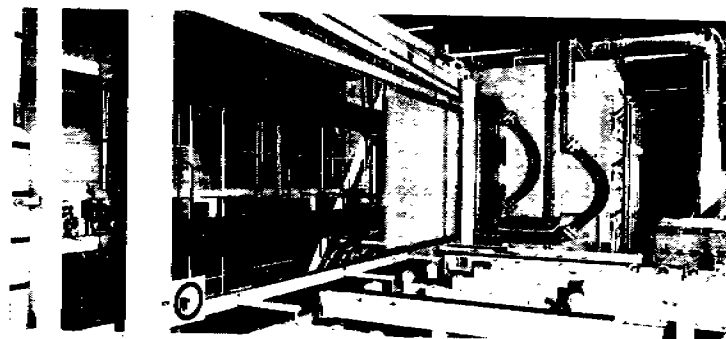


Figure 18.44. Finished panel leaving press. (Courtesy Becker & van Hüllen.)

Some cabinet tops which are fastened down can be made with these adhesives and no backing sheets.

It is also important to consider stabilizing the back or bottom face of a panel that has been wet finished on the top. Thus some sort of back sealing can be used for providing the same type of restraint on both sides of the panel.

Edge Finishing

A number of different edging materials are used, particularly with the thicker products such as particleboard and medium-density fiberboard. Wood strips can be edge banded to the board and these strips can be profiled to the preferred shapes, using conventional routers and shapers. Plastics can be used to fill the edges, and these plastics can be later finished similarly to the top of the panel. A molded polyester system has been developed that uses a carved wooden design to make silicone rubber molds. Exotic patterns can be thus developed and the polyester edge banding on the wood paneling will reflect accurately this pattern right down to the wood grain and pores. Other materials used for edge banding are vinyl, resin-free wood fiber which needs final finishing or which can serve as the backing of vinyl films, resin-saturated wood fiber, high-pressure plastic laminates, and wet finishes. The most widely used continuous decorative edge banding is a polyester decorative paper combination, generally in the same pattern or solid color used on the low-pressure or high-pressure laminate surface.

The wet finishing is similar to that found with surface finishing where filling and the application of graining, ground coats, printed designs, and a topcoat take place. Miter folding or V-folding of vinyl simultaneously with its application to the surface of the panel has already been mentioned. Also previously mentioned was vacuum forming of vinyl over three-dimensional configurations on a panel. T-molded pieces of plastic can be used for edge banding where the vertical member of the T is fitted into a slot cut into the edge of the panel.

Another type of edge finishing takes place with postforming, where the edges and surface, as with V-folding, are covered with one sheet of laminating material. In postforming, a rigid plastic laminate is molded to the shape of the substrate. Heat is first applied until the plastic becomes pliable. This must be controlled precisely; otherwise, cracking will occur if the plastic laminate is too cool or blistering will happen if the laminate is too hot. The pliable part is then held by the postforming machine against the substrate until the adhesive has cured. This is the popular method for applying a laminate to a countertop where a curved or rounded front edge is desired.

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19.

ENVIRONMENTAL PROTECTION

It is no secret that there is a great emphasis on environmental protection throughout the world and in particular in the United States, where no state may adopt standards lower than those that have been specified in federal regulations. The Clean Air Act of 1970 stipulates that prescribed ambient air standards and emission standards must be complied with no later than July 1, 1975 or 1977. The 1975 deadline was for the Primary Standard protecting the health and welfare of the people. The 1977 deadline is for the Secondary Standard which covers protection of vegetation. The Federal Water Pollution Control Act classifies all river and lake waters in the USA in regard to permissible uses and minimum permissible quality. Guidelines for waste effluent properties are in the process of being defined for all major pollution sources and compliance will be enforced by 1977 at the earliest or 1983 at the latest, depending on the pollution category and available technology. An additional goal has been established to require achievement of zero discharge for all water pollutants from all point sources by 1985.

The particleboard and fiberboard industry has provided great assistance to the forest products industry by utilizing waste materials previously disposed of by burning, and such utilization has had a tremendous impact on reducing both wood waste and pollutants while returning a profit on the enterprise. However, while these new manufacturing complexes are relatively much cleaner than the old-time sawmill, environmental problems exist in these industries which have been operating on material that was once considered waste. The main problems with pollution in board plants are found with steam- and power-generating facilities; open-air storage of particles where wind forces can scatter the particles around the locality, causing a general nuisance, or where wood extractives can be leached out with the possibility of subsequent pollution of the ground and surface water; offgases from particle dryers, especially when they are direct-heated; volatile vapors and dust from resin blenders; dust escaping from cyclones that handle sander dust or other small particulate matter; vapors from secondary processing where volatile solvents are used in finishing; and flyash and smoke from waste burners. Other problems can be found with hydrocarbon vapors and odor from oil-tempering lines for treating hardboard and with formaldehyde release from the hot press. A further type of pollution is found in noise that is associated with milling equipment, dryer burners, high-pressure blowers, high-pressure pumps, sanders, and sawing equipment. The problems with sanders and sawing equip-

ment were discussed earlier necessary to change the equipment, or go to an entirely different specifications.

Solving such problems, however, while in others the been estimated to increase in addition, maintenance and course, throughout the United States, having to handle the same type not have such regulations on them. Some people may feel that environmental control policies market. However, this may rarely interested in polluting the

Water pollution is not a problem that must be handled. A source the cleanup water needed for along with the cleaning of the water. Other minor sources coming from pressurized refills there may be some water fire treated.

The 1972 Amendments to U.S. Environmental Protection point sources of discharge levels of technology involve technology currently available discharge by July 1, 1977. It exemplary plants of various sizes. Level II technology is the best must be attained by all point sources of technology is based on the technology or which is transferred industry or which is transferred. Possible methods for use in incineration of the polluted water being used and perhaps is the relatively small amount of water

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ment were discussed earlier. With any noise-producing equipment it will be necessary to change the equipment, remodel it and close it in soundproof chambers, or go to an entirely different type of equipment in order to meet noise specifications.

Solving such problems, where the solutions in many cases have been long overdue, while in others the "problems" that exist are still being debated, has been estimated to increase the capital cost of a plant by as much as 30%. In addition, maintenance and operating costs are also increased. All plants, of course, throughout the United States as well as in most parts of the world, are having to handle the same type of problems by government edict. If a country does not have such regulations now, it appears it will not be long before it does have them. Some people may feel that developing countries may not pursue such tight environmental control policies, thereby gaining a competitive edge in the export market. However, this may not be true because these countries are not particularly interested in polluting their own air and waterways.

WATER POLLUTION

Water pollution is not a great problem in board plants, but problems do exist that must be handled. A source of contaminated water, for example, is found with the cleanup water needed for purging resin and wax containers and lines. This, along with the cleaning of the blenders, results in a certain amount of polluted water. Other minor sources are also found, for example, with water leakage coming from pressurized refineries. If a coating plant is a part of the board plant, there may be some water from this part of the facility that will also have to be treated.

The 1972 Amendments to the Federal Water Quality Control Act call for the U.S. Environmental Protection Agency to develop effluent limitations for all point sources of discharge exclusive of publicly owned sewage. There are two levels of technology involved. Level I is defined as the best practicable control technology currently available and it must be achieved by all point sources of discharge by July 1, 1977. It is based on the average existing performance by exemplary plants of various sizes, ages, and types of processes within an industry. Level II technology is the best available technology economically achievable and must be attained by all point sources by July 1, 1983. Performance under this level of technology is based on the best control and treatment technology existing in an industry or which is transferable from another industry.

Possible methods for use in the board industry are lagoning, evaporation, and incineration of the polluted water. The sewage lagoning technique is one that is being used and perhaps is the best one to follow at the present time because of the relatively small amount of waste water that is found in a dry-process board plant.

AIR POLLUTION

Two types of air pollution occur in board plants: dust and offgases. The board plants in every state are subject to one or more types of air-quality standards enacted either specifically for the particular board industry or for a broad range of

source types. Under federal law, full compliance with state standards was generally required by April 1975, with demonstration of compliance by July 1, 1975.

Board plants are a source of concern in air pollution to the extent that they contribute to community problems associated with suspended particulate matter and particle fallout. As an industry based on the utilization of coarse and fine wood residues with extensive use of pneumatic materials-handling systems, the board industry has a problem with particulate emissions. Sources of the particulate emissions can be placed in three categories, distinguishable by the nature of the source and the type of problem attributed to it. These include: combustion sources, truck dump and storage areas, and cyclones. With combustion sources a problem occurs with smoke and particulate matter. This can result in localized fallout or particulate matter suspended in the air throughout the community. Familiar sources of this type of problem are boilers, wigwam burners, and open-burning pits. From truck dumps and storage areas, a localized nuisance occurs from wind-blown particles. Cyclones, as used for many years with particle generating equipment, dryers, classifiers, sanders, and other materials handling equipment, have resulted in localized nuisance problems with particle fallout. Some of this very fine material can also contribute to the particulate matter in the air over a community.

Industry-wide emission standards, whether based on visible emissions, grain loading, or a certain number of pounds per thousand pounds of flue gas, are used to establish standards on combustion sources. As is well known, some of these, such as wigwam burners and open-burning pits, have had to be eliminated almost completely for compliance. Sophisticated systems for making smokeless burners have also been developed. The nuisance resulting from wind-blown particles from truck dumps and storage areas has been eliminated in most places by enclosing these two facilities.

A major problem area of board plants has been with the cyclones. A stranger to a community can usually find the particleboard plant, for example, quite easily by looking for the buildings that have a large number of cyclones on top. It was quite common for many years, for fine dust to be emitted from these cyclones, covering the board plant as well as some of the property surrounding it. Aggregate emissions from 20 to 40 cyclones operating on a typical particleboard plant have been measured at between 70 and 300 lbs (31.8-136.4 kg) per hour. Normally the highest particulate emitters have been those cyclones associated with the sanders or dryers or those handling dried and milled fines. The control of cyclone emissions has been one of the most difficult problems to overcome.

Standards

It is not the intention of this chapter to go into great detail on the various regulatory approaches since they can differ throughout the country, and changes or potential changes are occurring rapidly. There are three types of approaches, however, that can be taken: enforcement of ambient air standards, performance standards, and emission standards.

The enforcement of ambient air standards is one by which the air quality of a community is evaluated, and achieving and maintaining the standards is the basic

objective of the pollution program in establishing *normal air*. This basic program which originates from cosmic dust, collects and evaluates standards to handle such a standard, and evaluate standards was difficult to secure criteria against which inadequate control measures. Performance standards for a certain operation options for control are uniform guidelines for the truck dump and site of the pollution problem. The third type of a and sanction with the an engineering approach shows schematically federal legislation. The used. The visible emissions

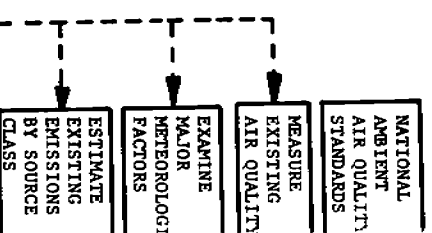


Figure 19.1. Flow diagram of Clean Air Act (Odell)

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objective of the pollution-control program is to establish a very concrete value of what might be called *normal air*. This background value can be defined as the quantity of material which originates from natural sources such as wind-blown soil, forest fires, or cosmic dust, collected during the year. The problem was very difficult to handle such a standard in that it required a great deal of effort to collect and evaluate samples, it was difficult to establish the background value, it was difficult to secure representative samples, and there was a lack of definitive criteria against which to measure the results of the program. The program was inadequate control measures to be taken.

Performance standards specify the minimum efficiency of equipment required for a certain operation. They have been found useful in situations where the options for control are few. A definite performance standard can be used as uniform guidelines for control. A performance standard can be used to control the truck dump and storage areas and to provide a means of controlling the pollution problem.

The third type of approach is the concept of a "pollution credit" or "pollution bank" with the passage of time. This concept is based on the idea of an engineering approach to a problem. The idea is that if a certain amount of pollution is allowed, then a certain amount of pollution can be "banked" for use in the future. This shows schematically the process which has been following under the federal legislation. There are five major types of emission standards that can be used. The visible emission standard is the most commonly used.

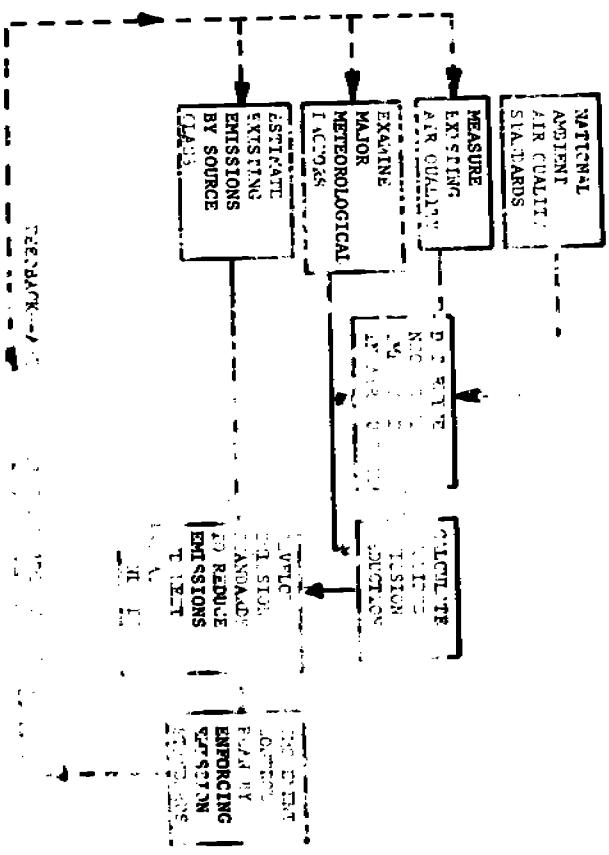


Figure 19.1. Flow diagrams of the Clean Air Act (Ozelli 1977)

in pollution control. Initially based on the Ringelmann chart for black smoke, it can be applied to any visible emission by use of percentage opacity. The most common regulation specifies a maximum of Ringelmann 2 (40% opacity) for existing sources, and Ringelmann 1 (20% opacity) for new sources. In 1970, for example, the state of Oregon adopted Ringelmann 1 for most sources in special control areas (high population densities — basically western Oregon). However, the state of Maryland adopted a regulation allowing no visible emissions except by variance. Particleboard plants in most states are now subject to the visible emission standard. There are some problems with the standard, however, which makes it undesirable as a sole means of regulation of cyclones. Since there is a wide variance in the ratio of cyclone material throughput to airflow, no consistent relationship can be established between visible emissions and mass emissions; much of the air-quality problem associated with particleboard plants is the fallout of large particles (>20 microns), which may or may not contribute to a visible emission; and the evaluation of low-level non-black visual emissions (zero to 40% opacity) is a difficult task for even the best trained observer.

A second type of standard is that of dust concentration, which has been used by many authorities to regulate both combustion and noncombustion sources. The most common such standard specifies for manufacturing process equipment and combustion sources a maximum emission concentration of 0.2 grain per dry standard cubic foot for existing sources and 0.1 grain per dry standard cubic foot (0.028 m^3) for new sources, although there are many variations of this standard. The major problem in using this concentration standard has been with cyclone emissions, where poor correlation between airflow and emission rates occurs. It left open the possibility of bringing a source into compliance by increasing the rpm on a blower fan, and thus the airflow, without reducing the emissions at all.

A third type of standard is that of process weight where an emissions limitation in pounds per hour for each piece of equipment, depending upon the rate of materials input, is established. A materials input is the process weight. The process weight standard prescribes a progressively more stringent emission limitation for operations with a large process weight. Variations in applying process weight standards can be found where one group will treat each individual emission source as a separate process, another will treat each grouping of physically interconnected process equipment as a single process, while a third will treat an entire plant site as a single process.

A fourth type of standard is that of potential emission, where an allowable emission in pounds per hour is provided for a given potential emission, defined as an uncontrolled emission from the process in question. The greater the potential emission, the higher the required collection efficiency becomes. A major drawback with this type of standard is that it requires twice the amount of source testing to determine compliance.

The fifth type of standard is a specific emission for the plant in question. The emission limitation can be established for either individual units or the entire process. One such standard, as adopted by the state of Oregon in March 1971, was based on the concept of requiring the highest and best practicable treatment and allows a maximum plant site emission of 3 lbs (1.36 kg) of particulate matter per 1000 ft^2 (304.8 m^2) of particleboard produced (¾-19 mm basis).

Cyclones

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Figure 19.2 shows t been possible to put a s very fine material being through such means a many years to separate the air. Cyclones, or as since the late 1800s. S cyclones, and some ma or size only on an em predictable results for approach.

Figure 19.3 shows s normally used in boar collector tangentially down the body and into cone decreases. Simul and forms an inner and course and is ascendi Most designers agr main vortex will conve cone, as witnessed by cyclone the axis of the observed in cyclone d the dust as it is throw

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Cyclones

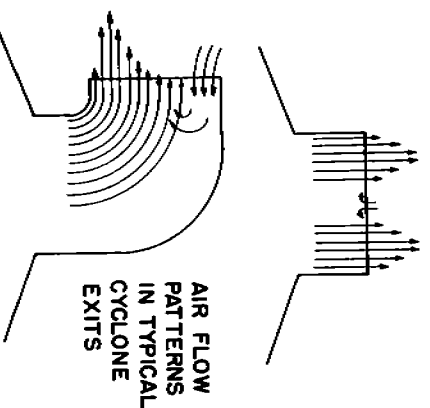
For meeting the dust control standards, cyclones have had to be remodeled and refined or equipped with bag filters, scrubbers, or other sophisticated dust-collecting apparatus. Other control methods used have been to convert to mechanical or high-pressure pneumatic conveying systems in order to cut down on the dust problem.

Figure 19.2 shows typical airflow patterns, exhausting from cyclones. It has been possible to put a skimming device around the exhaust to skim off some of the very fine material being exhausted, thereby leaving less to be cleaned from the air through such means as baghouses or scrubbers. Cyclones have been used for many years to separate particulate material from conveying air and not to clean the air. Cyclones, or as properly called, *centrifugal collectors*, have been known since the late 1800s. Since that time there have been many refinements upon cyclones, and some manufacturers rate theirs as to performance of a certain shape or size only on an empirical base. There is still no design formulae leading to predictable results for a new configuration. It is essentially a trial and error approach.

Figure 19.3 shows six different types of cyclones. The large-diameter types are normally used in board plants. Generally speaking, the dust-laden air enters the collector tangentially at moderate velocities and, as the air travels a spiral path down the body and into the lower cone, the velocity increases as the radius of the cone decreases. Simultaneously the air begins to separate from the outer vortex and forms an inner and rising spiral vortex until all the entering air has reversed its course and is ascending spirally through the top gas discharge.

Most designers agree that the cone is not essential to cyclonic action, since the main vortex will convert to the vortex cone shape without the use of a restrictive cone, as witnessed by nature's cyclone. It also should be noted that in a natural cyclone the axis of the free vortex has an eccentricity or curve, and this has been observed in cyclone dust collectors. The cone does, however, confine and collect the dust as it is thrown outward and downward to a central collection point. At a

Figure 19.2. Arrow length indicates relative flow velocity. There is usually some cyclonic component to the gas flow, which is not shown by this diagram (Nicholson 1971).



point in the lower cone near the dust outlet, the outer and inner vortex join and have a common base. At this point there is a high negative pressure. Therefore the air tries to move towards this point from all directions. In a cyclone without an air-locked dust outlet and with an open-top air discharge, there is a combination of flow, as is shown in Figure 19.4. There is an even flow of air into the tangential inlet. In the lower cone, there is a downward flow around the periphery of the dust outlet and an upward flow in the center. At the top air discharge, there is an upward flow around the periphery of the outlet and a downward flow into the center from the atmosphere.

Various methods are employed at the lower cone dust outlet to prevent the upward flow of air with consequent re-entrainment of dust. A sealed container or bin is generally satisfactory when intermittent unloading is employed. Common methods are to use a shear blade in the lower cone, a rotary air-lock feeder, or double dump gate or valve, all of which are shown in Figure 19.5. In many of the wood plants, the large cyclone discharges its material into a relay fan system, and a negative pressure on the inlet side of the fan prevents the upward flow into the cyclone (Figure 19.5). This action has shown up frequently in converting large cyclone systems with relay fans to a mechanical dust relaying system wherein this air lock is lost and the re-entrainment of dust is severe. While it is known that the

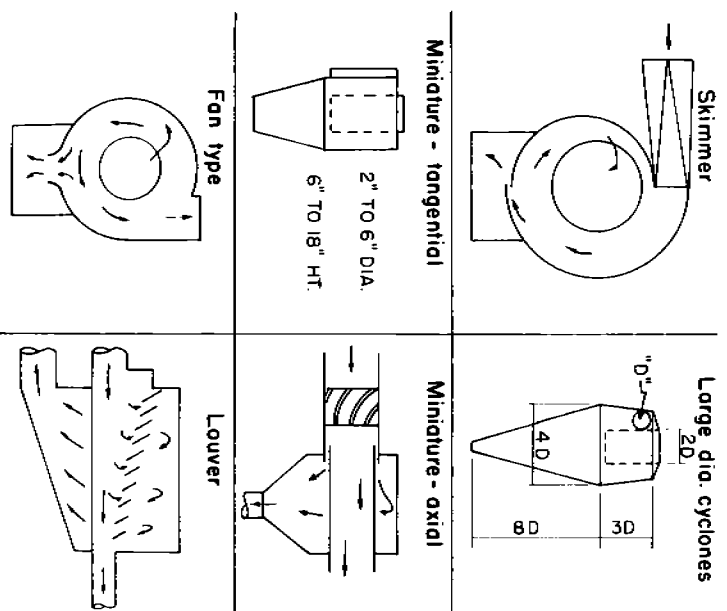


Figure 19.3. Types of dry centrifugal collectors (Shumate 1971).

Figure 19.4. The dry pattern in a dry cyclone (Shumate 1971).

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The cyclone set material velocity is cyclones tilted at a collection point for cyclones, 2 to 6 in.

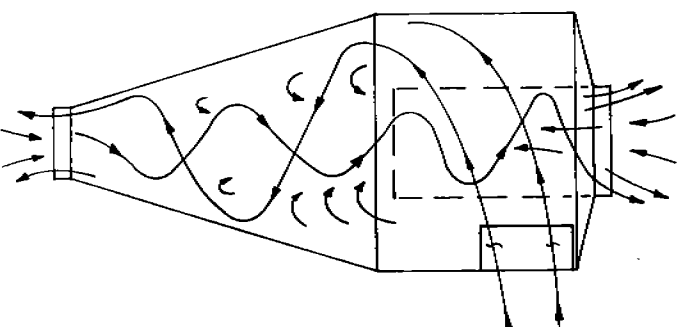
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Figure 19.4. *The typical airflow pattern in a dry centrifugal collector (Shumate 1971).*



separating efficiency of a cyclone is a function of the angular velocity, there is an optimum range for best separation. If the optimum is exceeded, the increased separation is offset due to higher angular velocities by the high re-entrainment of dust because of increased turbulence in the lower cone. If the inlet velocity is decreased below the optimum, then the angular velocity falls off until the cyclone is acting more like a settling chamber.

The cyclone separator can be mounted in any position when the air and material velocity is carefully controlled. It is not uncommon to see large-diameter cyclones tilted at an angle of up to 45 degrees in order to acquire a central collection point from the dust outlets of a cluster of cyclones. Some miniature cyclones, 2 to 6 in. (50.8–152.4 mm) in diameter, are designed with a horizontal axis, and the same cyclonic action occurs. It is possible to make a properly designed small cyclone operate upside down so long as the angular velocity is sufficient to carry the separated particles to the top of the cone.

Since the cyclone is a low-cost, large-capacity device for primary collection, and since no available bag filter to date is capable of receiving and discharging the extremely large tonnages handled in some pneumatic conveyors, cyclones will continue to be used as primary receivers for such systems. However, they will have to be aftercleaned for any emissions. The cyclone dust collector is an essential industrial device which, after 85 years of widespread use, is subject to many variables. Some of these variables can be controlled and others have yet to have their characteristics determined.

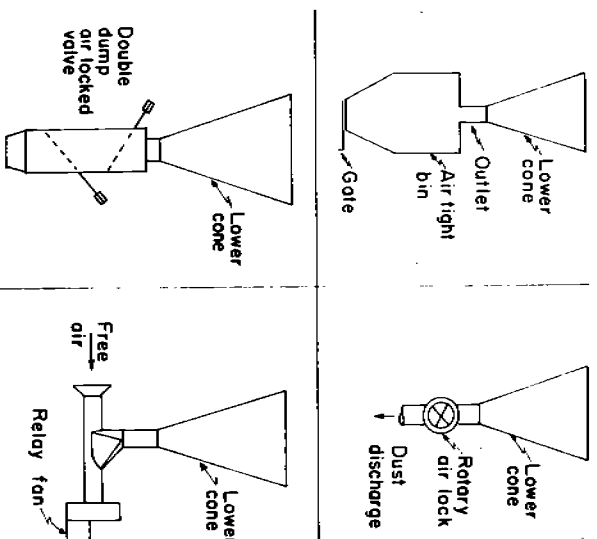


Figure 19.5. Four methods used to seal the dust outlet from a centrifugal collector (Shumate 1971).

Baghouses

The most significant control device to find wide acceptance in the board industry during the past five years is commonly known as the baghouse. It has been used for many years in other industries on such applications as grain elevators, cement plants, fertilizer plants, and sandblast houses. Extremely large baghouses have found use with electric furnace and metallurgical fume types of industries where high temperatures are common.

A large board plant will have many baghouses in use to perform secondary cleaning on cyclones. The very fine dust that is accumulated can then be fed back into the burner of the dryer or into the boiler where the dust provides energy to the plant. There are four basic designs of baghouses called the *pulse-puff* or *pulse-jet*, *reverse-flow*, *shaker*, and *reverse-jet*. These use felt or woven cloth filtering media, either natural or synthetic, to collect the dust.

The pulse-jet uses cloth tubes, usually of dacron, in diameters ranging from 4 in. (102 mm) up to about 6 or 8 in. (152–203 mm) in diameter. The tube length varies from 6 to 10 ft (1.83–3.05 m). The dust is collected on the outside and the tubes are prevented from collapsing by being supported on wire cages. Cleaning is accomplished by injecting a high-velocity bubble of air through a venturi nozzle located at the top of the vertical bag. This bubble is usually injected by the opening and closing of a solenoid valve which is actuated by a timer. The bag is expanded from the wire cage as the bubble travels downward. This expansion and contraction of the bag releases the dust cake. The industry uses few such houses.

The reverse-flow machines are round and have about incorporating horizontal have a cross section resemble their bags on cages and filters. The envelope type (Figure 19.6). The envelope baghouse. The filtering space between the envelope and the bag is counterflow into the cone portion of rotary air lock.

A newer type revers conjunction with a cyclone reinjected. The cyclone can range in size from 1 (6.1 m) long.

Another version of this air is blown into the cone bags. The dust is collected A rotating vacuum, on a bag in turn. The vacuum the bottom.

The shaker-type collection already mentioned. Dust released by shaking of the they are not used in the

Figure 19.6. One type of machine. (Courtesy Car.

vertical collector

nice in the board baghouse. It has applications as grain collector. Extremely large vertical fume types of airform secondary can then be fed back to provide energy to the pulse-jet or pulse-jet, even cloth filtering units ranging from 4 ft. The tube length is outside and the cages. Cleaning is by a venturi nozzle released by the opening of the bag is expanded and contraction and contraction of such houses.

The reverse-flow machines may have either tubes or "envelopes." The tubes are round and have about the same dimensions as the pulse-jet collector. The units incorporating horizontal envelopes will measure about 5 ft (1.52 m) in length and have a cross section resembling the shape of a racetrack. These collectors support their bags on cages and collect the dust on the outside similar to the pulse-jet filters. The envelope type of bag may also be mounted in the vertical position (Figure 19.6). The envelope design allows maximum filter area in any given size of baghouse. The filtering media can be spaced very closely together. However, as the space between the media is decreased, the possibility of plugging increases. Each bag is counterflow-cleaned once each minute, and the dust is dropped back into the cone portion of the filter. The dust is discharged at the bottom through a rotary air lock.

A newer type reverse-flow baghouse is shown in Figure 19.7. It is used in conjunction with a cyclone into which the purged dust from the baghouse is reinjected. The cyclone is an integral part of the closed-loop filter system. Bags can range in size from 11½ to 22 in. (292–559 mm) in diameter and up to 20 ft (6.1 m) long.

Another version of this type of baghouse is shown in Figure 19.8. Dust-laden air is blown into the central chamber and then moves into the surrounding filter bags. The dust is collected on the bags as the air passes through to the atmosphere. A rotating vacuum, on an automatic cycle, reverses the airflow and cleans each bag in turn. The vacuumed dust is returned to the collector where most of it falls to the bottom.

The shaker-type collectors have bags about the same size as the two types already mentioned. Dust is collected on the inside of the vertical tubes and released by shaking of the bags which is effected by timers. As far as it is known, they are not used in the industry.

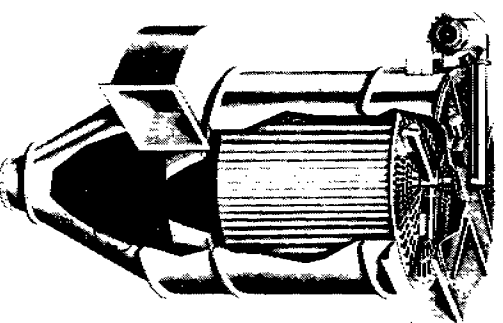


Figure 19.6. One type of reverse-flow machine. (Courtesy Carter Day.)

The reverse-jet (Figure 19.9) uses bags which are mounted vertically. These may be from 12 to 18 in. (305–457 mm) in diameter and as much as 20 ft (6.1 m) in length. The dust is collected on the inside of the bags. They are cleaned by a traveling ring, moving up and down the outside of the bags, actuated usually by a pressure switch which senses the amount of dust collected on the inside of the tubes via static pressure drop in inches of water gauge across the baghouse. The reverse-jet air is normally furnished by a single-stage blower or by blowers,

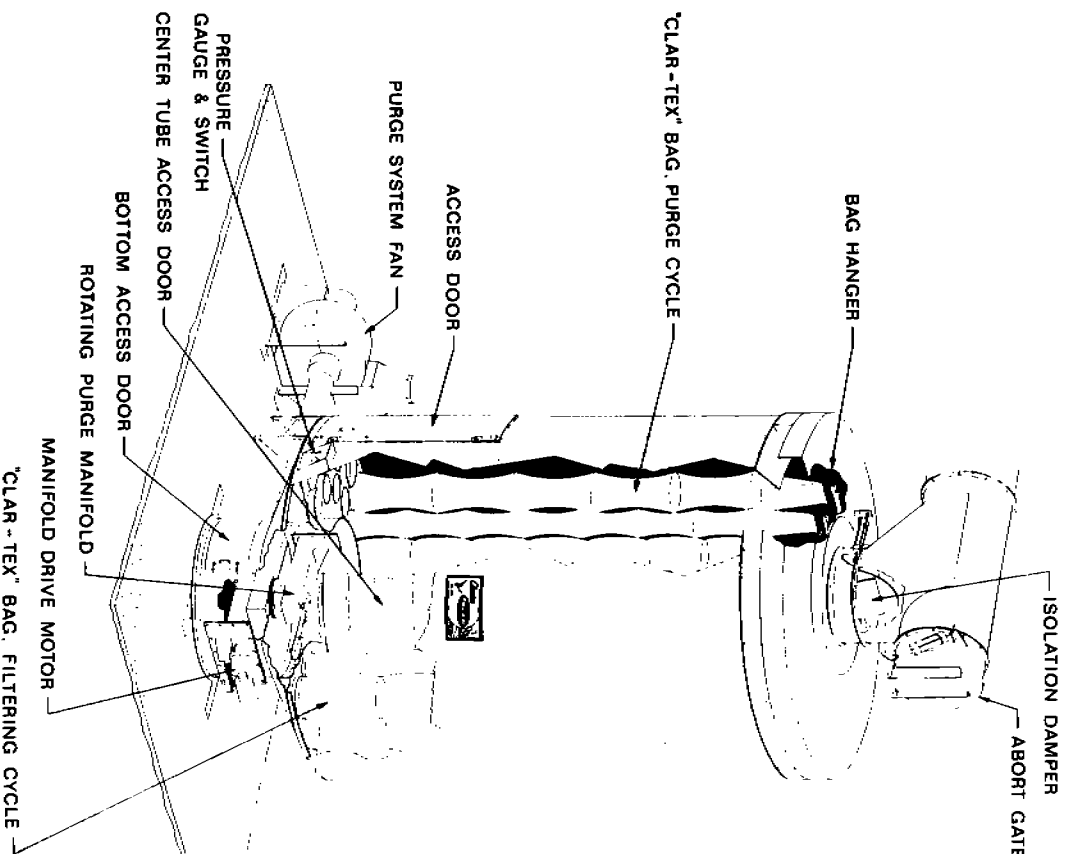


Figure 19.7. A reverse-airflow baghouse. (Courtesy Clarke's Sheet Metal, Inc.)

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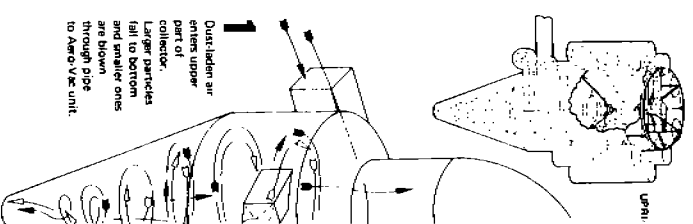


Figure 19.8. Another reverse-airflow baghouse. (Courtesy Clarke's Sheet Metal, Inc.)

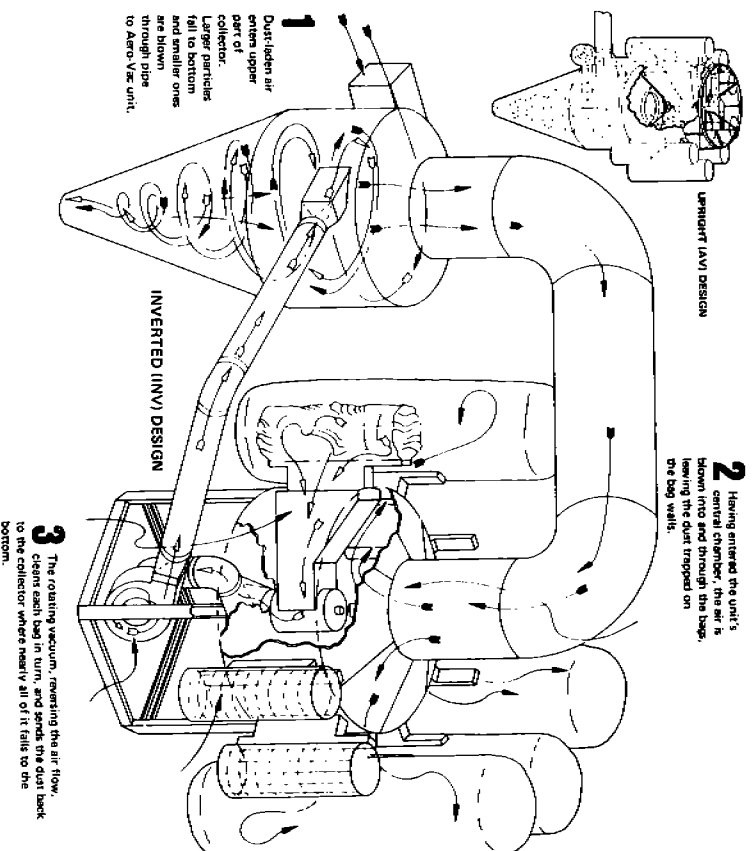
critically. These 20 ft (6.1 m) in diameter bags are cleaned by a reverse-jet air flow inside of the baghouse. The reverse-jet air is supplied by blowers,

DAMPER
— ABORT GATE

capable of delivering around 1 psi (6.89 kPa) to the rings. As the rings travel up and down, they slightly deflect the bags fatiguing the dust cake, which is then released by the pressure of the reverse-jet air blowing through the bag. The dust is collected in a hopper at the bottom.

The pulse-jet machines usually will use plant air or a high-pressure positive displacement compressor providing air to about 100 psi (689 kPa). The reverse-flow uses higher-volume fans to reverse the flow of air through the filter, which will release the dust cake. Steel rings may be sewn into the outside surface of the bags to prevent them from completely collapsing during the cleaning cycle. The reverse-jet blowers use a fairly low volume of air compared with the reverse-flow blower. However, their pressures are higher. The compressors on the pulse-jet collectors will be very low flow but will provide extremely high pressures. The reverse-jet and pulse-jet types may be cleaned while remaining in operation. The others usually have to be arranged so that the portion being cleaned is taken out of service during the cleaning cycle.

The baghouse type selected should be determined by cubic feet of air per minute being handled by the particular system. Sanders will require very high



ERING CYCLE
et Metal, Inc.)

Figure 19.8. Another version of a reverse-flow baghouse. (Courtesy Aero-Vac, American Sheet Metal.)

volumes of up to 55,000 ft³ (1557 m³) per minute. Baghouses utilized in other parts of the operation will handle much lower amounts of air. Air to cloth ratios (ft³ of air to ft² of cloth area) will vary from 5:1 to 10-12:1 depending upon the service and physical characteristics of the contaminant particles, and the type of collector to be used.

There have been problems with bag binding or plugging, due to wood resins or volatiles accumulating on the filtering media. This seems to be applicable to

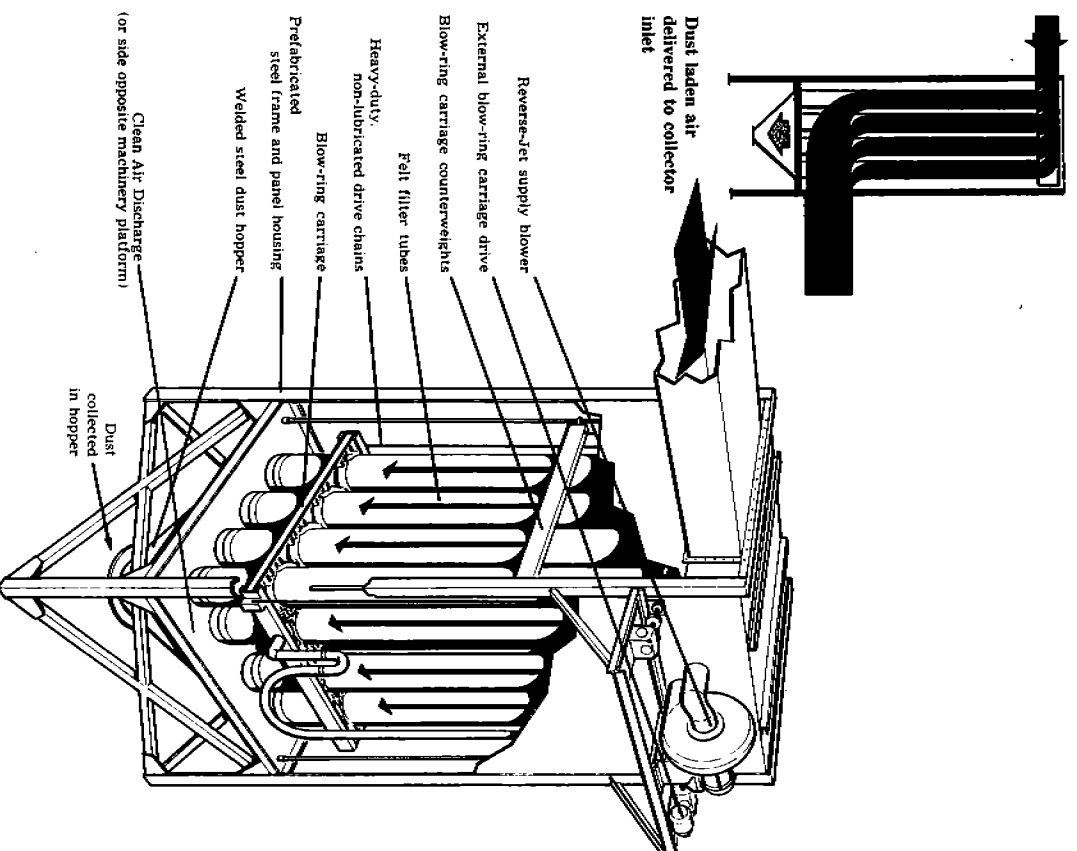


Figure 19.9. A reverse-jet baghouse. (Courtesy Buffalo Forge Co.)

certain plants where provide more of the problems apparently lower material in de faces, ranging up to 1 board, provides a si operation process, th which cause the prot these problems, but has also been found other types of plant sanding of higher-de atiles vaporizing an shorter bag life.

Baghouses after c in the industry. Ther air that must be treat the closed-loop pnel

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Conservation of Air

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Closed-Loop System

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certain plants where the wood species or the board-processing system tends to provide more of the sticky-type volatile material that can cause blinding. Similar problems apparently have not occurred with plywood, but plywood is a much lower material in density. Particleboard in particular, with its high-density surfaces, ranging up to perhaps 0.9 in specific gravity for a so-called medium-density board, provides a situation where much more heat is generated in the sanding operation process, thereby making it easier to vaporize the resin or other volatiles which cause the problem. It is not clearly understood at this time what is causing these problems, but they have occurred in plants in several parts of the world. It has also been found in composition board plants that bag life is shorter than in other types of plants where wood dust is collected. It would appear that the sanding of higher-density material with the accompanying problems of the volatiles vaporizing and causing eventual blinding, may be responsible for this shorter bag life.

Baghouses after cyclones for secondary cleaning of the air are now widely used in the industry. There are other options for eliminating or reducing the quality of air that must be treated. These include mechanical conveying, conservation of air, the closed-loop pneumatic system, and high-pressure conveying.

Mechanical Conveyors

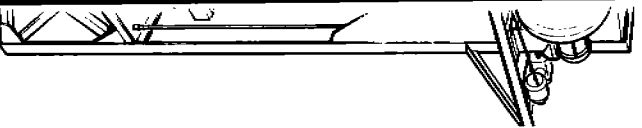
Mechanical conveyors and elevators can be used in place of pneumatic systems in several areas of board production, which will cut down on the emission of dust. These include the following locations: truck unloading to storage, storage to refining, refining to dryer storage, blending to the forming machine, the mat reject to forming storage, and mat end and side trim to forming storage. Some local exhaust air at transfer points may still be needed to prevent puffing of dust through small openings in the conveyor housing. This will be much less than that required for pneumatic transfer.

Conservation of Air

Because of the new air-quality regulations, each cubic foot of air used in a plant is more costly than before; it is therefore desirable to conserve on the amount of air being used to accomplish the job effectively. Several areas where savings can be made include: proper sizing of a blower system; alternate use of a blower system, such as mat reject or dust control as dictated by a damper controlled by the reject mechanism; and reducing the amount of air required for dust control by sealing off with skirting and housing all of the unnecessary openings.

Closed-Loop System

In the closed-loop system as shown in Figure 19.10, a basic pneumatic system is modified to duct the cyclone air back to the blower inlet, thus providing a closed loop. Since the air is recycled, there is neither airflow into or out of the system. It can be detrimental however, if the material pickup is dependent on airflow as in the case of a refiner or hammermill. In one application where a closed loop was



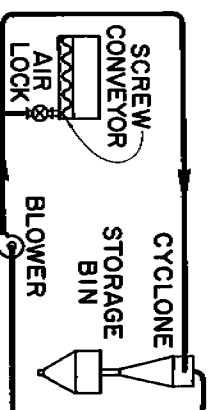


Figure 19.10. A closed-loop pneumatic system (Harrison 1971).

used on a disc refiner and the air lock was located below the cyclone, a modification was required. Initially the air return was ducted below the refiner for conveying of the fibers. However, due to the lack of airflow through the mill, improper refining resulted. This was corrected by returning a portion of the air into the side of the mill through existing openings.

High-Pressure Conveying

The high-pressure system varies from a low-pressure system in that it will convey the same quantity of material through a smaller pipe at approximately the same velocity and thus require less conveying air. The great dust concentration should be of some benefit in increased cyclone efficiency, but more importance should be placed on the lower air capacity and the resultant reduced filter costs. The air required to convey 1 lb (0.45 kg) of flakes by low pressure, for example, is approximately 35 ft³ (0.99 m³) compared to 3.5 ft³ (0.099 m³) required to convey the same amount of flakes by high pressure.

Other Approaches

There are two other approaches that may possibly be of advantage in the board industry for reducing problems with air quality. One is to use a venturified system which enjoys wide use in other fields. The venturi can pass materials of a size and shape which would be difficult or impossible to pass through a rotary air-lock feeder and can be manufactured at a fraction of the cost.

In particleboard plants anywhere from 15 to 30 individual waste and process material fan systems can be found in use. Each is a separate entity with widely separated fans and cyclones which require separate controls and individual filters or extensive piping to a centrally located baghouse. The possibility of a central station for all air systems based on the pleum design has been suggested. This would furnish the total plant air required at the necessary pressures with its built-in cyclones for primary material collecting, its filters for positive cleaning of centrifugal emission, and its boiler for direct injection of unusable waste material. This would also include all controls, motors, fans, pumps, dry filters, wet scrubbers, and associated equipment in one unified design. Of course, for best advantage this concept would have to be included in the general plant design before the plant is constructed. Because of the newly found importance of air quality, air systems should now be carefully designed into the plant with the process equipment for maximum operating efficiency.

Dryer

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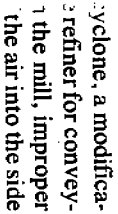
Table

Opacity

Less than 1.0% - 1.00% of light

Source:

*SCF =



Particleboard and fiberboard dryer blue haze condensible hydrocarbon emissions usually result from overcharging dryers at excessive drying temperatures, causing flash off of volatile hydrocarbons that condense upon discharge to the ambient air. As already discussed, the dryer configuration and operation varies widely. The typical dryer, however, accomplishes a tremendous amount of work in a relatively short time, in a relatively small space, and within rather demanding limits. At the same time, unacceptable emissions can be generated that can be categorized as solid particulate matter, which is normally invisible, and liquid particulate or blue haze condensible hydrocarbons, which are normally very visible.

Most dryers in operation utilize high volumes of air to convey varying-size material through one or more passes within the dryer and then discharge pneumatically to a material transfer cyclone. The high material flow rate through a cyclone handling a lot of smaller-sized material results in emissions even when performing at a high removal efficiency. As an example, it is not uncommon for a rotary dryer to handle 12,000 lbs (5455 kg) per hour of oven-dry weight material with a discharge of 25 lbs (11.4 kg) solid particulate at a removal efficiency of 98%. This alone has the potential to dry the material to a level that will not be removed before coming into contact with the atmosphere. If the material is not dried to a level that will not be removed before coming into contact with the atmosphere, it represents the waste control aspect of plant design. In addition, the waste control aspect of plant design is represented by the removal of the material from the dryer by discharging a dryer by discharging to remove the material from the dryer a given time. This is prompted by introducing the green material to a high-temperature flame or gas stream of up to 2000°F (1093°C) that causes a thermal shock resulting in rapid and extensive volatilizing of lightweight hydrocarbons which condense upon release to ambient air, causing the characteristic blue haze. Other contributors to the emission are believed to be due to small-sized material that can be scorched or singed and pulsating flame cycles caused by modulating fuel feed in response to the control of outlet gas temperatures during plant operation.

In general, there are three emission standards that can apply to particleboard and fiberboard rotary dryer emissions, as shown in Table 19.1. Even though some jurisdictions may now have all three, it is important to recognize that they may exist in order to determine what requirements may be the most demanding.

Opacity	Loading	Process weight
Less than 20%	New	Variable depending on plant's
1. 0% - Invisible	0.1 gr/SCF*	process flow rate and regulatory
2. 100% - Total obscuration of light	Existing 0.2 gr/SCF*	agency's regulation. Allowable emissions stated lbs/hr

*SCF = Dry standard cubic foot.

Of the three emission standards, normally visible emissions measured by opacity (obscuration of view or transmission of light) is expected to be the most demanding requirement for unaltered stack gases. It has been observed that evaporative cooling in agglomeration may substantially reduce, if not totally eliminate, visible blue haze after dissipation of water vapor. As mentioned previously, most states and local control agencies limit opacity to less than 20% for new sources and 40% for older sources. However, new regulations for veneer dryers, for example, in Oregon limit emissions to less than 10% for new sources and less than 20% for older sources. With the grain-loading standard, the stack gas concentration is normally stated as grains per standard cubic foot (dry). The designation *dry* means that stack gas moisture content cannot be used to dilute the emission to a lower value. Since it takes 7000 grains for 1 lb., the normal allowable emission of 0.1 to 0.2 grains per standard cubic foot is a demanding requirement. Normally the more restrictive requirement of 0.1 grain per standard cubic foot applies to new sources and 0.2 grain per standard cubic foot applies to older sources. Many control agencies determine the grain-loading emission rate to include both solid and liquid particulate. Including liquid particulate can many times cause the emission to exceed the allowable level.

A rather uniformly conceived but nonuniformly implemented regulation known as *process weight* and discussed previously, can be the most lenient and/or most flexible regulation to satisfy. This depends upon how the method of regulation is administered or applied to the respective source.

Control strategy cannot be determined until one familiarizes himself with all the regulations so he can appraise which regulation or regulations may be most binding. Consequently it is imperative that one conduct an analysis of the regulations as they apply to a specific installation, prior to proceeding with selecting control alternatives.

Opacity may be the most difficult regulation to satisfy, because the particle size that causes a light scattering, visible emission is normally the most difficult to remove. It is believed the composition of the visible emission comprises mainly volatilized hydrocarbons that condense to liquid aerosols (small-sized particulates) upon entering the ambient air. Opacities of 40 to 60% are quite common and on occasions opacities as high as 100% have been observed.

A selection of control technology is expected to give some flexibility in determining how to meet a visible emission standard. Good incineration should eliminate visible emissions, but particulate reduction may not be the same as that accomplished with good water scrubbing, due to ash and fixed carbon discharges from combustion. The ultimate control would utilize incineration with heat recovery and water scrubbing for solid particulate removal. Because the public sees the visible emissions, these are the ones that are to be removed initially, with the solid particulate to be controlled at a later time. This approach varies depending upon the plant's proximity to visual observation and its location relative to other air-pollution problems as well as the control official's outlook.

With process weight the allowable emission is determined from the process weight itself, which normally is the mass loading of processed materials into the system generating particulate emissions. Because of this variable, it must be determined what are the estimated emissions prior to assessing what control

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strategy should be investigated to accomplish compliance. This probably will require source testing. One such procedure has been established by the Source Test Committee of the Pacific Northwest International Section, Air Pollution Control Association.

Particulate removal efficiency required will depend not only upon the nature and magnitude of emissions from the dryers but also on how the regulations address themselves to the contribution of the dryer's emission to the total plant site limitation. The control strategy would have to consider meeting all three of the previously mentioned emission standards if they apply. As an example, consider a plant's process weight regulation limits for particulate emissions as 40 lbs (18.2 kg) per hour for the total plant. Without control the emissions are estimated to be 500 lbs (227 kg) per hour, including 100 lbs (45.5 kg) per hour from the dryers. To proceed in controlling the dryers, the following sequence of operations could be followed. Reduce the particulate emissions from other than the dryers from 400 to 30 lbs (18.18-13.6 kg) per hour and select control strategies that will reduce dryer emissions from 100 lbs (45.5 kg) per hour to 10 lbs (4.55 kg) per hour. Most steps would require approximately 90% overall removal efficiency. In doing this, it would be necessary for the operator to be cognizant of satisfying the grain loading and opacity limitation. This, as can be seen, is a complicated operation and one that is causing a lot of difficulty in the industry.

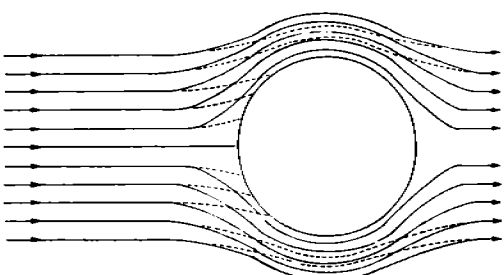
There are several control alternatives that are available for handling the dryer emissions. They comprise adaptation of technology for similar solid and liquid particulate emissions from other industries. A number of these will be mentioned here, including water scrubbing, afterburning (with sander dust firing only in heat recovery), additional drying capacity, incineration in the boiler, HEAF (high-energy air filter) with mist eliminator and afterburning with natural gas. Other approaches are to recycle the offgas through the dryer burner so as to incinerate volatile hydrocarbons and combustible particulate matter. The resultant ash and noncombustibles are then removed from the airstream by means of a baghouse.

Scrubbers have been used on both dryers and sanders. However, they are particularly interesting with dryers because of the hot gas exhaust. Normally in a scrubber, water is used as the cleaning fluid. Such systems have found applications in many industries, such as steel mills, fertilizer plants, asphalt roofing plants, and chemical processing plants. These industries have used some form or design of the scrubber either as their primary or secondary means of controlling particulate discharge.

The scrubbers operate under the basic concept of making particulate matter heavier than its normal state in an airstream. This is accomplished by surrounding the particulate with water which not only makes the particle heavier but tends to attract other particles in a like state. It is intended in a scrubber system that the water in the system should form droplets which, because of their size and weight, tend not to travel as fast in the airstream as the engrained particulate matter. Hence, collisions occur between the particulate matter and the water droplets. Various methods are used to separate the water and trap particle matter from the airstream. The range of particle sizes which can be handled is limited.

A brief summary of the fundamental theories of scrubber operation is as follows. Impingement, which is also called *impaction*, results when the particulate

Figure 19.11. A schematic illustration of the impingement theory (Bunrock 1971). Solid lines indicate fluid; dashed lines, particle.

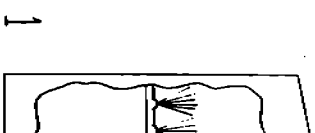


matter in an airstream collides with water droplets introduced to the airstream as shown in Figure 19.11. The agglomeration theory is the tendency of particles to form clusters and includes three methods: (1) Brownian motion, which is the tendency of particles in motion to diffuse to the neighboring particles; (2) turbulent coagulation, which occurs when particles deviate from the normal path and possibly affect other particles in the airstream; and (3) sonic agglomeration, which is an induced effect through the introduction of high-intensity sound waves into the carrier airstream causing variations in the normal path and velocities of the entrained particles through vibrations in the particles. These methods refer to the interactions between particles and not between particulate matter and water. The third concept is contacting power which has come into being in the last several years and claims that fluid turbulence is the primary operating mechanism in wet-type scrubbers. It establishes mathematical criteria for indicating efficiency in power consumption levels which show that power consumption and pressure drop in inches of water gauge increase when attempting greater efficiency in removing particles in the submicron ranges.

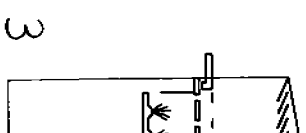
Wet scrubbers can be generally divided into five types: spray chambers, self-induced spray, impingement centrifugal, centrifugal collectors, and venturi scrubbers. There are many variations of these including several different operating concepts. Several scrubbers are schematically illustrated in Figure 19.12.

Spray chambers are the simplest of all systems in construction and have the lowest pressure drop. They are merely large tanks which can be one of several shapes, usually round or rectangular. The airstream passes through a water spray produced by a nozzle or nozzles as shown in Figure 19.12. In the self-induced spray collectors, the airstream is forced directly onto the surface of the scrubbing liquid. The imparted velocity of the fluid is either forced through an orifice creating atomization of the fluid, or the airstream is discharged directly into the scrubbing fluid. Collection is usually through baffling. This type of system usually

has lower water requirements (mm) of water, due to the impingement. The impingement theory (Bunrock 1971) is shown in Figure 19.12. It is a schematic diagram of a particle being entrained through a plate with each hole. A collision occurs in each section. The venturi scrubber has gas velocities, high (38.1-203.2 m/s, or 2.03 m/s) are to the throat of the venturi. The water requirement types of scrubber submicron range.



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Figure 19.12. Illustration (2) self-induced spray



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has lower water requirements, with a pressure drop of from 2 to 6 in. (50.8–152.4 mm) of water, depending on design.

The impingement collector may be one of several forms. The one shown in Figure 19.12 is not necessarily representative of all. The airstream, in this case with the entrained particulate, passes through a water spray and then is forced through a plate with many perforations, where a baffle plate is positioned opposite each hole. A collector of this type may have a series of impingement sections or only one section. Pressure drop for this type of collector may range from 1½ to 8 in. (38.1–203.2 mm) of water.

The venturi scrubber incorporates several typical features into its design. High gas velocities, high contact power requirements, and high pressure drop (up to 80 in. or 2.03 m) are inherent in this collector. The water is introduced at or just prior to the throat of the venturi, with the gas velocity atomizing the water into droplets. The water requirements of this type of collector are usually greater than the other types of scrubbers, but this scrubber is very efficient with particulate matter in the submicron range.

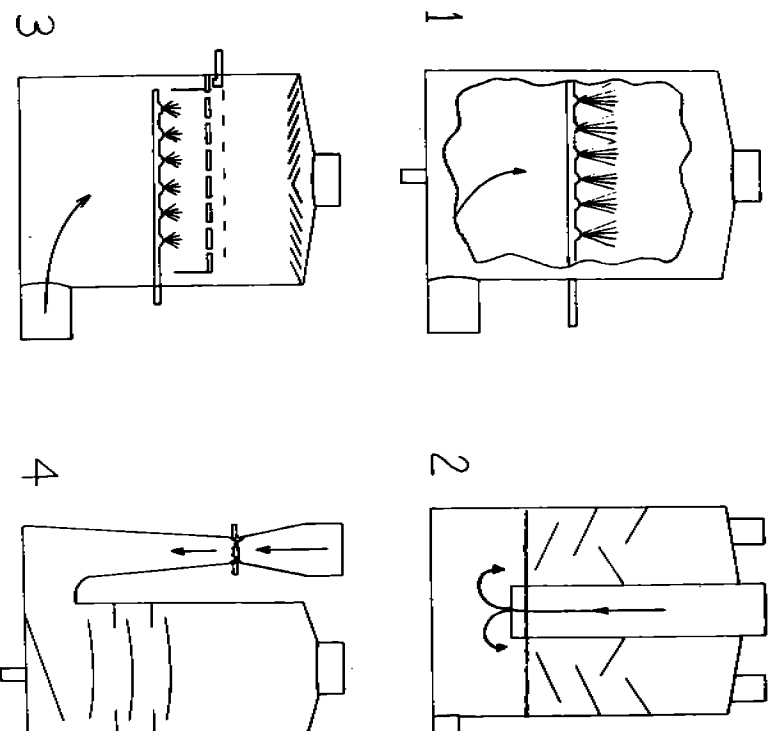
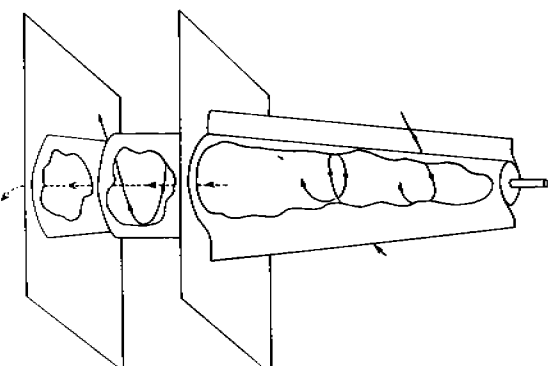


Figure 19.12. Illustrations of the following types of scrubbers: (1) spray chamber, (2) self-induced spray, (3) impingement and (4) venturi (Buntrock 1971).

Figure 19.13. A cutaway view of one of the scrubber cone sections, showing the fluid stream path (Buntrock 1971).



A single cone of a centrifugal scrubber is shown in Figure 19.13. A number of these cones are assembled together for a complete collector, as shown in Figure 19.14. This type of collector uses impingement principles as the collecting medium. Water is introduced into each cone and is carried to the periphery by high-velocity dust-laden air entering the two tangential inlets of each cone. Dust particles impinge against the wetted surfaces. As the incoming air is spun down the inlet cone, the water and approximately 10% of the air are forced between the barrel and the outlet cone and the bleed-off air is passed through a vent tube and into the clean air cleanup.

Figure 19.14. A cutaway view of the scrubber showing: (A) collection section, (B) water eliminator section and (C) the clean air plenum (Buntrock 1971).

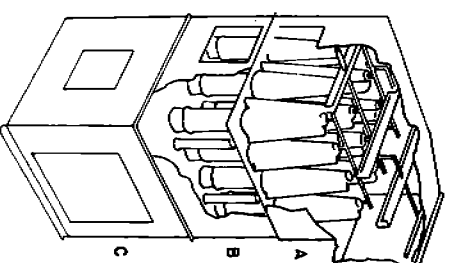


Figure 19.15. The

DRAIN
PIPE

Another scrubber is shown in Figure 19.15. This type of scrubber is shown in a cutaway view, revealing the internal components. The diagram shows a cylindrical collector with a central riser and a water eliminator section. The cutaway reveals the internal components, including the water eliminator section and the clean air plenum. The diagram shows the flow of air and water through the system, with a drain pipe leading from the water eliminator section. The diagram is labeled with 'DRAIN PIPE' and 'The'.

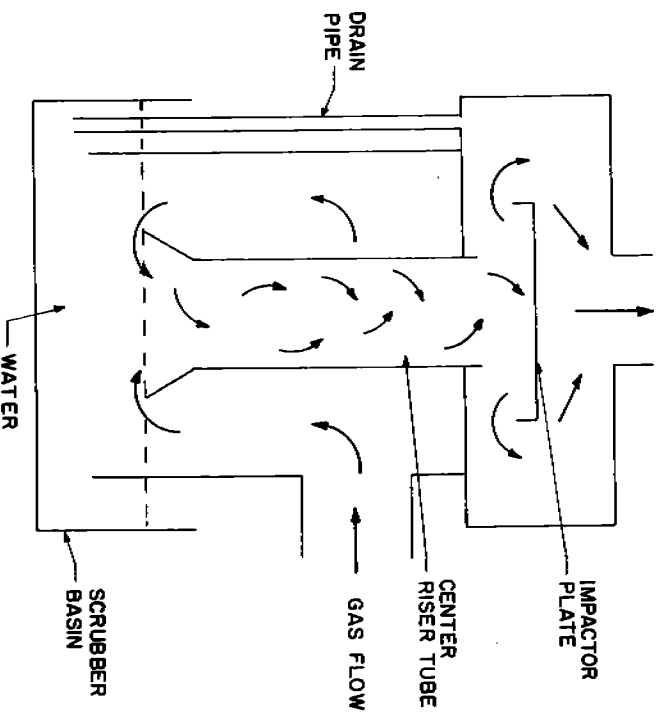


Figure 19.15. *The Leckenby tornado scrubber (Bruns & Duzan 1973).*

Another scrubber that has been used with both veneer dryers and particleboard dryers is shown in Figure 19.15. The air containing the particulate matter is diverted down into the water in the scrubber basin and is then forced to make a 180-degree turn to pass up through the inner riser tube. Air and water are pulled up the center riser cone to an impaction against the impactor plate. Water and captured particulate fall out due to reduced velocity at this point and return to the scrubber basin via the domed drainpipe. The clean air passes through the atmosphere through a conventional air-induction blower.

The particulate matter removed by scrubbers must be taken out of the scrubbing water. In one design, a skimming system is utilized to remove the captured pitch, wood fiber, and other particulates. In this operation, because of the large quantities of air diffused by the process into the captured sludge, the material remains afloat. It is moved toward a roller scraper as shown in Figure 19.16 by means of water-skimming lines. The roll and scraper mechanism is located above a weir which forces the material to the underside of the roller. Once removed by the scraper, the material moves by gravity into a trough as shown in Figure 19.17, where the material is collected for final disposal. It has also been suggested that a system utilizing a second high-efficiency cyclone between the dryer cyclone and the scrubber will be desirable. This will reduce the amount of fine wood fiber reaching the scrubber and the system will be better able to capture the hydrocarbon materials.

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As mentioned, either partial or complete gas recycle systems are being used on composition board dryers now. In the partial systems, skimmers have been designed which remove most of the fine dust and up to 50% of the stack gas. The mixture is then carried by a recirculating fan and ductwork back to the hot-air furnace to supply the secondary air normally added to the furnace.

Previously the HEAF with mist eliminator was mentioned. This high-energy air filter is used for asphalt saturator emissions. Pilot plant runs have been made with this unit and at least one has been placed in operation on a veneer dryer. It has been reported that it has been performing satisfactorily in eliminating blue haze emissions.

Of particular interest is a new control process developed by Georgia-Pacific Corporation to eliminate the blue haze from veneer dryers. In this process the emissions are passed through a series of showers and filters. The water is then evaporated, leaving a heavy liquid. It is accumulated on a stainless steel belt and dropped into large vats. This material is presently being used for fuel but is being evaluated as a source of chemicals. This system may be applicable to composition board dryers, and further work is planned along this line.

In conclusion, it can be noted that composition and quantity of particleboard and fiberboard dryer emissions are very similar to veneer dryer emissions in most operations. The composition board emissions approximate 2.7 lbs per ton (1.23 kg/0.91 mt) of oven-dried feed total particulate. Solid particulate accounts for approximately 1.6 lbs (0.73 kg) per oven-dried ton, or 60%, and condensable hydrocarbons account for approximately 1.1 lbs (0.5 kg) per oven-dried ton, or 40%. Emission standards vary from jurisdiction to jurisdiction and require differing control strategies and timetables. However, most control strategies will have to address themselves to visible and total particulate emissions which may require



Figure 19.16. *Skimming system for removing particulates from the scrubbing water (Bruns & Duzan 1973).*



Figure 19.17. *Scr*

up to 99% removal to range from \$2 per minute, dependent management show amount of energy

Solvent Cleaning

Scrubbers have oil-tempering unit fumes have caused plant at least opte the odor problem. cies. In this operat of linseed oil, petr nate. The excess c racks. These racks hours at 300°F (1 tempering ovens a being taken care c In this operatio to preheat the inc recovery system r required. In additi stacks. Cleaning jction has also redu

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Figure 19.17. Scrubbed material in collection trough (Bruns & Duzan 1973).

up to 99% removal efficiency. Capital costs to control emissions can be expected to range from \$2 per standard cubic foot per minute to \$30 per standard cubic foot per minute, depending upon the methodology used. In light of the energy crisis, plant management should be employing the alternative that will require the minimum amount of energy that is environmentally sound.

Solvent Cleaning

Scrubbers have also been used for cleaning the stack offgases coming from oil-tempering units in hardboard plants. In these cases odor as well as the stack fumes have caused problems. The odor has been one particular problem, and one plant at least opted for changing to incineration with heat recovery to overcome the odor problem. It was found that this method also provided operating efficiencies. In this operation the board is dipped into oxidizing or tempering oil made up of linseed oil, petroleum polymer, and a dryer such as iron tallate or iron naphthate. The excess oil is squeezed off through nip rolls, and the boards are put into racks. These racks of boards are then placed in an oven and dried for about three hours at 300°F (149°C). It is at this point that the volatiles pass off from the tempering ovens and a certain percentage goes up the stacks. This material is now being taken care of by incineration.

In this operation the heat recovered from the fume incineration process is used to preheat the incoming contaminated gas prior to its incineration. This heat recovery system results in about a 60% saving in the fuel that would normally be required. In addition to fuel savings, there is less cleaning and maintenance of the stacks. Cleaning jobs were needed almost monthly previously. Thus the installation has also reduced the fire hazard in the stacks.

scrubbing

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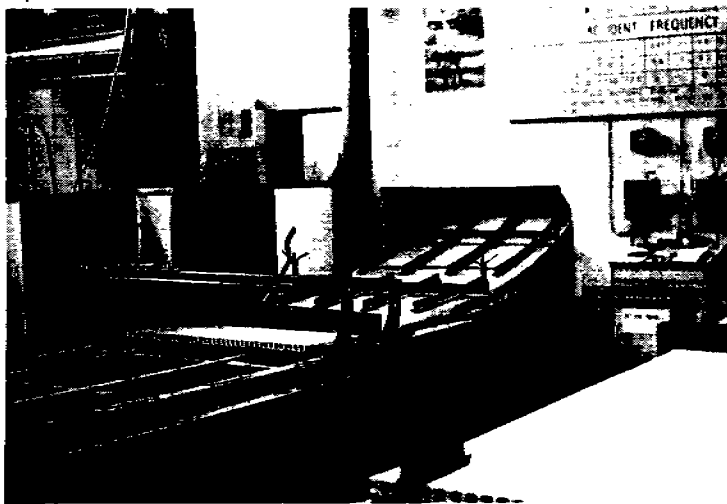


Figure 3.6. Extruded board leaving the die. (Courtesy Washington State Univ.)

manufacture smaller amounts of product from their residuals. The first commercial machine will produce a continuous sheet 40 in. (1.02 m) wide with 13/16-in.-thick (20.6 mm) ribs every 2 in. (50.8 mm) across the width on one side (Figure 3.8). Relatively small particles are used to minimize detrimental particle orientation. The board density ranges from 40 to 65 lbs/ft³ (0.64–1.04 sp gr). Gluing Rib-Wood panels together at rib ends or staggering ribs forms a hollow core panel 3/4 in. to 3 in. (19–76.2 mm) thick (Figure 3.8). It has a high-density surface that will take 1/28-in. (0.91 mm) veneer or 0.028-in. (0.71 mm) high-pressure laminate without crossbanding, which is an important feature. Overlaying is planned for this product.

Board width can be varied on different machines for various products, and mold variations will change with thickness, by length and distance between rib center.

Standard processing equipment is used except for the extruder. The extruder is heated to 400°F (204°C) and cures board at about 40 in. (1.02 m) per minute. A reciprocating ram is also used in this system for driving the furnish through the extruder.

MOLDED PRODUCTS

Molded composition board can take one of several forms. One type of molding consists of a product with over 25% of an adhesive binder mixed with wood flour. Such a product may be classified as a plastic. A familiar product of another, but lower-quality, type is a toilet seat which can be made with slightly larger particles

and less resin. Another type of product is a panel which has embossed patterns imprinted on its face either during the pressing operation or by a post treatment. This is done with standard platen-pressed panels. A third type of molded product is that made with particles, fiber, or flakes for furniture parts, boxes, and counter-tops. Figure 3.9 shows examples of this type of product.

While the molded product segment of the industry is relatively minor, it is of interest for at least two reasons. One is that, while molding wood composition material has not been particularly economical up to now in the United States because of competition from all-plastic material, the great increase in prices for petrochemicals has possibly changed the economics of producing wood molded parts. Consequently, it may soon be economical for a significant expansion in this industry. Such molding has been taking place in Europe for quite a number of years. The second reason for interest in molded products is the future possibility of molding structural composite building panels that will have very high strengths. Such a molding has been visualized all along by those involved in the dry-process industry. Some initial work has been done along this line, but much is yet to be learned about molding such large pieces of material. Experience in molding the smaller pieces such as the furniture parts should be invaluable in assisting with the development of the molded structural board industry.

Embossed Faces

The imprinting of a wood-grain type or other pattern on faces of hardboard has been quite successful. (*Embossed* is the descriptive term used in this discussion

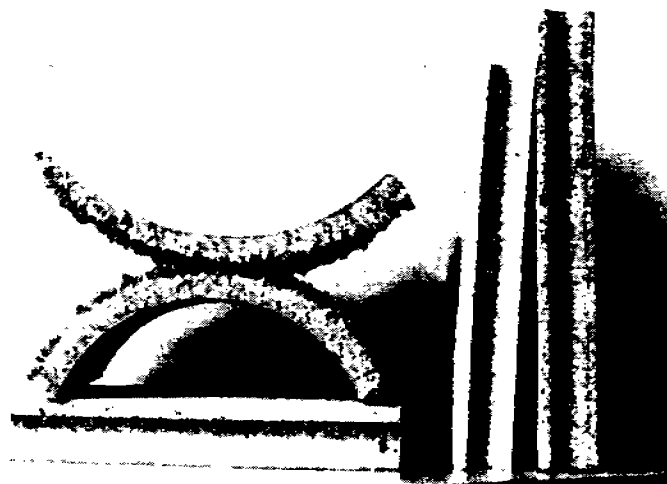


Figure 3.7. This extruded board with veneer overlay was accidentally water soaked and has sheared apart. (Courtesy Washington State Univ.)

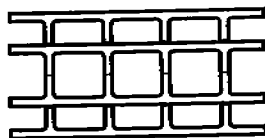
BASIC CONSTRUCTIONS



RIB-WOOD is formed in continuous ribbon.



RIB-WOOD is assembled rib-to-rib for thickness.



RIB-WOOD thick panel construction.



RIB-WOOD assembled in staggered fashion for extra strength.



RIB-WOOD assembled with other sheet material.

EDGE CONSTRUCTIONS



Exposed edge



Edge banded



Built rim edge



Lumber Inserts
Revealed Edge



Lumber Inserts
Concealed Edge

Figure 3.8. Examples of Rib-Wood. (Courtesy ITP Corp.)

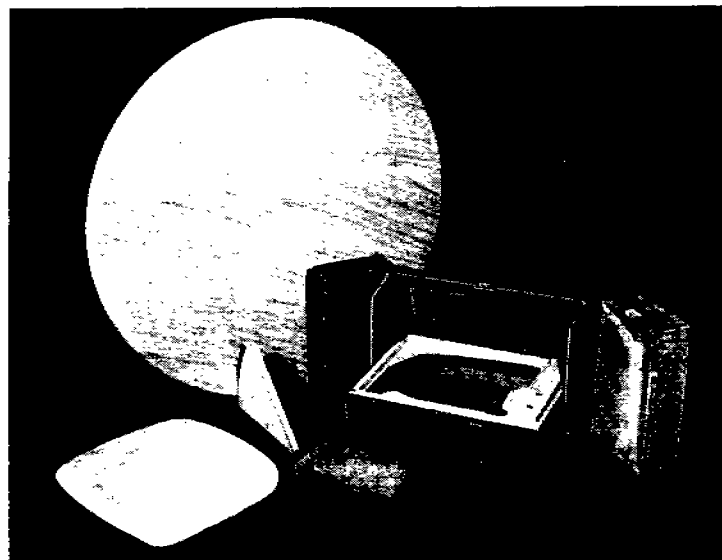


Figure 3.9. Molded parts manufactured from wood particles (Pagel 1967).

where the pattern sticks out from the plane of the board surface.) The pattern is imprinted by means of a false caul mounted in the press in which the desired pattern is etched or engraved.

In the case of particleboard, some of this imprinting or embossing has been performed successfully for many years on a small scale. It is done on a relatively high-density board with fine material in the faces. Figure 3.10 shows a sample of this particleboard. This same type of product is produced in Europe, as well as one where the pattern on the panel is impressed after the board leaves the hot press. *Repressed* board is the descriptive term used for this latter type of European board.

The U.S. board that has been produced as a flat panel with an embossed face has not had any paper-overlay type of material applied. For the repressed board, a white paper presaturated with resin is applied to both the top and bottom faces of the board. The pattern to be embossed into the board is etched into an aluminum false caul which is attached to the top of a hot press. A press temperature of 300°F (149°C) and a pressing pressure of 350 psi (2.41 MPa) is needed with a 40 lbs/ft³ density (0.64 sp gr). The total cycle time is two minutes per panel. In general, the maximum depth or draw of the design is 1/16 in. (1.6 mm). This process is limited to quite shallow designs.

Aluminum cauls are used, rather than stainless steel, because they are easily etched and are relatively low in cost. In the U.S. plants, relatively high-cost dies have been used for embossing the panel.

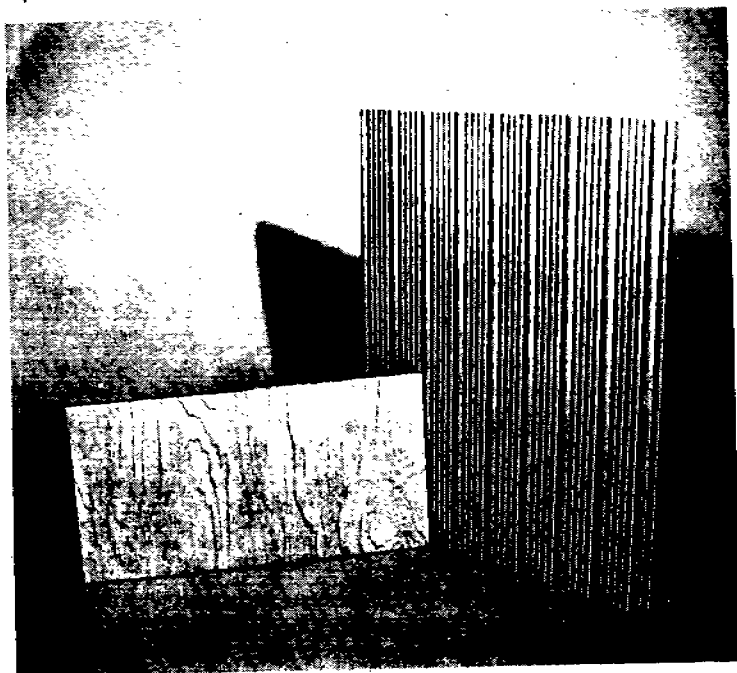


Figure 3.10. An embossed particleboard. (Courtesy Washington State Univ.)

To obtain deeper designs in the panel, it is necessary to produce the embossed pattern as the board is being pressed. However, as with the repressed board, a low-density, resin-impregnated paper is used for surfacing both sides of the panel. The bottom sheet acts as a balance sheet, stabilizing the board and assisting in minimizing warp. However, the top paper does not have the resin applied until after it has been laid on top of the mat prepared for the hot press. A very fine spray of polyester resin is then applied to this top paper. The polyester resin then acts as a binding agent, gluing the paper to the upper surface of the particleboard mat, and it also gives the finished product a smooth, hard finish, which can be easily treated with paints or lacquer. It is important in this process to keep fine particles on the faces. Otherwise, the coarser particles usually found in the core would tend to puncture the surface paper.

As with the repressed embossing, this one-shot process also uses etched aluminum plates in the press. Press temperatures are between 300° and 325°F (149-163°C). The pressure applied is around 350 psi (2.41 MPa) for a board of 40 lbs/ft³ density (0.64 sp gr). The curing time is, in general, about the same as for a standard particleboard being made without surface treatment. Figure 3.11 is a photograph of several panels produced by this one-shot process.

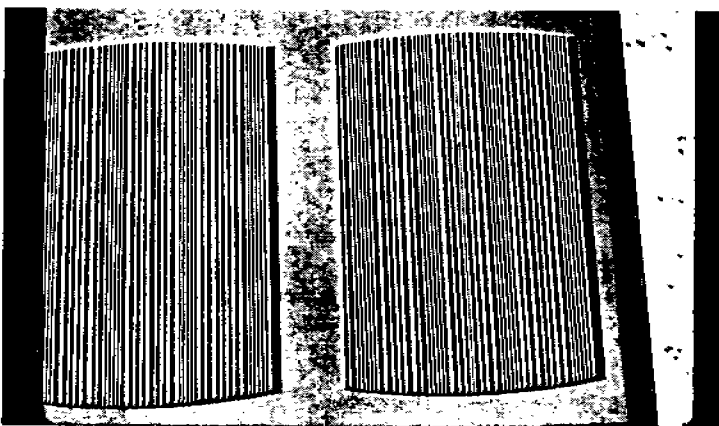
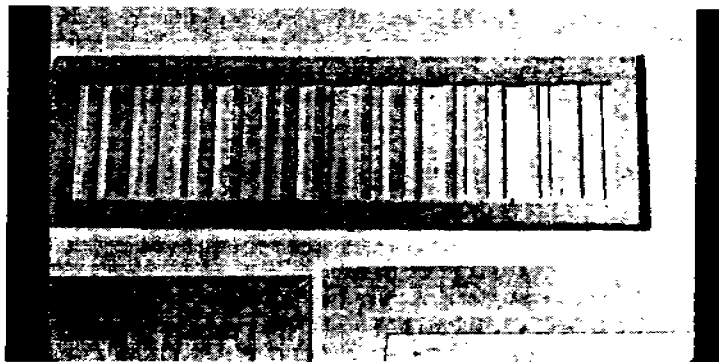
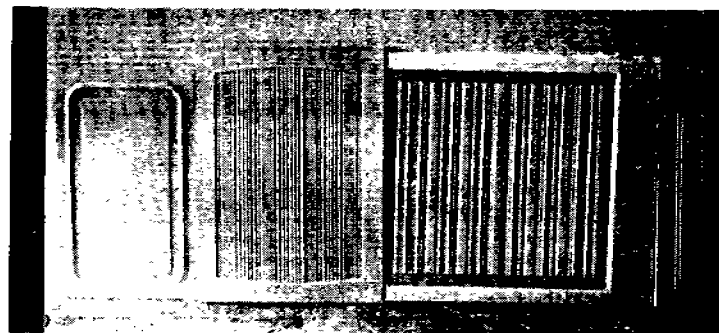


Figure 3.11. Examples of embossed board (Wentworth 1969).



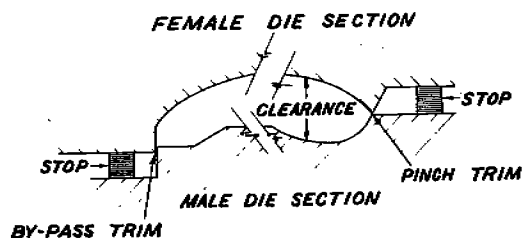


Figure 3.12. Die-making terms (Pagel 1967).

Many different patterns are embossed onto hardboards. It is relatively easy to emboss the higher-density fibrous products as the fibers will tend to flow into the design being embossed. The same is true, of course, with particleboard with fine fibrous material on the faces, which is necessary for getting good, clean designs with this type of operation.

Molded Parts

A standard flat-panel composition board could be characterized as being two-dimensional, whereas a molded part would be three-dimensional. The relatively simple molding is accomplished with the embossed type of board product. However, it becomes much more complicated when molding parts with deep draws such as tabletops with profiled edges, irregular boxes, curved drawer fronts, and beverage cases. Problems are encountered with mat formation, lack of particle and resin flow, expanding or contracting molds, and pressing conditions.

These parts are consolidated in matched metal dies or molds which are sometimes called *tools*. The female section is known as the *cavity* and the male section, the *punch*. The opening between the two parts of the die is predetermined and is fixed by stops. The distance between the male and female sections is called *clearance* or *closed opening*. The edges of the parts can be formed by pinch trimmers or bypass trimmers as shown in Figure 3.12.

This is a very sophisticated part of the particleboard industry. It took many years to overcome the problem encountered with the first crude attempts. However, there are some successful processes, particularly three that originated in Germany: Thermodyn, Collipress, and Werzalit. The Weyerhaeuser Company and the Plex-O-Wood Company in the United States have been using the Werzalit process, or parts of it. In addition, the Plex-O-Wood people have contributed their own developments to molded products. Newer developments, such as molding wood particles with a high level of isocyanate resin, may prove successful.

The general process conditions for producing molding products are not unlike the standard board system until the forming station is reached. Many different raw materials and particle types are used. Various amounts of resin are used depending upon the process and product. The commonly used resins are urea-formaldehyde and phenol-formaldehyde, although isocyanate resins have potential because of their lack of tack or stickiness which interferes with particle flow.

The prepared furnish is then formed and sometimes prepressed. In this mold, there may be a resin-impregnated paper, a veneer, or other type of sheet material added for decorative effect. This formed "mat" is then put into the hot press where the mat is consolidated into its final shape. Where the male and female parts of the metal dies meet, some material is normally squeezed out. This is called the *flash*. Some degree of deflashing is usually required. Other types of finishing, such as spray painting or vacuum-formed overlaid plastic sheets, may also be used to upgrade a raw part.

Figure 3.13 is a schematic drawing showing three different processes for making molded parts. A plant producing molded parts may have anywhere from

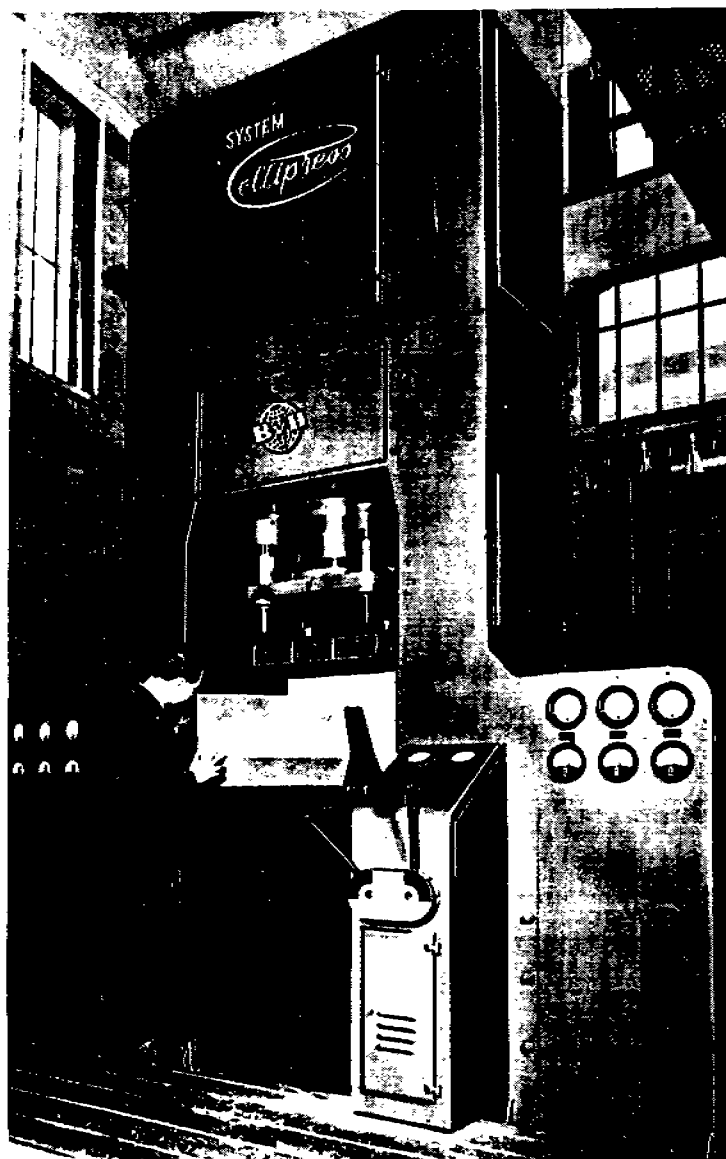


Figure 3.14. Press for Collipress process (Pagel 1967).

1 to 40 or more hydraulic presses. It is in the blending and pressing that differences exist between the systems.

Thermodyn Process: This is a closed system which does not allow for any volatiles formed during pressing to escape. It is somewhat like pressing wet-process high-density hardboard where some of the wood components such as lignin are activated and also act as a binder. The wood particles also lose some of their features and are fused together. The resulting product is called Lignoplast, which is a high-density, high-strength product. Species with high contents of hemicelluloses, especially pentosan, promote the reaction process. Species having a high amount of pentosan, such as beech, birch, and poplar, are more desirable for use in this system as contrasted to low pentosan-containing species such as spruce, pine, and Douglas fir.

It is a characteristic of this process that certain parts of the wood itself are chemically altered. During the first phase of pressing, the hemicelluloses are hydrolyzed. Acetic and formic acids are formed and thereby cause further hydrolysis. These attack the lignin-cellulose bonds and form "active lignins." In the second phase of the pressing, the gases formed by the hydrolysis react with the altered wood substance and condense to a plastic. It is important that the die in this system is not open during pressing to let any gases escape. Because of the high vapor pressure being developed within the piece being molded, it is necessary to cool the die and the parts within below the boiling point of water before opening the press. This means a relatively long and expensive press time.

This material is very high in density—about 85 lbs/ft³ (1.36 sp gr). A relatively fine particle is the most desirable for yielding a smooth-surfaced product. Thus, while it is good for some applications, its high density restricts its use in many others.

In this process, about 5% of phenolic resin is usually used. It is prepressed at about 2500 psi (17.2 MPa) before going into the hot dies. The dies can be heated between 320° and 550°F (160°-288°C) with pressures between 2500 and 4500 psi (17.2-31 MPa), depending on the product being produced. A conditioning time after being removed from the press is also required.

Collipress Process: This process was developed to produce heavy-duty containers for bottles, cans, and other packaged material requiring a box-shaped container. The preferred wood particle geometry is a flake with recommended flake size from 0.4 to 0.5 in. (10.2-12.7 mm) in length, 0.08 to 0.16 in. (2-4 mm) in width, and 0.008 to 0.016 in. (0.2-0.4 mm) in thickness. However, it has been found that any particle size common to the particleboard industry can be used, although final board properties may be changed. Fluffy fibers are not desirable because they are difficult to form into the die. Both urea and phenolic particleboard resins have been used at levels between 5 and 15%. The mat moisture content must be controlled between 8 and 18%, and thus in this respect is not unlike the regular dry-process system.

The resin-blended furnish is then formed into a preformer and then moved into the hot die. Figure 3.14 gives a general view of a typical Collipress which is equipped with one vertical and two lateral rams. The side rams compress two of the vertical sides while the other two side walls are compressed by wedge-shaped side members which are actuated by the lateral rams. The wall thickness of the

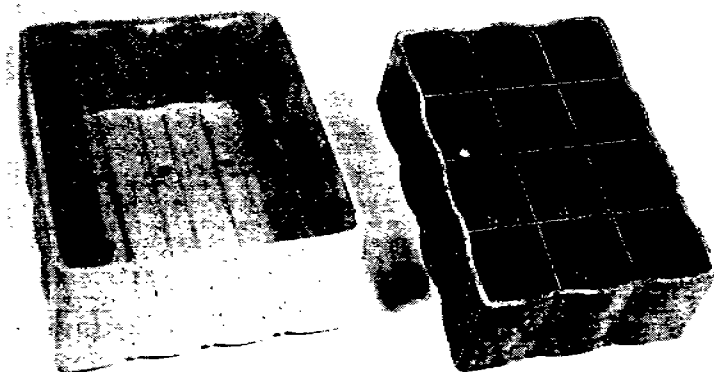


Figure 3.15. Collipress containers (Pagel 1967).

parts can be varied ± 0.08 in. (2 mm) without major changes of the die. Figure 3.15 shows typical beverage cases which can be produced using this system.

Pressing conditions range from 700 to 1500 psi (4.8-10.3 MPa) pressure with temperatures of 320° to 400°F (160°-204°C). Pressing time can take from one to two minutes.

A volume of about 150,000 units has been found to be minimum for the economic success of a particular container. A press can turn out more than one million units per year on a three-shift basis. One press, however, is not economical to run because of all the other production equipment necessary. Thus, a minimum plant usually will have at least three presses. At least three million units per year could be produced by a single plant.

Finished parts for the furniture industry may be covered with wood veneer in a second operation in the same mold, or in a rubber bag press. Many of the parts, particularly the beverage containers, have some type of finish applied by spraying or dipping.

Werzalit Process: This process can use all raw material suitable for the manufacture of standard particleboard. However, a fine sliverlike particle is recommended. Standard board resins can be used, with urea-formaldehyde being the preferred one at the present time.

Furnish blended with resin normally is formed into preforms before going to the hot press, although in some cases the furnish can be fed directly into the heated die. The preformed dies are mounted in cold presses for prepressing. These preforms, when used, are then transferred into the hot dies where the temperatures can range between 270° and 350°F (132°-177°C). The pressure requirements can vary between 200 and 1500 psi (1.4-10.3 MPa), again depending on the density of the molded parts. In this operation, the molded parts can also be overlaid with fine wood veneers, polyester films, or melamine and phenol-formaldehyde resin-impregnated papers or any other desired sheet-type material. Press times may

vary between 1 and 10 minutes, depending upon board thickness and the surface materials. The part density can be controlled between 35 and 70 lbs/ft³ (0.56-1.12 sp gr).

The normal way of heating the dies is by conduction from the hot press platens. However, in the case of large dies such as those used for molded drawers, auxiliary heating can be placed into the dies.

The automated molding lines are very much like those of a flat-panel plant. The particles are generated, dried, passed through a continuous blender, and formed into a variable-thickness mat fitting the desired die. This process is quite flexible in that it is relatively easy to change the dies.

The wide variety of molded parts that can be made with this system is one of its strong points. Completely finished products such as countertops can leave the press with both the face and edges completed.

Design of Molded Parts

As has already been mentioned, there are many different types of molded products now being manufactured. Some of the dies being used at present are very expensive. However, unless large-volume sales are made with an expensive die, its costs cannot be recovered. Minimum volume requirements appear to be as low as 10,000 units up to a high of over 150,000 units per mold.

Some of the operating parameters of the three systems discussed here are mutually exclusive. Thermodyn, for example, must work with the absolutely closed system which eliminates the use of any side rams or other moving elements in the die. Also, a very high-density part is produced by this process. Collipress is designed for building containers. Werzalit is designed to produce complicated boxlike constructions as well as flat tabletops with molded edges.

Boxes or cases produced by molding have much better strength than those assembled out of flat pieces. The typical right-angle joint in wood products is very weak. This is eliminated in a molded product, and, by eliminating the weak joint, the molded box gains strength as well as an improved appearance. In the case of molded tabletops, the strength is not improved but the appearance of the tabletop is, as special resin-impregnated papers applied on the face and around the smoothly finished edge contours do not have any seams.

In any molded product, high-wear sections can be reinforced by increasing the density in that area, or reinforcing ribs can be added. The potential for improving the physical properties of the weak areas in a molded product is of great importance when considering building structural panels with a molded configuration. Molded products can be built with reinforced areas properly located to provide high working stresses. It should be possible to do this in a structural component production plant, opening up many new avenues of design.

Physical Properties

Because of the many different configurations of molded products, it is difficult to come up with absolute figures on their physical properties. They do not relate to the commercial standards established for the other dry-process panel products.

As with most of these products, density is a very important factor. Higher density, as with the other dry-process products, usually means better properties. It also means higher weight and the possibility of more warping, both of which are undesirable.

Because of the way they are produced, most overlaid molded parts will have an unbalanced structure, because different types of overlay are used on each face. Normally in an unbalanced structure, if more moisture penetrates through one face than through the other, the differential expansion will cause the board or product to warp. However, it has been found with the molded parts that, by using the proper overlay materials, the rate of moisture flow is impeded to such a degree that this warping does not take place.

Molded wood parts can be made to exhibit good acoustical properties, particularly for use in electronic cases, and they can be made to exceed the National Electrical Manufacturers Association (NEMA) specifications for the surface characteristics of high-pressure laminates. They have general mechanical properties similar to or better than the properties of the higher-quality particleboards. These improved properties are associated with the previously mentioned higher density and a usually higher level of resin in the molded products. Also, as in other board products, particle size, shape, and geometry have considerable influence on the properties.

MINERAL-BONDED PRODUCTS

There are three types of mineral-bonded products that are produced. The first type is made of excelsior or wood wool, as it is officially named, and is made in slabs ranging up to about 3 1/2 in. (88.9 mm) in thickness. The second type consists of a product known as wood aggregate concrete. This product can be made as building blocks, full wall sections, or is poured in place as a slab for walls or floors. The third type is a building panel produced with thin flakes.

In comparison to concrete, these products are much lighter in weight. However, they are usually much heavier than the standard wooden building products that could serve the same end use. They are particularly good for acoustical and fire-resistant applications. The various mineral-bonded building products can range from about 18 lbs/ft³ to about 78 lbs/ft³ (0.20–1.20 sp gr).

Binders used for mineral-bonded products are magnesium oxysulfate, magnesite, gypsum, or Portland cement. The most important one is cement because of its high quality and availability in virtually all parts of the world. The cement should be rapid setting to enable a short working time in the process. However, the setting time of the cement is often strongly influenced by substances in the wood. These substances act as retarders to the cure of the cement and are said to "poison" the cement. The most important retarders appear to be wood sugars and/or the group of compounds known as *hemicelluloses*. They can sometimes be removed adequately by washing with cold or hot water. *Mineralizers*, a misleading term, can also be used to help with the bonding. Mineralizers are cement accelerators which speed the cure before the poisoning of the cement can occur. Three mineralizers are in common use: calcium chloride in Western Europe, sodium silicate in North America, and aluminum sulfate in the USSR.

In areas where many species are intermixed, this poisoning is a serious problem. Extensive work is going on in the United Kingdom and in the Federal Republic of Germany to overcome this problem. Recent reports indicate that pretreating by steaming or storage in hot water containing certain chemicals has increased the number of species suitable for use in cement-bonded products.

Excelsior Products

As noted in Chapter 1 the first excelsior boards named Heraklith were produced in Radenthein, Austria, in 1914. The binder used was magnesite. The first boards produced with cement came on the market in 1928. Before World War II, the binding agent used in Germany for the manufacture of this board was a combination of 39% cement, 35% magnesite, and 26% gypsum. However, after the war, the use of cement increased so that it became the dominant binder. Particularly in Europe, the processes and equipment have been highly developed and the dimensions, weight, and properties of excelsior boards are standardized.

This type of product has been made in the United States for many years. However, it has been difficult to determine the exact history of the early plants. It is known that such panels have been manufactured in currently operating plants since the 1940s but board was available much earlier from other sources, particularly one in Chewelah, Washington.

The Chewelah plant was the Thermax Division of the Northwest Magnesite Co. The process was based on the Heraklith process. A sawmill was built to cut large planks which were then cut into excelsior. Two products were produced: Thermax which was a "standard" excelsior panel and absorbex which was a higher-density panel made for acoustical and decorative purposes.

The superintendent of Northwest Magnesite Co. became interested in the manufacture of this type of board as a means of using the flue dust which was extracted from the kiln gases expelled during the burning of magnesite. For the manufacture of Thermax, which was made in 1-, 2-, and 3-in. (25.5, 50.8, and 76.2 mm) thicknesses, western larch and magnesium oxysulfate were used as the raw materials. To produce the cement, fresh flue dust was passed through a ball mill and then reacted with dilute sulfuric acid to form an emulsion. A small amount of caustic magnesite was added to improve the board strength. This emulsion was mixed with larch excelsior and then the material was spread onto a thin, steel belt and passed through a heated dryer or press. Steel belts were operated on the top and sides of the mat to hold to the desired dimensions. Heat was introduced into the shell of the dryer to speed curing. This was a continuous operation and the finished board was cut to the desired lengths as it emerged from the press.

Absorbex was made with cottonwood and caustic magnesite. It did not have the dark grey color of Thermax which was caused by the carbon content of the flue dust. It had a natural light tan color and was used extensively without further finishing. It was, however, a more costly product and this limited its use.

Production reached its peak in early World War II when much of the output went to the armed services throughout the world. However, limited production, and inadequate sales structure and difficulty in obtaining parts from Europe caused the plant to cease production in 1943.