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**DEVELOPMENT DOCUMENT FOR
EFFLUENT LIMITATIONS GUIDELINES
AND NEW SOURCE PERFORMANCE STANDARDS**

**TIMBER PRODUCTS INDUSTRY
VENEER/PLYWOOD AND HARDBOARD, WOOD PRESERVING**

**VENEER/PLYWOOD AND HARDBOARD
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GAINESVILLE, FLORIDA
JUNE, 1973**

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MAY, 1973**

**FOR:
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY**

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The regulations to be published by EPA under Sections 304(b) and 306 of the Federal Water Pollution Control Act, as amended, will be based to a large extent on the report and the comments received on it. However, pursuant to Sections 304(b) and 306 of the Act, EPA will also consider additional pertinent technical and economic information which is developed in the course of review of this report by the public and within EPA. EPA is currently performing an economic impact analysis regarding the subject industry, which will be taken into account as part of the review of the report. Upon completion of the review process, and prior to final promulgation of regulations, an EPA report will be issued setting forth EPA's conclusions regarding the subject industry, effluent limitations guidelines and standards of performance applicable to such industry. Judgments necessary to promulgation of regulations under Sections 304(b) and 306 of the Act, of course, remain the responsibility of EPA. Subject to these limitations, EPA is making this draft contractor's report available in order to encourage the widest possible participation of interested persons in the decision making process at the earliest possible time.

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U. S. Environmental Protection Agency
Office of Air and Water Programs
Effluent Guidelines Division
Washington, D. C. 20460

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DEVELOPMENT DOCUMENT FOR
EFFLUENT LIMITATIONS GUIDELINES
AND STANDARDS OF PERFORMANCE

TIMBER PRODUCTS INDUSTRY:

veneer/plywood and hardboard

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WOOD PRESERVING

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ABSTRACT

This document presents the findings of an extensive study of the timber products industry by Environmental Science and Engineering, Inc., (Veneer/Plywood and Hardboard) and Mississippi Forest Products Laboratory (Wood Preserving), for the purpose of recommending to the Environmental Protection Agency, Effluent Limitations Guidelines, Federal Standards of Performance, and Pretreatment Standards for the industry, to implement Sections 304, 306, and 307 of the "Act."

Effluent limitations guidelines contained herein set forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best available technology economically achievable which must be achieved by existing point sources by July 1, 1977 and July 1, 1983, respectively. The Standards of Performance for new sources contained herein set forth the degree of effluent reduction which is achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives.

The hardboard industry has been divided into two subcategories; dry process hardboard and wet process hardboard. The proposed regulations for the dry process hardboard industry for all three levels of technology set forth above establish the requirement of no discharge of wastewaters to navigable water. The proposed regulations for the wet process hardboard industry for July 1, 1977 are a discharge of BOD₅ and suspended solids of 1.6 kilograms per ton (3.2 pounds per ton) and 2.8 kilograms per ton (5.6 pounds per ton), respectively. The recommended discharge limitations for July 1, 1983 for BOD₅ and suspended solids are 0.2 kilograms per ton (0.4 pounds per ton) and 1.1 kilograms per ton (2.1 pounds per ton), respectively. The recommended Standards of Performance for new sources are the same as those for July 1, 1983.

The veneer and plywood industry is considered as one category of the timber products industry without further subcategorization. The proposed regulations for all three levels of technology set forth above establish the requirement of no discharge of wastewaters to navigable waters, with special considerations for plants with existing steam vats.

The best practicable treatment and control technology currently available and the best available treatment and control

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technology economically achievable are defined for the wood preserving industry, along with technology applicable to new sources. Effluent limitations commensurate with these levels of technology are recommended for each of four industry sub-categories.

An evaluation of the results has shown that the most serious waste problem in terms both of volume and quality of effluent is at plants that steam condition stock prior to treatment with oily preservatives. Among plants that condition stock by other means, treat with water-soluble chemicals, or use non-pressure processes for preservative treatment, a zero discharge of process water is currently practical.

Supportive data and rationale for development of the proposed Effluent Limitations Guidelines and Standards of Performance are contained in this document.

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SECTION I
CONCLUSIONS

VENEER AND PLYWOOD INDUSTRY

For the purpose of establishing Effluent Limitations Guidelines and Standards of Performance, the veneer and plywood industry as a whole serves as a single logical category. Factors such as age, size of plant, process employed, climate, and waste control technologies do not justify the segmentation of the industry into any subcategories. Similarities in waste loads and available treatment and control technologies further substantiate this.

It is concluded that by July 1, 1977 all veneer and plywood mills except those with existing steam vats can achieve zero discharge of wastewaters to navigable water. This can be achieved by the application of existing technology. Plants with existing steam vats may be able to do likewise, but the technology is not yet established. It is, therefore, believed that mills with existing steam vats should be given special consideration, keeping in mind that with biological treatment BOD loads can be reduced to about 80 kilograms (180 pounds) per day for the typical mill producing 9.3 million square meters (100 million square feet) per year on a 9.53 millimeter (three-eighths inch) basis.

HARDBOARD INDUSTRY

For the purpose of further establishing Effluent Limitations Guidelines and Standards of Performance, the hardboard manufacturing industry (which is a category of the timber products industry) has been broken down into two subcategories--dry process hardboard and wet process hardboard--because of their wide variation in process and wastewater flow. Factors such as age, size of plant, climate and waste control technologies do not justify the segmentation of the industry into further subcategories. Similarities within the two subcategories in waste loads and available treatment and control technologies further substantiate this.

It is concluded that the dry process hardboard mills can achieve the requirement of no discharge of wastewater by July 1, 1977 as 25 percent of the mills presently have no discharge.

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It is concluded that the wet process hardboard mills can achieve the requirements of 1.7 kilograms per ton (3.4 pounds per ton) and 2.8 kilograms per ton (5.6 pounds per ton) of BOD₅ and suspended solids, respectively, by July 1, 1977, as 22 percent of the mills are presently meeting this limitation.

WOOD PRESERVING INDUSTRY

For the purpose of further establishing Effluent Limitations Guidelines and Standards of Performance, the wood preserving industry (which is a category of the timber products industry) has been divided into four subcategories as follows:

<u>Plant Subcategory</u>	<u>Description</u>
1	Pressure process employing oily preservatives in which the predominant method of conditioning green stock is by steaming and/or vapor drying
2	Pressure processes employing oily preservatives in which the predominant method of conditioning green stock is by water-borne salts
3	Pressure processes employing water-borne salts
4	Non-pressure processes

The basis for the subcategorization was the variation both in volume and composition of discharges, the method of conditioning wood preparatory to treatment, and whether a pressure or non-pressure process is used.

The volume of wastewater originating from non-pressure preservative processes is small and consists principally of precipitation that enters the open tanks employed. Modification of existing facilities to prevent the entry of rain and snow and/or dehydration of oil to maintain water content at an acceptable level can be used to eliminate discharges from this segment of the industry.

Plants that employ pressure retorts and treat unseasoned stock with oily preservatives have a more serious pollution problem. Their effluents are normally characterized by a high phenol content and a high oxygen demand, the latter due primarily to

entrained oils and various extractives, principally carbohydrates, that are removed from wood during conditioning. This process may be accomplished by either one of two techniques, depending primarily upon species of wood. Boultonizing is the predominant conditioning method used at plants that treat Douglas-fir and other West-Coast species, while open steaming is the predominant method used with the pines and other species native to the East. Wastewater from the Boulton process consists of water removed from the wood. Because the volume is relatively small, amounting to less than 9,500 liters per day (2,500 gallons per day) at most plants, it is practicable to reuse it for cooling water and dispose of the surplus by evaporation. A zero discharge of process water has already been achieved by many plants that employ the Boulton method of conditioning.

The waste stream from plants employing open steaming is composed both of the water removed from the wood and the steam condensate that forms in the retort during the steaming operation. The volume is large relative to that for the Boulton process, and the waste usually has a much higher oxygen demand because of emulsified oils and dissolved solids. Elimination of discharges from plants in this group is not practicable. The waste is amenable to conventional wastewater treating methods, and the volume of discharge can be reduced substantially by in-plant process changes and control techniques.

Wastewaters from pressure processes in which water-soluble preservatives and fire retardants are employed contain trace amounts of the chemicals used. These are primarily salts of copper, chromium, arsenic, and zinc, as well as fluorides, phosphates, and borates. A zero discharge is practicable for such plants because of the small volume of wastewater involved and the feasibility of reusing it as makeup water in preparing fresh batches of treating solution.

SECTION II
RECOMMENDATIONS

VENEER AND PLYWOOD INDUSTRY

For the veneer and plywood industry, the recommended effluent limitations for the best practicable control technology currently available (July 1, 1977) are no discharge of wastewaters to navigable water with special consideration for mills with existing steam vats. No discharge of wastewaters to navigable water is recommended as the Effluent Limitations Guidelines and Standards of Performance for the best available technology economically achievable (July 1, 1983) and for new sources.

HARDBOARD INDUSTRY

No discharge of wastewater to navigable water is also recommended as the Effluent Limitations Guidelines and Standards of Performance for the dry process hardboard industry. This represents the degree of effluent reduction obtainable by existing point sources through the application of the best practicable control technology currently available, and the best available technology economically achievable. This also represents, for new sources, a standard of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction achievable through application of the best available demonstrated control technology, processes, operating methods or other alternatives.

For the wet process hardboard industry, the recommended effluent limitations for the best practicable control technology currently available (July 1, 1977) are a BOD and suspended solids of 1.7 kilograms per metric ton (3.4 pounds per ton) and 2.8 kilograms per metric ton (5.6 pounds per ton), respectively. The recommended effluent limitations for the best available technology economically achievable (July 1, 1983) are a BOD and suspended solids of 0.2 kilograms per metric ton (0.4 pounds per ton) and 1.1 kilograms per metric ton (2.1 pounds per ton), respectively. The recommended standards of performance for new sources are a BOD and suspended solids of 0.2 kilograms per metric ton (0.4 pounds per ton) and 1.1 kilograms per metric ton (2.1 pounds per ton), respectively.

WOOD PRESERVING INDUSTRY

A high degree of pollution abatement is practicable in the wood preserving industry through the application of conventional wastewater treatment methods and in-plant process changes and controls. Recommendations pertaining to effluent guidelines for the four subcategories into which the industry was divided are summarized below:

(1) A zero discharge requirement for all levels of treatment and control technologies is recommended for: (a) all non-pressure processes; (b) plants employing only water-soluble preservatives and fire retardants, and that portion of the production facilities used to apply salt-type chemicals at plants that also treat with other types of preservatives; and (c) plants that employ the Boulton process as the predominant method of conditioning.

(2) The following effluent limitations are recommended for plants that use steaming and vapor drying as the predominant methods of conditioning stock for preservative treatment:

	<u>Phenols</u>	<u>COD</u>	<u>BOD</u>	<u>Oil and Grease</u>	<u>Suspended Solids</u>
Best Practicable Control Technology					
Currently Available (Kg/1000M ³)	0.658 (0.041)	109.236 (6.806)	69.272 (4.316)	11.987 (0.747)	33.304 (2.075)
Best Available Technology Economi- cally Achievable and New Sources					
(Kg/1000M ³)	0.064 (0.004)	41.301 (2.573)	6.662 (0.415)	3.338 (0.208)	13.323 (0.830)

NOTE: Values in parentheses are discharge equivalents in pounds per 1,000 cubic feet)

A variance to the effluent guidelines is recommended for certain plants for which circumstances make unrealistic a uniform application of effluent limitations. Specifically, it is recommended that:

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(1) A discharge of trace quantities of pollutants in non-process water be permitted at older plants in subcategories for which a zero discharge requirement is proposed.

(2) The discharge of copper, chromium, arsenic, and other ions used in salt-type treatments be permitted in specified amounts for subcategory 1 plants, the oils wastewater from which becomes contaminated with salt-type preservatives due to: (a) use of a single retort for both types of preservatives, or (b) dual treatment of certain products with both creosote and inorganic salts.

(3) In applying the best practicable control technology currently available guidelines, special consideration be given to plants that: (a) have already invested in wastewater treating facilities, the performance of which is adequate to protect receiving waters and to remove 95 percent or more of the major pollutants from the discharge, but which fails to meet the best practicable control technology currently available effluent limitation; or (b) have inadequate land area available to provide lagoon space for long-term detention time following biological treatment.

(4) A discharge equivalent to 25 percent of that allowed for subcategory 1 plants be permitted under best practicable control technology currently available for subcategory 4 plants that are unable to keep water out of open tanks during winter months because of ice formation on stock prior to treatment.

Wastewater from preservative treatments employing oil-type preservatives contains no constituent that is incompatible with a well-designed and operated publicly owned wastewater treatment plant. Wastewater from salt-type treatments containing arsenic, copper, zinc, and chromium potentially is incompatible with a biological treatment system, and it is recommended that such waste receive an appropriate pretreatment prior to discharge to the sewer.

SECTION III

INTRODUCTION

PURPOSE AND AUTHORITY

Section 301(b) of the Act requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best practicable control technology currently available as defined by the Administrator pursuant to Section 304(b) of the Act. Section 301(b) also requires the achievement by not later than July 1, 1983, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best available technology economically achievable which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b) of the Act. Section 306 of the Act requires the achievement by new sources of a Federal standard of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the best available demonstrated control technology processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants.

Section 304(b) of the Act requires the Administrator to publish within one year of enactment of the Act, regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedure innovations, operation methods and other alternatives. The regulations proposed herein set forth effluent limitations guidelines pursuant to Section 304(b) of the Act for the plywood/veneer, hardboard, and wood preserving categories of the timber products processing industry.

Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306(b) (1) (A) of the Act, to propose regulations establishing Federal standards of performance for new

sources within such categories. The Administrator published in the Federal Register of January 16, 1973 (38 F.R. 1624), a list of 27 source categories. Publication of the list constituted announcement of the Administrator's intention of establishing, under Section 306, standards of performance applicable to new sources within the plywood/veneer, hardboard, and wood preserving categories of the timber products processing industry.

SUMMARY OF METHODS USED FOR DEVELOPMENT OF THE EFFLUENT
LIMITATIONS GUIDELINES AND STANDARDS OF PERFORMANCE

Those effluent limitations guidelines and standards of performance proposed herein were developed in the following manner. The point source category was first categorized for the purpose of determining whether separate limitations and standards are appropriate for different segments within a point source category. Such subcategorization was based upon raw materials used, product produced, manufacturing process employed, and other factors. The raw waste characteristics for each subcategory were then identified. This included an analysis of (1) the source and volume of water used in the process employed and the source of waste and wastewaters in the plant; and (2) the constituents (including thermal) of all wastewaters including toxic constituents and other constituents which result in taste, odor, and color in water or aquatic organisms. The constituents of wastewaters which should be subject to effluent limitations guidelines and standards of performance were identified.

The full range of control and treatment technologies existing within each subcategory was identified. This included an identification of each distinct control and treatment technology, including both inplant and end-of-process technologies, which are existent or capable of being designed for each subcategory. It also included an identification in terms of the amount of constituents (including thermal) and the chemical, physical, and biological characteristics of pollutants; of the effluent level resulting from the application of each of the treatment and control technologies. The problems, limitations and reliability of each treatment and control technology and the required implementation time was also identified. In addition, the non-water quality environmental impact, such as the effects of the application of such technologies upon other pollution problems, including air, solid waste, noise and radiation were

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also identified. The energy requirements of each of the control and treatment technologies were identified, as well as the cost of the application of such technologies.

The information, as outlined above, was then evaluated in order to determine what levels of technology constituted the "best practicable control technology currently available," "best available technology economically achievable" and the "best available demonstrated control technology, processes, operation methods or other alternatives." In identifying such technologies, various factors were considered. These included the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application, the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques process changes, non-water quality environmental impact (including energy requirements) and other factors. Consideration of the technologies was not limited to those presently employed in the industry, but included also those processes in pilot plant or laboratory research stage and those used by other industries. The alternative of combined industrial/municipal treatment, including the compatibility and economic ramifications, was also examined.

The data for identification and analysis were derived from a number of sources. These sources included Environmental Protection Agency research information, published literature, internal reports furnished by the industry and equipment manufacturers, qualified technical consultation, on-site visits and interviews at exemplary plants throughout the United States, and evaluation of permit application data provided under Permit Programs of the Rivers and Harbors Act of 1899 (Refuse Act). All references used in this study are included in Section XIII.

GENERAL DESCRIPTION OF THE INDUSTRY

The timber products processing industry includes a broad spectrum of operations ranging from cutting and removing the timber from the forest to the productive utilization of wood wastes. The greatest water pollution potential in the industry exists in the case of plywood/veneer mills, hardboard mills, and wood preserving plants, and although a greater total volume of wastes may be discharged from other liquid waste generating factories of the industry, the strength is lower and total flow is distributed over a substantially

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larger number of installations. At any given location the environmental impact of the relatively higher strength wastes from an installation of the three categories mentioned above will be considerably greater. Therefore, Phase I of this study includes plywood/veneer mills, hardboard mills, and wood preserving plants.

Veneer and Plywood

Plywood is an assembly of numbers of layers of wood joined together by means of an adhesive. It is a multi-use material characterized by its ability to be designed and engineered for construction purposes, decorative purposes, flat shapes, curves, and bent shapes. Hardwood plywood is distinguished from softwood plywood in that the former is generally used for decorative purposes and has a face ply of wood from deciduous or broad leaf trees. Softwood plywood, on the other hand, is generally used for construction and structural purposes, and the veneers typically are of wood from evergreen or needle bearing trees. Hardwoods include such species as oak, walnut, lauan, elm, cherry, hickory, pecan, maple, birch, gum, cativo, teak, rosewood, and mahogany.

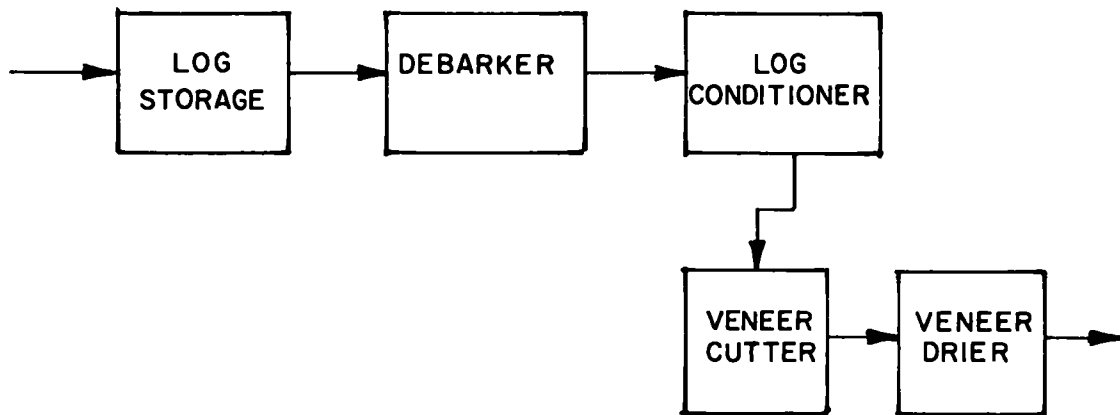
The principal raw material in the veneer and plywood industry is roundwood, with species varying according to geographical location.

The various operations for converting roundwood into veneer and finally into plywood are relatively simple and chiefly mechanical. A simplified process flow diagram for the production of veneer and plywood from roundwood is shown in Figure 1.

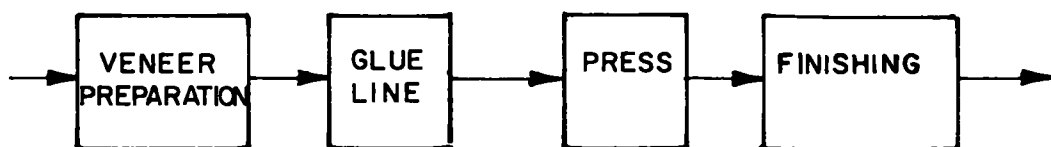
The most important operation in this process is the cutting of the veneer. The appearance of a plywood panel is greatly dependent upon the manner in which the veneer is cut. This is the chief reason for cutting veneers in different ways. Prior to the cutting of veneer, most logs are heated to make cutting easier and to help insure smooth-cut veneer.

Veneer can be cut in four ways: (1) rotary lathing; (2) slicing; (3) stay log cutting; and (4) sawing veneer.

After rotary veneers are cut, they may go directly to a clipper or may be stored temporarily on a series of horizontal storage decks or on reels. The green clipper clips the veneers to various widths and also may remove defects. From the clippers the veneers are conveyed to the dryers, large chambers which are equipped with heating elements and fans and which have automatic conveying systems on which the veneer moves. Some mills now use high speed drivers



VENEER OPERATION



PLYWOOD OPERATION

FIGURE 1 - SIMPLIFIED PROCESS FLOW DIAGRAM FOR VENEER AND PLYWOOD PRODUCTION

located behind the rotary lathe which allow the veneer to be dried in a continuous sheet after it is cut. Veneers are generally dried to moisture contents of below ten percent, which is a level compatible with gluing and consistent with the moisture content to which hardwood plywood products will be exposed while in service.

After drying, less than full-size sheets are dry-clipped and joined together to form full-size sheets in preparation for gluing. Taping machines and tapeless splicers are used in this joining process. Patching and repairing are then accomplished.

After pressing, the panels are stacked for conditioning, sawed to dimension, and sanded. They are then ready for inspection, grading, strapping, and shipping. Grading and inspection usually are done at intermediate steps in the manufacturing process.

Hardboard

The industry refers to panel products reconstituted from wood fibers and chips as "board." To a great extent, the board is manufactured from chips or fibers which are by-products of lumber or plywood production. Particle board, insulation board, and hardboard make up this group of products.

There are two major subcategories of hardboard manufacturing based upon the manner in which the board is formed. In the wet process, water is used as the medium for carrying the fibers and distributing them in the forming machine. In the dry process air serves that function. The present hardboard industry in the United States developed from a defiberization process invented by William H. Mason during the 1920's. It was the prototype of wet process hardboard. Other methods of fiber preparation were later developed. All are intended basically to provide ultimate bonding in the hardboard. The resulting fibers may be washed, screened, and refined before being carried in a liquid slurry to a board-forming machine similar to that used in making paper, a cylindrical former, or a batch unit. After forming, the wet mat may be pressed either wet or dry. If the mat is to be pressed dry, then all of the moisture must be removed by evaporation after wet-forming. All but one of the wet-dry hardboard mills discussed later are associated with an insulation board mill.

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Fiber preparation in the dry process is similar to that in the wet process. After fiber preparation, existing water is reduced in a dryer. The fibers are then transported by an air stream to a dry-felting machine for mat formation. After formation of the dry mat, the mat is pressed in a dry state by all but two of the dry press hardboard mills to be discussed later. Two mills add water to the mat after dry formation; however, in one mill any water added is evaporated in the pressing operation. Virtually all new hardboard installations since the 1950's have utilized the dry process.

Wood Preserving

The wood preserving industry applies treatment to round and sawn wood products by injecting into them chemicals that have fungistatic and insecticidal properties, or that impart fire resistance.

The most common preservatives used in wood preserving are creosote, pentachlorophenol, and various formulations of water-soluble, inorganic chemicals, the most common of which are salts of copper, chromium, and arsenic. Fire retardants are formulations of salts, the principal ones of which are borates, phosphates, and ammonium compounds. Eighty percent of the plants in the United States use at least two of the three types of preservatives. Many treat with one or two preservatives plus a fire retardant (1).

Consumption data for the principle preservatives for the five-year period between 1967 and 1971 are given in Table I. In terms of amount used, creosote in its various forms is the most important, followed in order by pentachlorophenol and salt-type preservatives. Among the latter, the CCA (copper-chromium-arsenic) formulations account for most of that used.

The general trend in preservative use is a decrease in creosote consumption and an increase in the use of pentachlorophenol and salt-type preservatives. This trend is expected to continue. Consumption of fire retardants has been relatively stable for the past five years, but it is anticipated that it will increase significantly as existing building codes are modified to permit the use of fire retardant treated wood in lieu of other flameproof construction materials.

TABLE I
CONSUMPTION OF PRINCIPLE PRESERVATIVES AND FIRE RETARDANTS
OF REPORTING PLANTS IN THE UNITED STATES, 1967-1971 (2)

Material	(Units)	Year				
		1967	1968	1969	1970	1971
Creosote	Million Liters	329	293	274	256	242
Creosote-Coal Tar	Million Liters	216	219	206	229	218
Creosote-Petroleum	Million Liters	135	121	115	125	118
Total Creosote	Million Liters	559	518	485	475	441
Total Petroleum	Million Liters	279	279	258	286	307
Penta-chlorophenol	Million Kilograms	11.2	12.0	11.6	12.9	14.5
Chromated Zinc Chloride	Million Kilograms	0.8	0.7	0.6	0.7	0.6
CCA	Million Kilograms	1.0	1.4	2.1	2.7	3.9
ACC	Million Kilograms	0.6	0.5	0.4	0.4	0.5
Pyresote	Million Kilograms	1.3	1.7	1.1	1.2	1.2
Non-Com	Million Kilograms	2.4	2.7	3.4	3.1	2.8
FCAP	Million Kilograms	2.4	1.8	2.0	1.2	1.0
Osmose Flame Proof	Million Kilograms	2.0	1.8	1.8	2.0	2.4
Other Solids	Million Kilograms	2.7	2.8	2.3	1.7	1.7

Note: Data are based on information supplied by approximately 357 plants for each year.

INVENTORY OF INDUSTRY

Veneer and Plywood

Today there are approximately 501 veneer and plywood mills in the United States, 248 of which use softwood, 253 use hardwood, and 27 use a combination of softwood and hardwood. As shown in Table 2, the largest concentrations of mills are in Oregon, Washington, and North Carolina. Figures 2 through 5 show the distribution of mills throughout the United States. Hardwood and softwood mills are located according to availability of raw materials, and their distribution, therefore, follows the timber distribution as shown in Figure 6. A detailed inventory of the mills in the United States is included in Appendix A of this document. A summary is presented in Table 2.

In 1968, a Forest Industry survey resulted in the most complete statistics available for the plywood industry. At that time there were 175 softwood and 242 hardwood plywood mills. Although hardwood plywood mills were more numerous, individual installations were smaller. In 1968, the production of softwood plywood in the United States was about 1.4 billion square meters on a 9.53 millimeter basis (15 billion square feet on a three-eighths inch basis), while that of hardwood plywood was slightly more than 186 million square meters on a 6.35 millimeter basis (2 billion square feet on a one-fourth inch basis). Included in Table 3 are statistics from the 1968 survey. More recent data collected as a result of correspondence with the industry association shows that in 1972, softwood plywood production was 1.71 billion square meters on a 9.53 millimeter basis (18.3 billion square feet on a three-eighths inch basis), while that of hardwood plywood was estimated as 205 million square meters on a 6.35 millimeter basis (2.2 billion square feet on a one-fourth inch basis).

During the decade 1950-1960, the world's production of plywood rose by 150 percent. The United States accounted for about 50 percent of the world's plywood production. More important, however, is that the United States along with Canada was the major source of softwood timber. As the demand for construction materials continues to increase so does the demand for softwood plywood. Twenty years ago practically all of the softwood plywood in the United States was produced in the Pacific Northwest from Douglas fir. In the past ten years, however, the industry has expanded into the southeastern United States where the use of southern

TABLE 2

SUMMARY OF VENEER AND PLYWOOD PLANTS IN THE UNITED STATES

<u>SOFTWOOD PLYWOOD</u>		<u>SOFTWOOD VENEER</u>	
Alabama	6	Arkansas	1
Arizona	1	California	8
Arkansas	8	Florida	1
California	15	Georgia	1
Colorado	1	Maryland	1
Florida	2	Minnesota	1
Georgia	5	New Jersey	1
Idaho	5	North Carolina	6
Louisiana	12	Oregon	31
Maryland	1	South Carolina	1
Michigan	2	Texas	1
Mississippi	6	Virginia	1
Montana	4	Washington	9
New Hampshire	1	Wisconsin	<u>2</u>
North Carolina	6	TOTAL	65
Oklahoma	1		
Oregon	81		
South Carolina	3		
Texas	9		
Virginia	1		
Washington	<u>29</u>		
TOTAL	199		

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TABLE 2 CONTINUED

<u>HARDWOOD PLYWOOD</u>		<u>HARDWOOD VENEER</u>	
Alabama	9	Alabama	4
Arkansas	4	Florida	4
California	6	Georgia	5
Florida	3	Illinois	1
Georgia	6	Indiana	13
Illinois	1	Iowa	2
Indiana	6	Kentucky	4
Louisiana	2	Maine	1
Maine	3	Maryland	1
Michigan	4	Michigan	3
Minnesota	2	Minnesota	2
Mississippi	6	Mississippi	3
New Hampshire	2	Missouri	2
New York	2	New Jersey	1
North Carolina	26	New York	5
Oregon	9	North Carolina	19
Pennsylvania	4	Ohio	2
South Carolina	16	Oregon	5
Tennessee	4	Pennsylvania	5
Texas	3	South Carolina	6
Vermont	5	Tennessee	2
Virginia	11	Vermont	1
Washington	5	Virginia	7
West Virginia	1	West Virginia	2
Wisconsin	<u>16</u>	Wisconsin	<u>4</u>
TOTAL	157	TOTAL	107

TABLE 2 CONTINUED

<u>SOFTWOOD & HARDWOOD PLYWOOD</u>		<u>SOFTWOOD & HARDWOOD VENEER</u>	
Alabama	2	Florida	1
Florida	1	Georgia	1
Michigan	1	Minnesota	1
New Hampshire	1	North Carolina	3
North Carolina	1	Oregon	3
Oregon	3	Virginia	<u>1</u>
South Carolina	1	TOTAL	11
Texas	1		
Washington	<u>4</u>		
TOTAL	16		

TOTAL PLYWOOD PLANTS - 340

TOTAL VENEER PLANTS - 161



FIGURE 2 - DISTRIBUTION OF SOFTWOOD VENEER AND PLYWOOD MILLS THROUGHOUT THE UNITED STATES



FIGURE 3 - DISTRIBUTION OF HARDWOOD VENEER AND PLYWOOD MILLS THROUGHOUT THE UNITED STATES

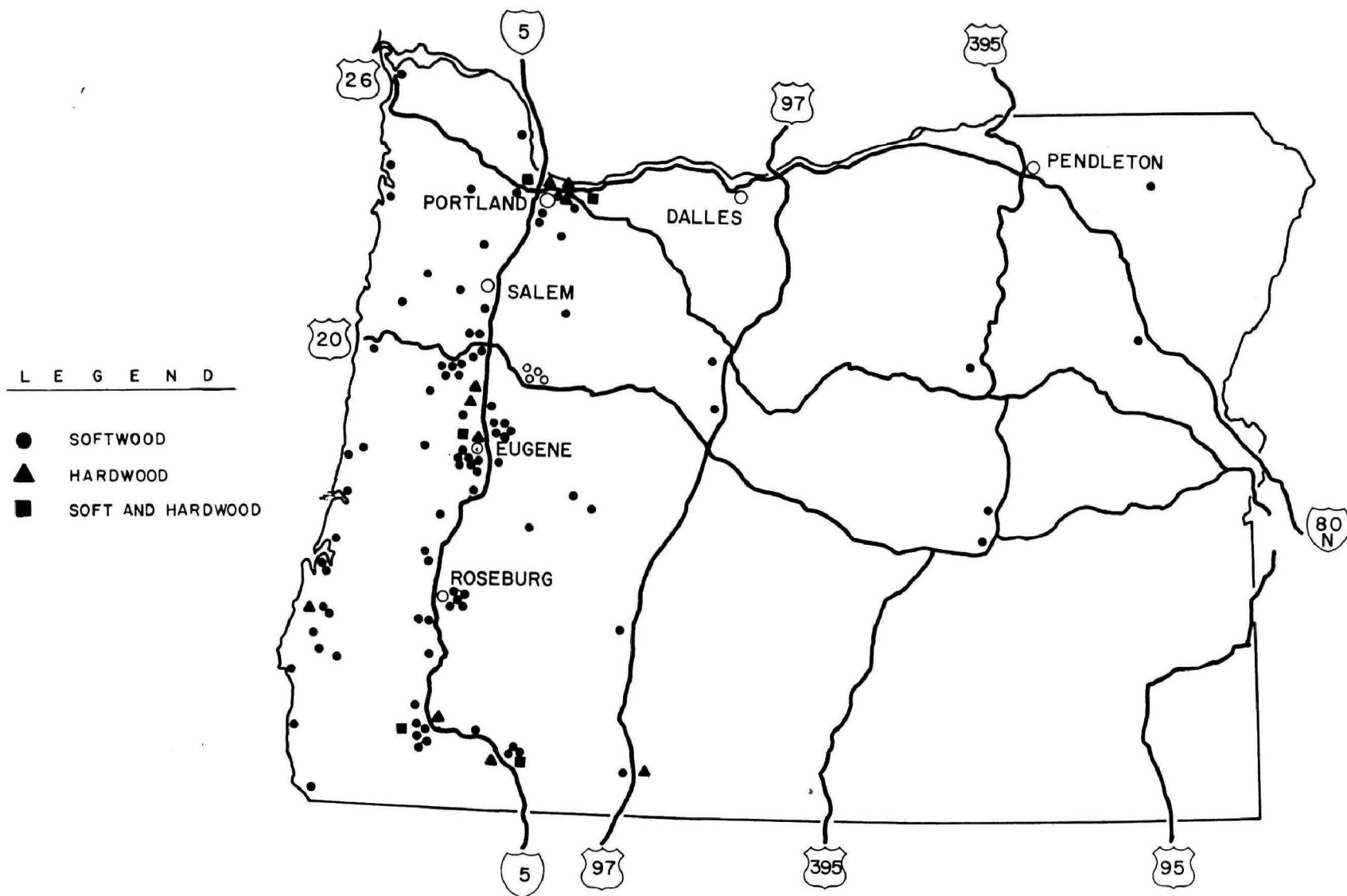


FIGURE 4 - DISTRIBUTION OF VENEER AND PLYWOOD MILLS IN THE STATE OF OREGON

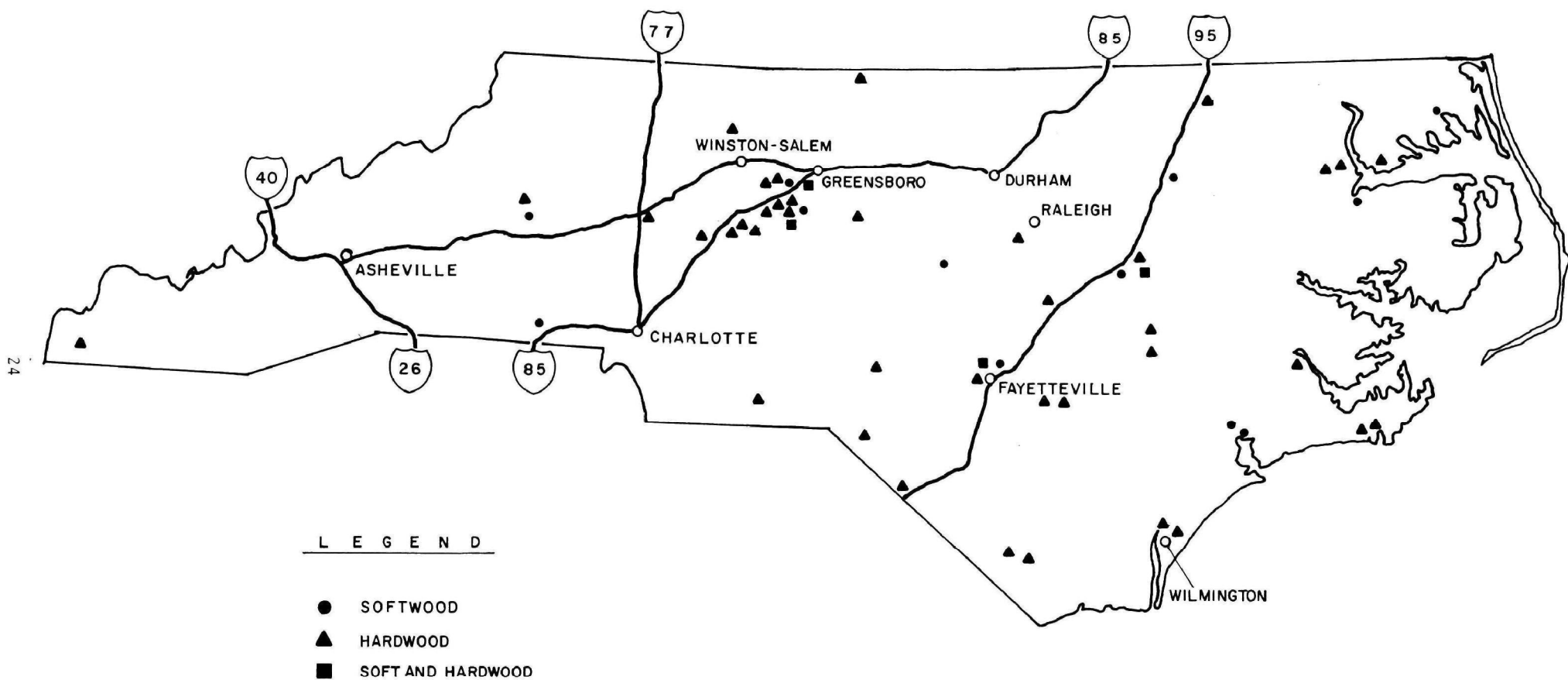


FIGURE 5 - DISTRIBUTION OF VENEER AND PLYWOOD MILLS IN THE STATE OF NORTH CAROLINA

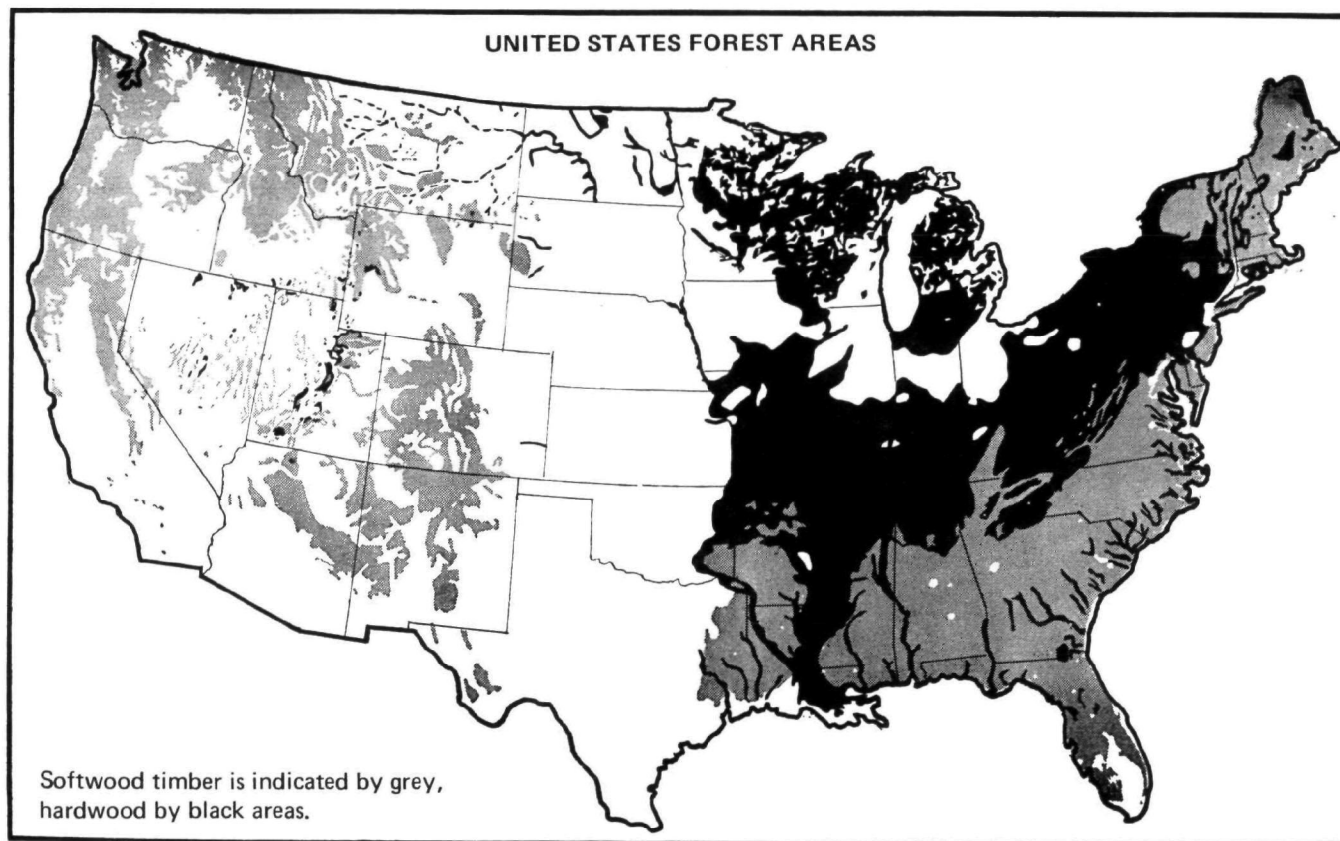


FIGURE 6 (3) - UNITED STATES FOREST AREAS

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TABLE 3
FOREST INDUSTRIES 1968 PLYWOOD STATISTICS (4)

Region	Number of Softwood Plywood Plants	Softwood Ply- wood Production In Square meters (9.53 mm Basis)	Number of Hardwood Plywood Plants	Hardwood Ply- wood Production In Square meters (6.35 mm - Sur- face Measure)
New England			15	7,175,000
Middle Atlantic			7	1,675,000
East North Central			41	29,950,000
West North Central			4	4,200,000
South Atlantic	10	54,730,000	72	42,660,000
East South Central	7	49,500,000	24	30,625,000
West South Central	17	142,500,000	11	4,100,000
Mountain	11	101,720,000		
Pacific	130	1,063,000,000	31	77,375,000
Total U.S.A.	175	1,411,500,000	205	197,750,000

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pine has catapulted this area into the plywood scene (See Table 4). In 1968, the southeast accounted for 20 percent of the nation's softwood plywood production.

As a result of demand, hardwood plywood production has remained fairly constant over the past 20 years (Tables 5 and 6, and Figure 7).

Hardboard

In 1973, there were 27 manufacturing facilities which produced hardboard by some variation of the two basic processes. As shown in Table 7, 17 of these were variations of the dry process and 10 were variations of the wet process. In addition, some hardboard is produced at six insulation board plants, but the wastewater aspects of these will be considered in Phase II of the study. It has been estimated that in 1972, the total production of hardboard in the United States, on a 3.2 millimeter (one-eighth inch) basis, was 0.54 billion square meters (518 billion square feet). The geographical distribution of the hardboard industry is shown more graphically in Figure 8.

From the viewpoint of total utilization of the forest resource, those categories of the timber products processing industry which are relatively indiscriminate in terms of the properties of the wood raw material used are of increasing importance. High quality lumber and plywood are prized for certain structural characteristics which are inherent in the structure of the harvested tree. As the timber products industry becomes more dependent on smaller, second-growth timber and as the demands for timber products increase, it becomes more important to develop those categories of the industry which can use wood and wood wastes in a variety of forms and in large quantities.

In general, the categories of this type include those which can use wood reduced to small particles or fibers and then reconstitute them into useful form. Essentially, these operations are represented by the "board" category of the industry as described previously. In its entirety, this is one of the most rapidly expanding industrial operations in the United States. Hardboard production contributes to that growth. It has been reported that 16 times as much hardboard was used in 1953 as compared with 1929. The Forest Products Research Society reported that hardboard production on a 3.2 millimeter (one-eighth inch) basis increased from 0.09 billion square meters (0.96 billion square feet) in 1948 to 0.14 billion square meters (1.5 billion square feet) in 1953 (5). In 1968,

TABLE 4

SOFTWOOD PLYWOOD PRODUCTION FOR 1972

<u>State</u>	<u>Sq. Meters-9.53 mm Basis</u>
California	140,543,000
Oregon	803,700,000
Washington	210,443,000
Idaho	156,366,000
Others (Mostly South)	495,066,000

Note: Data obtained from APA.

TABLE 5

HARDWOOD PLYWOOD PRODUCTION IN THE UNITED STATES

<u>Year</u>	<u>Square Meters Surface Area</u>
1947	68,700,000
1955	87,000,000
1960	82,500,000
1965	170,500,000
1970	146,600,000
1972	204,765,000

Note: Data obtained from Hardwood Manufacturing Association - April 1, 1973.

TABLE 6

SOFTWOOD PLYWOOD PRODUCTION IN THE UNITED STATES

<u>Year</u>	<u>Sq. Meters-9.53 mm Basis</u>	<u>No. of Plants</u>
1925	14,240,000	12
1940	111,690,000	25
1950	237,700,000	68
1960	727,500,000	152
1970	1,334,700,000	179
1972	1,707,400,000	--

Note: Data obtained from APA.

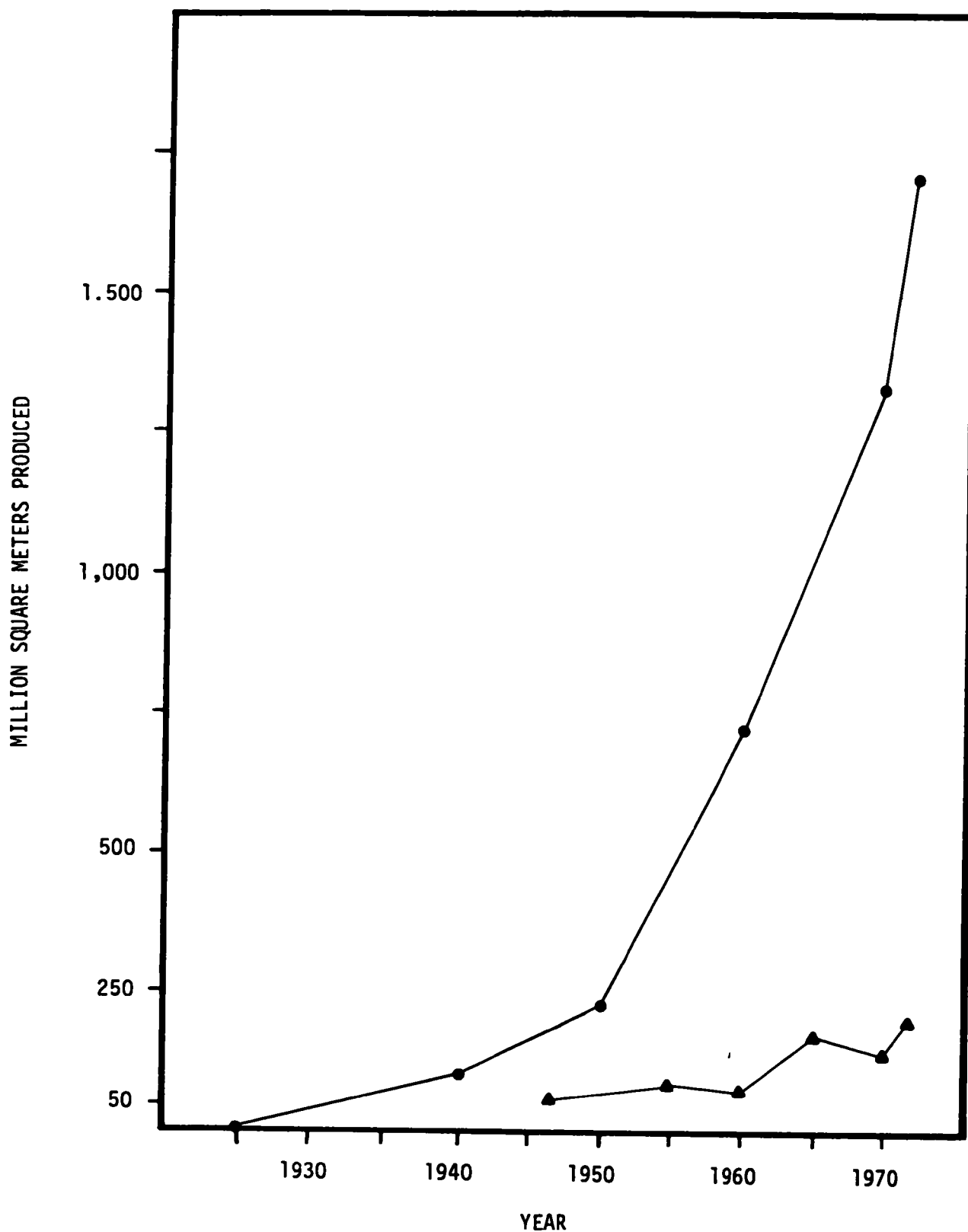


FIGURE 7 - GROWTH OF THE PLYWOOD INDUSTRY IN THE UNITED STATES

- ▲ - SOFTWOOD PLYWOOD PRODUCTION ON A 9.53mm (3/8") BASIS
- HARDWOOD PLYWOOD PRODUCTION ON A 6.35mm (1/4") BASIS

TABLE 7

INVENTORY OF HARDBOARD MANUFACTURING FACILITIESDRY PROCESS

Anacortes Veneer
Anacortes, Washington

Georgia Pacific Corporation
Conway, North Carolina

Celotex Corporation
Deposit, New York

Masonite Corporation
Spring Hope, North Carolina

Celotex Corporation
Marion, South Carolina

Masonite Corporation
Towanda, Pennsylvania

Celotex Corporation
Paris, Tennessee

Pope and Talbot
Oakridge, Oregon

Evans Products
Doswell, Virginia

Superwood (Nu-Ply)
Bemidji, Minnesota

Evans Products
Moncure, North Carolina

U.S. Plywood
Champion International
Catawba, South Carolina

Evans Products
Phillips, Wisconsin

U.S. Plywood
Champion International
Lebanon, Oregon

Georgia-Pacific Corporation
Coos Bay, Oregon

Weyerhaeuser Company
Craig, Oklahoma

DRY-WET PROCESS

Weyerhaeuser Company*
Klamath Falls, Oregon

WET PROCESS

Abitibi Corporation
Roaring River, North Carolina

Evans Products
Corvallis, Oregon

Forest Fibre
Stimpson Lumber Company
Forest Grove, Oregon

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TABLE 7 CONTINUED
(INVENTORY OF HARDBOARD MANUFACTURING FACILITIES)

Masonite Corporation
Laurel, Mississippi

Superwood
Duluth, Minnesota

Masonite Corporation
Ukiah, California

Superwood
North Little Rock, Arkansas

Superior Fibre
Superior, Wisconsin

U.S. Plywood
Champion International
Dee (Hood River), Oregon

WET-DRY PROCESS

Abitibi Corporation*
Alpena, Michigan

WET-DRY HARDBOARD PLANTS
OPERATED IN CONJUNCTION
WITH INSULATION BOARD PLANTS

Boise Cascade
International Falls, Minnesota

U.S. Gypsum
Greenville, Mississippi

Temple Industries
Diboll, Texas

U.S. Gypsum
Pilot Rock, Oregon

U.S. Gypsum
Danville, Virginia

Weyerhaeuser Company
Craig, Oklahoma

* To be given special consideration

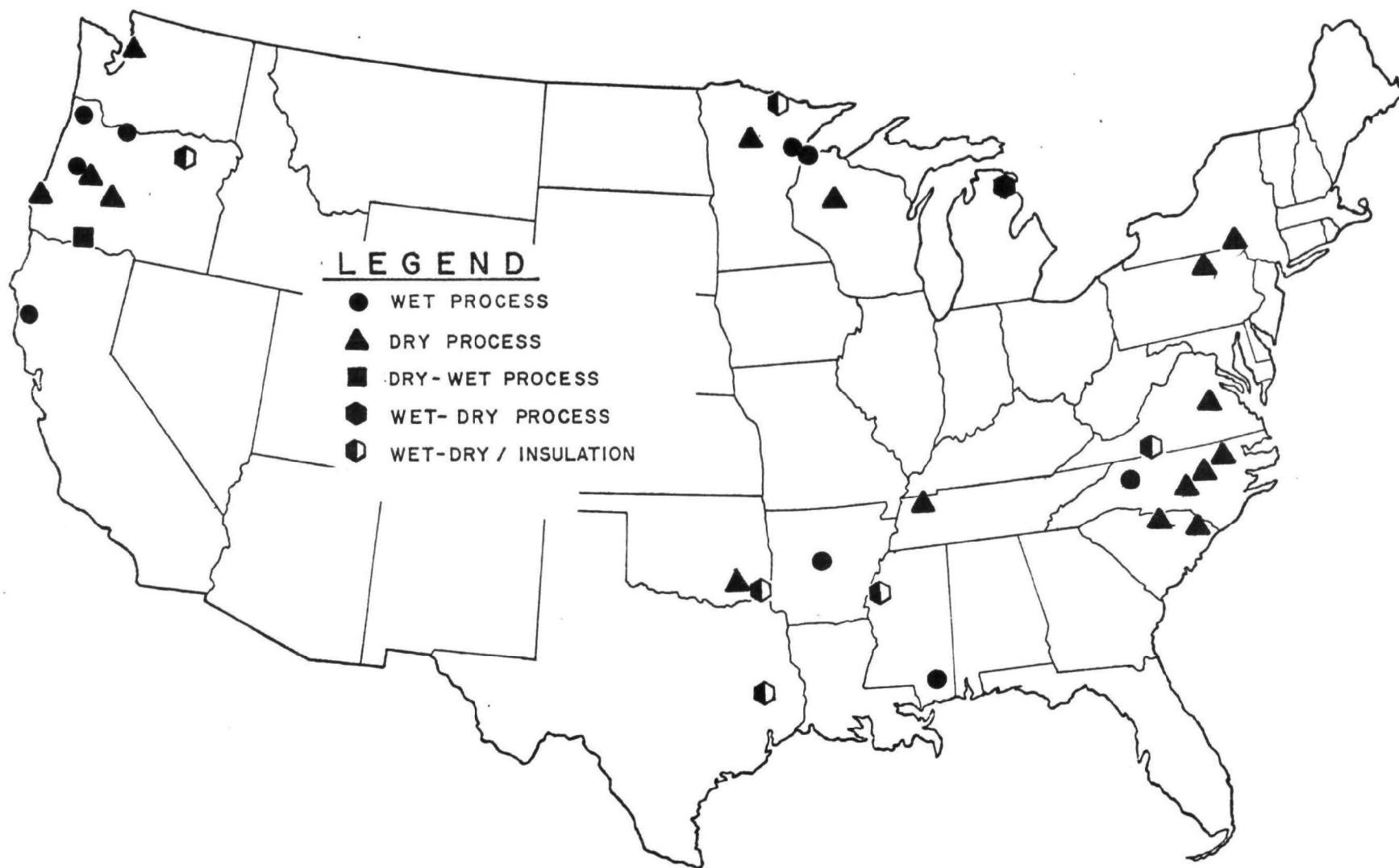


FIGURE 8 - GEOGRAPHICAL DISTRIBUTION OF HARDBOARD MANUFACTURING FACILITIES IN THE UNITED STATES

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27 hardboard plants in the United States produced approximately 0.39 billion square meters (4.2 billion square feet) of product. For 1972, hardboard production was estimated to be 0.54 billion square meters (5.8 billion square feet)(6). During the first part of 1973, plans for three new dry-process plants were completed and construction has already begun. A United States Forest Service survey published in 1964, based on information collected in 1962, established that the amount of timber consumed in the United States has increased to 0.37 billion cubic meters (13 billion cubic feet) annually. It projected a demand of 0.79 billion cubic meters (28 billion cubic feet) by the year 2000 - more than twice the 1962 level - based on a population of 325 million. The increased population must also be sheltered, and experts predict 100 million homes must be built in the next 30 years. If hardboard manufacture increases at the same rate during the next decade as in the last two decades, annual production is projected to be 0.93 billion square meters (10 billion square feet) by 1980 (6). This means that ten plants with annual capacity of 39 million square meters (420 million square feet) each would have to be completed during the next seven years.

Somewhat akin to the saw mill part of the forest products industry, the board portion is spread nationally with some production of each kind in each forest region of the United States. The hardboard and particle board industries utilize the residues from other wood working plants in large measure and accordingly provide opportunities to reduce the cost of other products and expand the development of completely integrated wood industries.

It is anticipated that there will be two major factors which will influence the location trend of future hardboard plant additions. The trend toward integrated forest product complexes, which involves pulp and paper, plywood, particle board and hardboard operations, all contained at one location is expected to increase. Installations such as these will be predicated upon the benefits derived from logistics and economics. Currently, 33 percent of the hardboard plants are owned by one of the major forest industry companies, and this percentage is expected to increase moderately in the near future, which will no doubt have some impact on the location trend.

The other major factor influencing growth trend is that associated with supply and demand, with new plants being located where there is demand predicted on the dynamic growth and expansion areas. Raw material availability and price may have some impact on the development of this particular growth trend.

By far the most dynamic growth areas are the South Atlantic, South Central, and Pacific Coast regions. It is anticipated that the growth trend will intensify in these two areas during the next decade and probably on into the 1990's.

Due to the anticipated demand for hardboard production, it is not expected that any operations will be phased out prior to 1980. After this time, however, wet process plants in the capacity range of 4.6 to 9.3 million square meters (50 to 100 million square feet) will become economically marginal due to operating performance and environmental capital expenditures.

Wood Preserving

The wood preserving industry in the United States is composed of approximately 390 treating plants, 315 of which use pressure retorts. Most of the plants are concentrated in two distinct regions. The larger region extends from East Texas to Maryland and corresponds roughly to the natural range of the southern pines, the major species utilized. The second concentration of plants is located along the Pacific Coast, where Douglas fir and western red cedar are the species of primary interest to the industry. Only 23 percent of the United States' plants are located outside these two regions. The distribution of plants by type and location is given in Table 8.

The production of treated wood is very responsive to the general state of the national economy, particularly the health of the construction industry. Production overall decreased from 1967 to 1971 (Table 9), but is expected to show a sharp increase for 1972.

The volume of wood treated with creosote showed the largest decrease during the 1967 to 1971 period, and accounted for most of the decrease in total production. Wood treated with pentachlorophenol registered a slight increase during the period, while that treated with CCA-type preservatives increased almost four-fold. Production of fire-retardant treated wood remained essentially constant. These trends are expected to continue, except that an increase in the production of fire-retardant treated wood is anticipated.

TABLE 8

WOOD PRESERVING PLANTS IN THE UNITED STATES BY STATE AND TYPE (2)

(1971)

	<u>Commercial</u>			<u>Railroad and Other</u>		<u>Total</u>
	<u>Pressure</u>	<u>Non- Pressure</u>	<u>Pressure and Non- Pressure</u>	<u>Pressure</u>	<u>Non- Pressure</u>	
NORTHEAST						
Connecticut	0	0	0	0	0	0
Delaware	1	0	0	0	0	1
Dist. of Columbia	0	0	0	0	0	0
Maine	0	0	0	0	0	0
Maryland	6	0	0	0	0	6
Massachusetts	1	0	0	0	0	1
New Hampshire	1	0	0	0	0	1
New Jersey	4	2	0	0	0	6
New York	5	0	0	0	1	6
Pennsylvania	6	0	0	1	0	7
Rhode Island	1	0	0	0	0	1
Vermont	0	0	0	0	0	0
West Virginia	3	0	1	0	1	5
TOTAL	28	2	1	1	2	34
NORTH CENTRAL						
Illinois	6	0	0	0	1	7
Indiana	6	0	0	0	0	6
Iowa	0	0	0	0	1	1
Kansas	0	0	0	0	0	0
Kentucky	6	0	0	0	0	6
Michigan	4	2	0	0	0	6
Minnesota	3	5	2	1	0	11
Missouri	7	5	0	0	0	12
Nebraska	0	0	1	0	0	1
North Dakota	0	0	0	0	0	0
Ohio	7	0	0	0	0	7
Wisconsin	3	0	1	1	1	6
TOTAL	42	12	4	2	3	63
SOUTHEAST						
Florida	23	1	1	0	0	25
Georgia	24	1	2	0	0	27
North Carolina	18	0	0	0	1	19
South Carolina	11	0	0	0	0	11
Virginia	15	1	1	0	0	17
TOTAL	91	3	4	0	1	99

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TABLE 8 CONTINUED

	<u>Commercial</u>			<u>Railroad and Other</u>		
	<u>Pressure</u>	<u>Non- Pressure</u>	<u>Pressure and Non- Pressure</u>	<u>Pressure</u>	<u>Non- Pressure</u>	<u>Total Plants</u>
SOUTH CENTRAL						
Alabama	22	1	0	0	0	23
Arkansas	11	0	1	0	0	12
Louisiana	21	0	1	0	0	22
Mississippi	18	1	3	0	0	22
Oklahoma	6	0	0	0	0	6
Tennessee	6	1	0	1	0	8
Texas	27	3	2	2	0	34
TOTAL	111	6	7	3	0	127
ROCKY MOUNTAIN						
Arizona	1	0	0	0	0	1
Colorado	2	0	0	0	0	2
Idaho	3	3	0	0	1	7
Montana	2	3	1	2	0	8
Nevada	0	0	0	0	0	0
New Mexico	1	0	0	1	0	2
South Dakota	0	0	1	0	0	1
Utah	0	1	1	0	0	2
Wyoming	1	0	1	0	0	2
TOTAL	10	7	4	3	1	25
PACIFIC						
Alaska	0	0	0	0	0	0
California	8	0	2	0	2	12
Hawaii	3	0	0	0	0	3
Oregon	6	0	4	0	0	10
Washington	7	5	4	0	1	17
TOTAL	24	5	10	0	3	42
UNITED STATES	306	35	30	9	10	390
TOTAL						

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TABLE 9

MATERIALS TREATED IN THE UNITED STATES, BY PRODUCT AND PRESERVATIVE, 1967-1971 (2)

(Note: Components may not add to totals due to rounding.)

Preservative	Year	Thousand Cubic Meters					Total
		Poles and Piling	Railroad Ties	Lumber and Timbers	Fence Posts	Other	
Creosote and Cresoste-Coal Tar	1967	1,636	1,683	504	184	100	4,146
	1968	1,456	1,712	528	184	100	3,980
	1969	1,330	1,497	451	175	93	3,545
	1970	1,315	1,650	357	181	78	3,587
	1971	1,172	1,856	342	193	70	3,6326
Creosote- Petroleum	1967	30	808	82	68	12	1,000
	1968	27	125	97	45	11	905
	1969	18	694	81	42	7	849
	1970	18	806	62	32	9	926
	1971	15	775	45	27	9	871
Petroleum- Pentachloro- phenol	1967	950	7	446	290	186	1,879
	1968	927	6	54	224	168	1,846
	1969	919	5	450	212	142	1,729
	1970	1,074	10	436	194	146	1,864
	1971	1,157	4	430	233	143	1,967
Chromated Copper Arsenate	1967	5	1	146	3	0.5	217
	1968	11	0.2	197	4	4	306
	1969	35	1	254	7	8	306
	1970	42	1	366	9	10	4287

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TABLE 9 CONTINUED

Preservative	Year	Thousand Cubic Meters					Total
		Poles and Piling	Railroad Ties	Lumber and Timbers	Fence Posts	Other	
Fluor Chrome Arsenate Phenol	1967	2	6	346	5	37	397
	1968	2	2	231	5	28	268
	1969	19	2	193	3	28	245
	1970	0.1	2	128	1	17	142
	1971	0.3	2	173	1	31	208
Creosote- Pentachloro- phenol	1967	222	0.1	0.9	0.5	1	225
	1968	211	---	9	1	0.8	222
	1969	187	---	13	0.5	0.2	200
	1970	140	---	11	1	---	152
	1971	97	---	17	0.1	---	114
Chromated Zinc Chloride	1967	0.1	---	29	---	6	35
	1968	---	---	29	---	0.6	29
	1969	0.6	---	26	---	0.2	27
	1970	---	---	22	---	---	22
	1971	---	---	20	---	0.1	21
Acid Copper Chromate	1967	---	---	61	0.1	---	61
	1968	----	----	48	---	---	48
	1969	---	---	37	0.1	---	37
	1970	---	---	31	---	---	31
	1971	---	---	56	0.1	---	56

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TABLE 9 CONTINUED

Preservative	Year	Thousand Cubic Meters					Total
		Poles and Piling	Railroad Ties	Lumber and Timbers	Fence Posts	Other	
Fire Retardants	1967	---	3	99	---	32	134
	1968	---	2	94	---	42	138
	1969	---	0.3	104	---	30	134
	1970	-----	2				
	1971	---	---	100	---	37	138
All Others	1967	12	---	47	6	7	71
	1968	15	0.1	18	4	6	43
	1969	13	---	72	3	13	102
	1970	12	0.1	3	62	6	83
	1971	4	---	19	3	2	28
All Preservatives	1967	2,857	2,508	1,716	595	382	7,538
	1968	2,649	2,447	1,772	466	360	7,695
	1969	2,522	2,199	1,687	443	323	7,175
	1970	2,600	2,469	1,576	428	292	7,366
	1971	2,492	2,639	1,694	472	305	7,602

SECTION IV

PROCESS DESCRIPTION AND INDUSTRY CATEGORIZATION

PROCESS DESCRIPTION-VENEER AND PLYWOOD

Raw Materials

A large variety of wood is utilized in the manufacture of veneers. A high percentage of veneer produced in the United States is manufactured from Douglas fir, in particular that manufactured in the Northwest, with lesser quantities of veneer made from ponderosa pine and hemlock also in the Northwest, and southern pine in the Southeast. In general, veneer is classified as softwood or hardwood due to the marked differences in the utilization of the respective products. Softwood veneer is manufactured on the west coast, the Rocky Mountain region, and the southeastern United States. The species that are used in the western United States include Douglas fir, sitka spruce, western hemlock, balsam fir, western larch, ponderosa pine, sugar pine, western white pine, and redwood. In the southeastern states bald cypress and southern pine are most common. The hardwood species commonly used in the United States are beech, birch, maple, basswood, red gum, yellow poplar, cottonwood, tupelo, sycamore, and oak.

Softwood veneer is almost exclusively used in the manufacturing of softwood plywood; however, small quantities are also used as center stock and cross-banding for panels made with hardwood faces. Hardwood veneer, on the other hand, has several important uses that can be categorized as (1) face veneer, (2) commercial veneers, and (3) veneers for containers. Face veneers are of the highest quality and are used to make plywood panels employed in the manufacturing of furniture and interior decorative panels. There are more than 50 such manufacturers throughout the eastern United States. Commercial veneers are those used for cross bands, cores, and backs of plywood panels and concealed parts of furniture. Container veneers consist of a large variety of inexpensive veneers used in the manufacturing of crates, hampers, fruit and vegetable baskets and kits, boxes and similar container items.

Manufacturing

Plywood is manufactured in practically every state in the Union. The majority of softwood plywood is produced on the Pacific Coast while the bulk of the hardwood plywood is manufactured in

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the southeastern states. The hardwood plywood industry is made up of a large number of small factories distributed widely over the eastern United States.

The detailed process description will be restricted to factors of the process which affect wastewater characteristics. A detailed flow diagram of the veneer and plywood manufacturing process is shown in Figure 9. This will also be the outline followed in the process description.

Log Storage

Veneer mills throughout the country, like many other mills within the Timber Products Industry, find it necessary to retain large inventories of logs to maintain a continuous supply throughout the year. There are three common methods of storing logs in the industry: (1) dry-decking, (2) wet-decking, and (3) log ponding.

Dry-decking is simply the practice of stacking logs on land. When logs are stored in this manner there exists a tendency for them to dry out rapidly at the ends which in turn causes cracks to be formed in the wood. This phenomenon is known as "end checking" and it greatly increases the amount of product wastage.

End-checking can be minimized by sprinkling the land-decked logs with water and this method of storing logs is referred to as wet-decking. Land-decking, whether wet or dry, requires large machinery to handle the logs.

The third method of storing logs is by floating them in a body of water. End-checking is not a problem with this form of storage and logs can be handled more easily. Logs may be floated in lakes, rivers, estuaries, or man-made ponds, with the last being the most common receptacle for this purpose. Log ponding, when feasible, has been accepted as the most convenient and economical form of log storage. Some logs, such as southern pine, sink in water and land-decking is therefore a necessity. Many veneer and plywood mills use a combination of log ponds and land-decking for log storage with the land-decking being used for short periods of detention and log ponds for long term log storage.

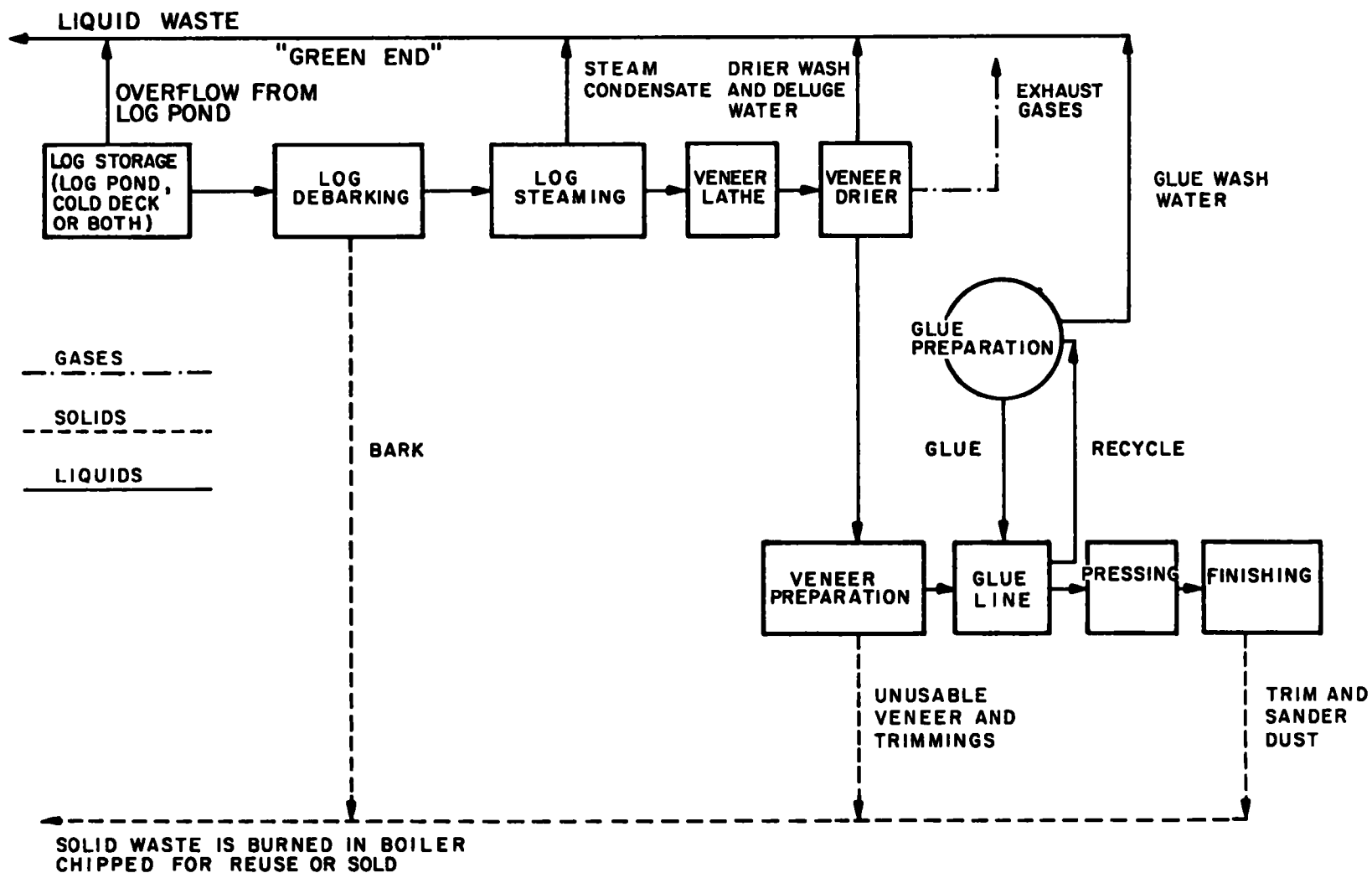


FIGURE 9 - DETAILED PROCESS FLOW DIAGRAM FOR VENEER AND PLYWOOD

Barkers

From storage the logs are first taken to a barker where the bark is removed before the logs are cut into smaller sections, usually about two and four-tenths meters (eight feet) long. The bark can be removed in either a dry or wet process.

Logs are debarked by several different types of machines (7), including: (1) drum barkers, (2) ring barkers, (3) bag barkers, (4) hydraulic barkers, or (5) cutterhead barkers.

Drum barkers are made in a wide variety of sizes, generally two and four-tenths to four and nine-tenths meters (eight to sixteen feet) in diameter and up to 22.8 meters (75 feet) in length. A drum barker consists of a cylindrical shell rotating on its horizontal longitudinal axis. Logs are fed into one end and the tumbling and rolling action removes the bark. Water sprays may be used to reduce dust, promote the thawing of wood in cold climates, or reduce the bond between the bark and wood.

Ring barkers or rotary barkers consist of a rotating ring on which several radial arms are pivoted. On the end of each arm is a tool which abrades or scrapes off the bark. A ring barker handles only one log at a time, but can handle logs up to 213.4 centimeters (84 inches) in diameter.

Bag barkers or pocket barkers are simple stationary containers in which the logs are rotated to remove bark by abrasion. Water may also be used in this process for the same purposes as were described for the drum barkers.

The hydraulic barker uses a high pressure water jet to blast bark from a log. Pressures from 56.25 to 112.4 kilograms of force per square centimeter (800 to 1600 psi) are used with flow rates varying from 25.2 to 101 liters per second (400 to 1600 gallons per minute). Due to the large volumes of ultra-clean water required, the inability to recycle water and the resulting wastewater flow, hydraulic barkers are slowly being phased out. In the cutterhead barker, logs are fed through the barker one at a time and a cylindrical cutterhead removes bark by a milling action as it rotates parallel to the axis of the log. No water is employed.

All of the wet barkers use large amounts of water and require a fairly complex operation (Figure 10) to separate the bark from the water and dry it so that it can be used as fuel in the boiler. In spite of the recovery operations, the effluent from wet barkers have high solids concentrations. It is

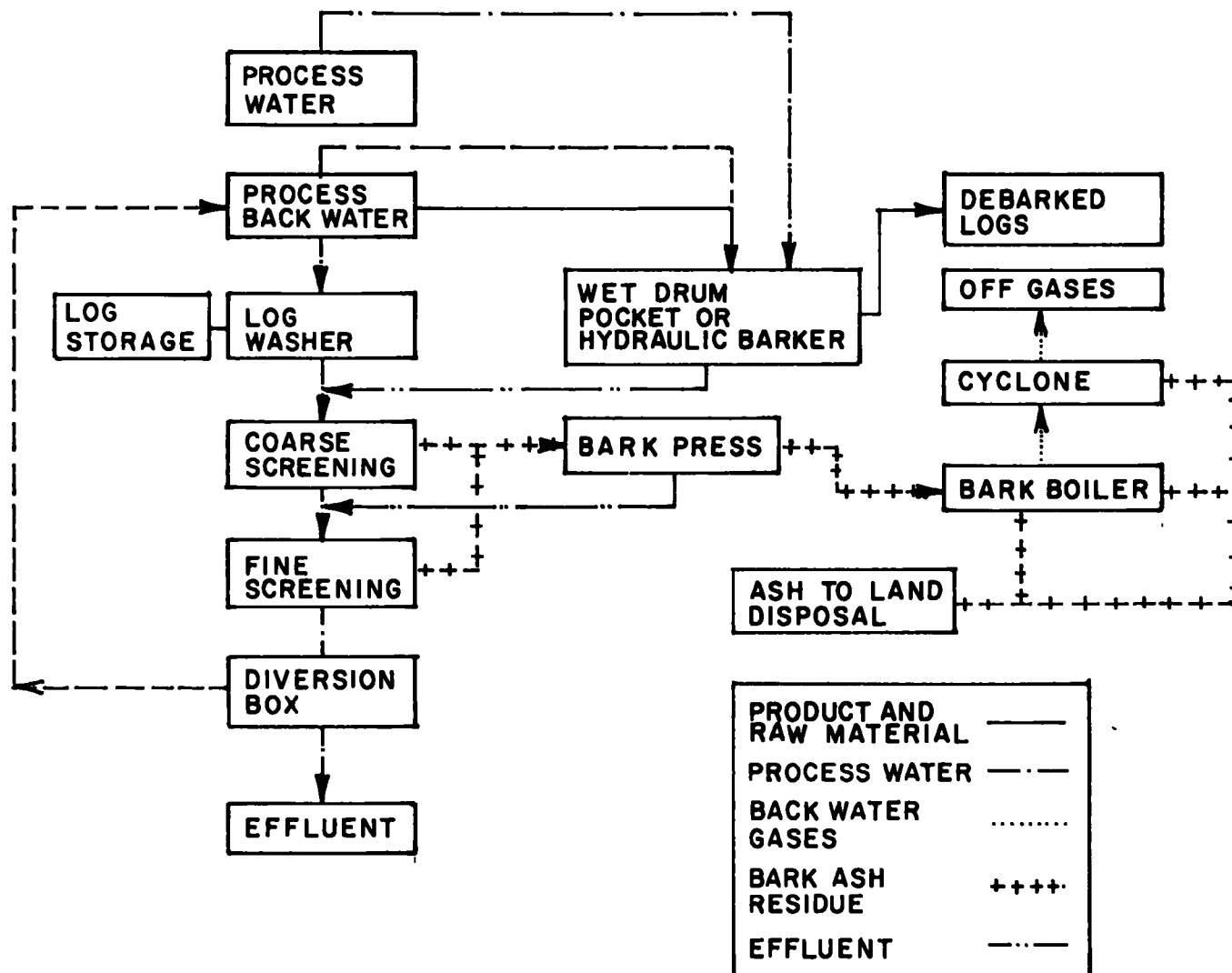


FIGURE 10 (8) - WET BARKING PROCESS DIAGRAM

expected that wet barkers will disappear in the near future since at the present time their main use is for debarking oversized logs, which are diminishing in supply.

Log Conditioning

Heating of logs prior to veneering serves to improve the cutting properties of wood, particularly hardwood. Historically, both hardboard and softwood mills have practiced log heating. There has been in recent years a trend away from log heating in the softwood industry, but the current trend is again toward this practice.

When the heating of logs occurs not only prior to veneering, but also prior to debarking, it also facilitates the debarking operation, and this has been the common practice in the past. With the increasing use of ring and cutterhead barkers whose operations are not aided by prior heating to the same degree as other debarking methods, heating commonly occurs between the debarking and veneering operations.

There are basically two methods of heating logs: (1) by directing steam onto the logs in a "steam vat" (steam tunnel), and (2) by heating the logs in a "hot water vat" full of water which is heated either directly with live steam or indirectly with steam coils.

Heating in steam vats is generally more violent than in hot water vats. Steam vats are therefore more applicable to species of wood that do not rupture under rapid and sudden thermal increases. The times and temperatures of these conditioning processes vary with species, age, size, and character of veneer to be cut. The experience has been that the harder (more dense) the species and the more difficult to cut, the longer the conditioning period and the lower the temperature required. Some of the softer woods can be cut satisfactorily without such conditioning. Among these are poplar, bass wood, cottonwood, and certain conifers.

Veneer Cutting

The principal process unit in the manufacturing of veneers is the cutting of the veneer. There are four methods used to cut veneer: (1) rotary lathing, (2) slicing, (3) stay log cutting, and (4) sawn veneering.

Currently more than 90 percent of all veneer is rotary cut (9). In this method of cutting, a bolt of wood is centered between two chucks on a lathe. The bolt is turned against a knife extending across the length of the lathe, and, as the log turns, a thin sheet of veneer is peeled from it. Lathes

capable of peeling logs from 3.66 to 4.88 meters (12 to 16 feet) in length are not uncommon. More commonly, however, veneer is cut in lengths ranging from 0.610 to 2.44 meters (two to eight feet). The bolts that are to be veneered are usually cut from 10 to 15 centimeters (four to six inches) longer than the width of veneer to be cut from them.

Most slicers consist of a stationary knife. The flitch to be cut is attached to a log bed which moves up and down. On each downward stroke a slice of veneer is cut by the knife. Slicers are used primarily for cutting decorative face veneers from woods such as walnut, mahogany, cherry, and oak.

Stay log cutting produces veneers which are intermediate between rotary cut and sliced veneers. A flitch is attached to a stay log or metal beam, mounted off center to a rotary lathe. The stay log method produces half-round veneer which is generally used for faces.

A very small quantity of veneer is cut by sawn veneering. A circular type saw, called a segment saw, with a thin, segmented blade turns on an arbor. The thin blade reduces saw kerf. This method generally is used only for certain species such as oak, red cedar, and Spanish cedar in order to achieve special effects. Veneers are cut to thicknesses ranging from .0231 to 9.53 millimeters (one-one hundred and tenth to three-eighths of an inch). Most of the rotary cut veneers are either .3.63, 3.18, 3.54, 1.69, or 1.27 millimeters (one-seventh, one-eighth, one-tenth, one-fifteenth, or one-twentieth of an inch) thick. Sliced veneer usually ranges from 1.27 to 0.635 millimeters (one-twentieth to one-fortieth of an inch). Sawed veneers vary from 6.35 to 0.795 millimeters (one-fourth to one-thirty second of an inch) in thickness.

The veneer coming from the lathe is cut to rough green size, and defects are removed at the green clipper.

Veneer Drying

Freshly cut veneers are ordinarily unsuited for gluing because of their wetness. In the undried (green) state, veneers are also susceptible to attack by molds, blue-stain, and wood-destroying fungi. It is therefore necessary to remove the excess moisture as rapidly as possible. Veneers are usually dried to a moisture content of less than ten percent.

Several methods for drying veneers are in common use. The most common dryers are long chambers equipped with rollers on belts which advance the veneer longitudinally through the

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chamber. Fans and heating coils are located on the sides of the chamber to control temperature and humidity.

The majority of high-temperature (above 100°C:212°F) veneer dryers depend upon steam as a heat source. The heat is transferred to the air by heat exchangers. However, direct-fired oil and gas dryers are becoming increasingly common in the industry.

The conventional progressive type and compartment type lumber kilns are also used in drying veneers. Air drying is practiced but is quite rare except in the production of low grade veneer such as that used in crate manufacturing. Air drying is accomplished by simply placing the veneer in stacks open to the atmosphere, but in such a way as to allow good circulation of air.

Veneer Preparation

Between the drying and gluing operations are a series of minor operations that prepare and/or salvage veneer. These operations may include grading and matching, redrying, dry-clipping, jointing, taping and splicing, and inspecting and repairing. These operations are self-descriptive and completely mechanical or manual except for jointing and splicing which may use some sort of adhesive; however, the bonding does not have to be as strong as that in the gluing of plywood, and the amount of adhesive used is kept to a minimum. Most of these gluing operations do not require washing.

Gluing Operations

A number of adhesives can be used in the manufacture of plywood. For the purpose of this discussion, distinction is made between (1) protein, (2) phenol-formaldehyde, and (3) urea-formaldehyde glues, since these are the classes of glue most often used in the industry. Protein glue is extracted from plants and animals, while the other two are synthetic and thermosetting glues. Table 10 lists ingredients of typical protein, phenolic, and urea glue mixes.

Both protein and urea-formaldehyde glues are chiefly interior glues, while phenol-formaldehyde is an exterior glue. Urea-formaldehyde is used almost exclusively in the hardwood plywood industry when the panels are used for furniture and indoor panelling. Phenol-formaldehyde is a thermosetting resin like

TABLE 10
INGREDIENTS OF TYPICAL PROTEIN, PHENOLIC AND UREA GLUE MIXES (10)

Protein Glue For Interior Grade Plywood:

Water
Dried Blood
Soya Flour
Lime
Sodium Silicate
Caustic Soda
Formaldehyde Doner for Thickening

Phenolic Glue For Exterior Grade Plywood

Water
Furafil
Wheat Flour
Phenolic Formaldehyde Resin
Caustic Soda
Soda Ash

Urea Glue For Hardwood Plywood

Water
Defoamer
Extender (Wheat Flour)
Urea Formaldehyde Resin

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urea-formaldehyde, but it is waterproof and is practically the only glue used to make exterior plywood. Exterior glue, however, is being increasingly used to produce interior plywood as well as exterior, so that the use of phenol-formaldehyde is increasing rapidly. Table 11 shows the break-down of glue usage in 1965 and the projected usage for 1975. At present, phenolic glues comprise about 50 percent of all glue consumed while by 1975 it is projected that about 80 percent of all the glue used in plywood manufacturing will be phenolic based.

Historically, protein glues had been the only adhesive used in the plywood industry. However, as a result of synthetic resins becoming less expensive and their versatility becoming more recognized, the use of protein glues is disappearing. At the present time, the main advantage of some protein glues is that they can be cold pressed. But while cold pressing is a simpler and cheaper operation, it is usually only satisfactory for interior plywood.

TABLE 11
CURRENT AND PROJECTED ADHESIVE CONSUMPTION IN
THE PLYWOOD INDUSTRY (10)

Plywood Type	(Millions of Kilograms)					
	1965			1975		
	Phenolic	Urea	Protein	Phenolic	Urea	Protein
Western Exterior	37	--	--	88	--	--
Western Interior	6.4	--	47	62	--	--
Southern Exterior	--	--	--	41	--	--
Southern Interior	4.5	--	--	39	--	--
Hardwood	--	25	--	--	54	--
TOTALS	48	25	47	230	54	Nil

Most plywood manufacturers mix their own glue in large dough type mixers. The glue is then applied to the veneer by means of a spreader, the most common of which consists of two power driven rollers supplied with the adhesive. Protein glues are usually applied with steel rollers, while other glues are usually applied with rubber-covered rollers. More recently the practice of applying glue by means of sprays and curtain-coaters has emerged. Since all glues harden with time, the glue system must be cleaned regularly to avoid build-up of dried glue. Some of the most recent spray curtain-coater glue applicators require less washing than the conventional rollers.

Pressing

The gluing operations in the plywood industry are finished by subjecting the sheets to pressure for the purpose of insuring proper alignment and an intimate contact between the wood and the glue. The adhesive is allowed to partially cure under pressure. Pressing may be accomplished at room temperature (cold-pressing) or at high temperature (hot-pressing). Cold-pressing is used with casein, some protein, and some urea-formaldehyde adhesives. Hot-pressing equipment is used to cure some protein, some urea-formaldehyde, and all of the phenol-formaldehyde adhesives.

Most presses are hydraulic and apply pressures from 6.1 to 17 atmospheres (75 to 250 psig). Presses can be hot or cold depending upon operating temperatures. Cold presses are operated at room temperatures, while hot presses are operated at temperatures of up to around 177°C (350°F) with heat being transferred by means of steam, hot water, or hot oil. Plywood pressing time ranges from two minutes to 24 hours, depending upon the temperature of the press and the type of glue used. The hotter the press, the shorter the pressing time.

In recent years, radio-frequency heat has been used to cure synthetic resin adhesives. This works on the principle that when an alternating electric current oscillating in the radio frequency range is applied to a dielectric material, the material will be heated. It is still questionable whether this method of heating is economically worthwhile; however, it is technically applicable for pressing plywood as well as edge-gluing.

Finishing

After the pressing operation, any number of a series of finishing steps, depending upon the operation and the product desired, can be taken. These operations include: (1) redrying, (2) trimming, (3) sanding, (4) sorting, (5) molding, and (6) storing.

PROCESS DESCRIPTION-HARDBOARD

The raw material for hardboard production like the pulp and paper industry is essentially all wood. This wood may be in the form of round wood, wood chips made from waste products from saw mills and plywood mills, or other sources of wood fiber. Raw material handling for both wet and dry process hardboard mills is shown in Figure 11.

Figure 12 shows a typical inplant process diagram of a dry process hardboard mill and Figure 13 shows a typical inplant process diagram of a wet process hardboard mill. All phases of the raw materials handling for both dry and wet hardboard mills are essentially the same. The principle difference between the two processes is the manner in which the fibers are carried and formed into a mat.

Raw materials, such as logs, chips, or other forms of wood, are transported to the hardboard mill site for storage and processing. Logs may be stored in a log deck or log pond upon arrival at the mill. Chips arriving by rail car, truck, or simply by conveyer from an adjoining mill are stored in bins or piles. Logs may or may not be debarked before being chipped. There are no general standards for bark removal as each mill has its own standards for the quantity of bark allowed in its finished product. In some mills logs are washed before debarking to remove dirt and other abrasive material that would be detrimental to machinery or to the final product.

Log Barkers

Logs are debarked by several different types of machines (7), including: (1) drum barkers; (2) ring barkers; (3) bag barkers; (4) hydraulic barkers; and (5) cutterhead barkers. Drum barkers are made in a wide variety of sizes, generally 2.4 to 4.9 meters (8 to 16 feet) in diameter and up to 22.9 meters (75 feet) in length. A drum barker consists of a cylindrical shell rotating on its horizontal longitudinal axis. Logs are fed into one end and the tumbling and rolling action removes the bark. Water sprays may be used to reduce dust, promote the thawing of wood in cold climates, or reduce the bond between the bark and wood.

Ring barkers or rotary barkers consist of a rotating ring on which several radial arms are pivoted. On the end of each arm is a tool which abrades or scrapes off the bark.

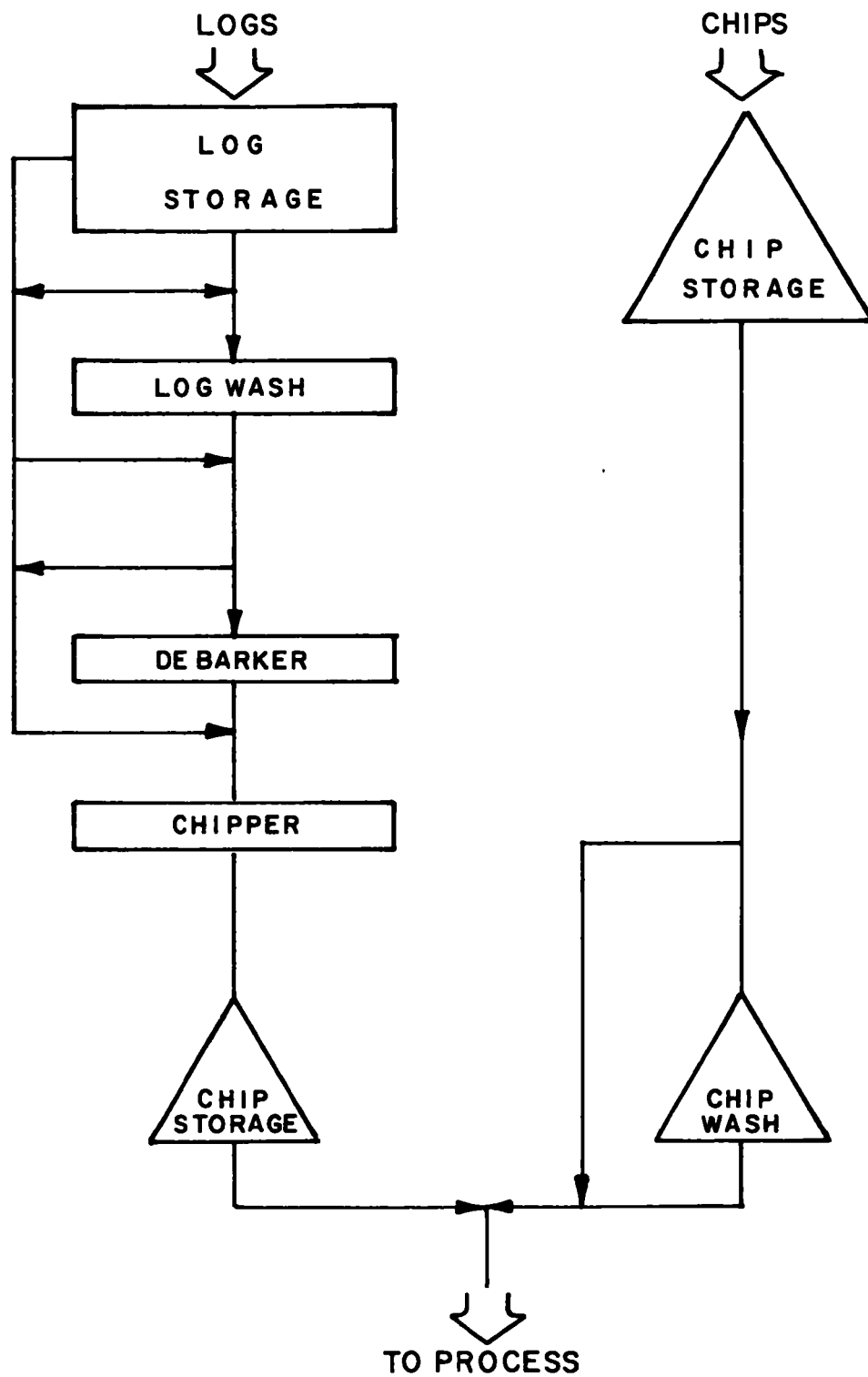
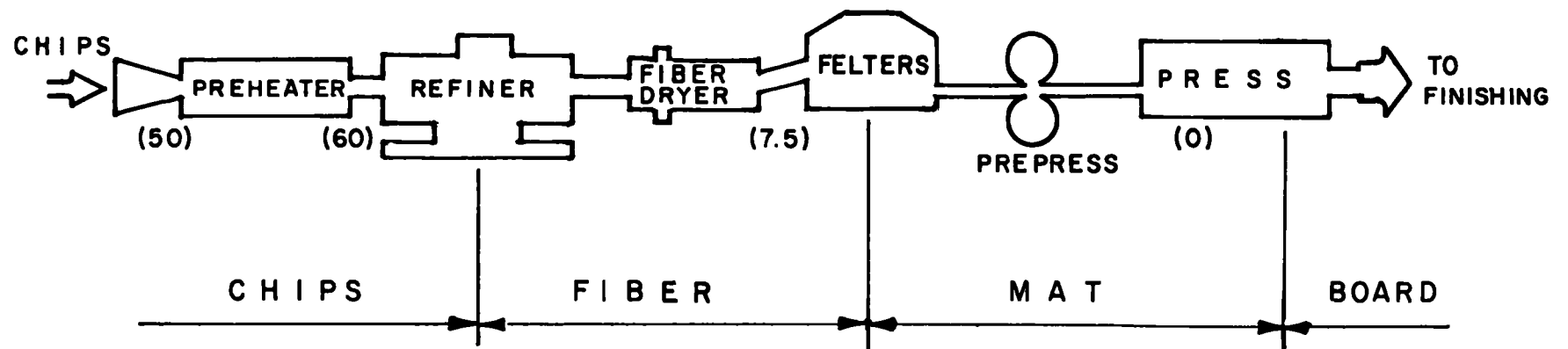


FIGURE 11 - RAW MATERIAL HANDLING IN THE HARDBOARD INDUSTRY



(XX) APPROXIMATE PERCENT MOISTURE

FIGURE 12 - TYPICAL DRY PROCESS HARDBOARD MILL

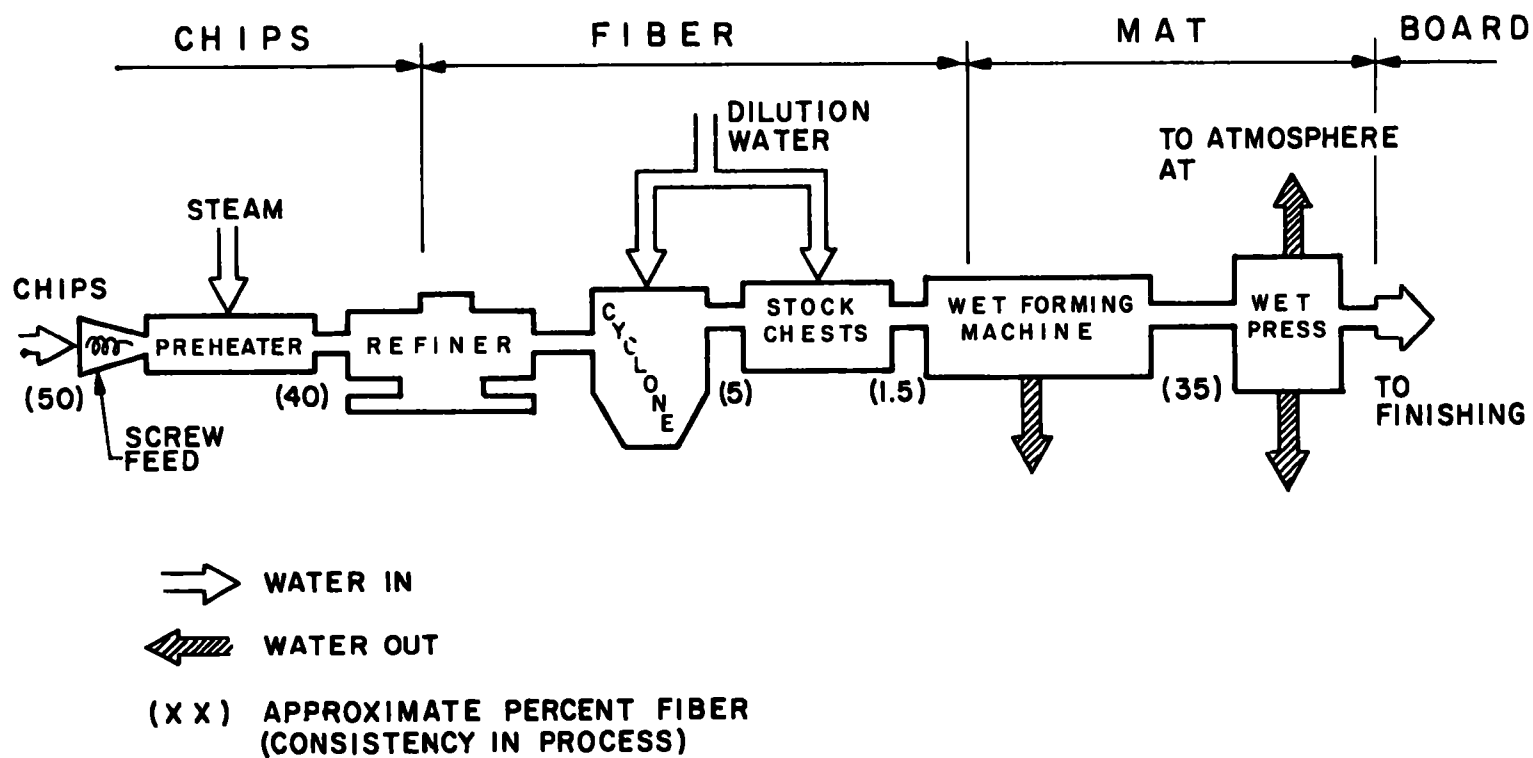


FIGURE 13 - TYPICAL WET PROCESS HARDBOARD MILL

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A ring barker handles only one log at a time but can handle logs up to 2.1 meters (7 feet) in diameter. Bag barkers or pocket barkers are simple stationary containers in which the logs are rotated to remove bark by abrasion. Water may also be used in this process.

The hydraulic barker uses a high pressure water jet to blast bark from a log. Pressures from 56 to 112 kilograms per square centimeter (800 to 1600 psi) are used with flow rates varying from 1,514 to 6,057 liters per minute (400 to 1600 gallons per minute). Due to the large volumes of ultra clean water required, the inability to recycle water because of nozzle plugging, and the resulting wastewater flow, hydraulic barkers are slowly being phased out. The last general type of barker is a cutterhead barker. Logs are fed through this barker one at a time, and a cylindrical cutterhead removes bark by a milling action as it rotates parallel to the axis of the log.

Logs or wood scraps must be either processed to chips on-site or converted to chips off-site and hauled to the mill. There are several types of chippers utilized in the industry with disc chippers being the most common. After chipping, chips are screened to segregate them into various sizes. Screens may be of the rotating, shaking, vibrating, or gyrating types, with vibrating and gyrating screens being the most prevalent.

Chips are stockpiled in the open, under a roof, or totally enclosed in chip silos. Some mills presently wash chips to remove dirt and other trash which would cause high maintenance in the fiber preparation stages. The quantity of dirt in chips depends upon many factors. For the future, hardboard manufacturers project the utilization of complete trees, including bark, limbs, and leaves. This will cause additional dirt to be brought to the mill. Weather conditions during logging operations also have a significant effect on the quantity of dirt as logs must be stored on the ground. Chip washing is also important for thawing frozen chips in more northern climates. There is a general industrial trend toward use of lower quality fiber because of the increased demand for timber products, high cost of logs, and their general scarcity. With the use of lower quality fiber, such as tree limbs and bark, it will become more and more desirable to wash chips.

Fiber Preparation

Fiber preparation is one of the most important process operations in the production of hardboard. There are two basic methods of

fiber preparation, but a wide range of variations exists within each basic method. These two basic methods are:

- (1) Thermal plus mechanical refining
- (2) Explosion process.

In the explosion process, wood chips are subjected to high temperature steam in a "gun," or high pressure vessel, and ejected through a quick opening valve (7). Upon ejection, the softened chips burst into a mass of fiber or fiber bundles. The process is essentially a high temperature acid hydrolysis and lignin softening procedure, and is adaptable to almost any ligno-cellulosic material. Chips approximately 19 millimeters (three-fourths inch) square, prepared in conventional chippers and screened, are fed into a battery of 50.8 centimeter (20 inch) calibre guns or high pressure vessels. Each gun is filled and closed. The chips are then steamed to 42 kilograms per square centimeter (600 psi) for about one minute after which the pressure is quickly raised to about 70 kilograms per square centimeter (1,000 psi equivalent to about 285°C [550°F]) and held for about five seconds. The time of treatment at this high pressure is very critical, and depends on the species and the desired quality of the product. The pressure is suddenly released into a brown, fluffy mass of fiber. Entering a cyclone the steam is condensed and the exploded fiber falls into a stock chest where it is mixed with water and pumped through washers, refiners, and screens. The yields of fiber from pulping by the explosion method are lower than those for other coarse pulping procedures, due largely to the hydrolysis of hemi-cellulosic material under conditions of steaming at high pressure. The explosion process is used in only two hard-board mills in the United States, both owned by the Masonite Corporation.

By far the most widely used fiber preparation consists of both thermal and mechanical pulping (11). Thermal plus mechanical refining, as its name implies, involves a preliminary treatment of the raw material with heat in addition to mechanical action in order to reduce the raw material to pulp. The mechanical reduction is carried out in disc refiners or attrition mills after the pulp-type chips or shredded raw materials have first been softened by steaming.

One of the advantages of this attrition mill method of pulping over conventional grinding lies in the fact that a greater variety of species and forms of raw material may be processed, including materials from roundwood, slabs, edgings and veneer residues, as well as materials such as pulp screenings, shavings, and sawdust. Furthermore, with the possibilities

of variation in pre-steaming, of plate pattern, of plate clearances, and of number of refiners, there is considerable latitude for the production of pulps possessing a wide range of properties. In general, attrition mills such as disc pulpers produce a good quality of pulp. A fast draining pulp can be readily produced, having few abraded fibers and coarse fiber bundles.

In the dry process, similar equipment can be used. However, the wood can also be subjected to lower steam pressures of 2.1 to 8.5 kilograms per square centimeter (30 to 120 psi) for somewhat longer periods (one to two minutes) and then passed through a disc refiner. In some cases the resin is added to the chips while they are being refined by pumping it through a hole drilled through the refiner shaft.

Prior to passing wood chips or other fibrous raw materials through disc pulpers or refiners, it is often expedient to give the material some form of pre-treatment in order to reduce subsequent power consumption and improve pulp qualities. However, the extent of the treatment will again depend upon the nature of the raw material and the end product desired. Steaming softens the wood to produce a pulp with fewer broken fibers and coarse fiber bundles. The fibers of pulp so made are more flexible and felt together more readily to form a stronger board than pulp from wood that has not been steamed. However, with some species, steaming may increase the toughness of the chips and thereby increase the energy required for defibering. The operation is carried out in digesters under a variety of conditions of time and temperature.

In one process the chips are brought to a temperature of 170° to 190°C (340° to 375°F) in a period of 20 to 60 seconds by means of steam pressure between 7 and 11.5 kilograms per square centimeter (100 and 165 psi) and at this temperature are passed through a disc refiner. It is claimed that due to the short steaming period little hydrolysis takes place and there is little loss of wood substance, the yield ranging from 90 to 93 percent.

Attrition mills of the disc type have two discs, one stationary and one rotating, or both rotating, for defibering and refining. Various disc patterns are available and choice depends on species, pre-treatment, and the type of pulp desired. In most cases, the discs are made of special alloys. The discs are usually 600 to 1,000 millimeters (23 to 40 inches) in diameter and operate at 400 to 1,200 revolutions per minute.

Double disc attrition mills, with the discs rotated in opposite directions, do more work on the fiber and consequently produce a higher stock temperature. Such equipment, when operating on wood chips, produces well fiberized material which may have all the strength required for board manufacture. However, where further development or strength is desired, further refining may be useful.

The single rotating disc mill has certain advantages. The feed opening is more accessible and can be made very large to accomodate bulky materials. It has fewer moving parts and fewer bearings than the double disc mill.

Factors which determine the pulp quality produced by attrition mills are properties of the raw material, pre-treatment, the physical shape of material to be refined, plate design, plate clearance, rate of feed, consistency, temperature, speed of rotation, and rate of energy consumption. Many of these factors can only be determined by experiment. Plate clearances usually vary from 1.30 millimeters (0.05 inches) for an initial breakdown of chips to a very low clearance for the final refining. As the clearance between the plates is reduced the strength of the pulp is increased, but because of the production of more fines, the rate of drainage is reduced. An improved quality of stock may be obtained by using a plate clearance of about 0.25 millimeters (0.01 inch), screening out the acceptable stock, and recycling the coarse material. This procedure reduces the power consumption and the pulp will have a higher percentage of intermediate length fibers and fewer fines. A certain amount of fines, however, is desirable as they improve board properties, such as rigidity, and provide a smoother surface.

The power requirements for refiner stock from woods commonly used vary from about 200 to 800 kilowatt hours per ton (10 to 40 horsepower per ton) depending on species and pre-treatment.

The consistency of pulp leaving the attrition mill in a wet process hardboard mill may vary over wide limits, but in general is between 30 and 40 percent fiber. Lower consistencies are used with certain material to prevent feed chokes. High consistencies tend to produce better pulps by raising the temperature.

After conversion of the raw material to a fibrous pulp in the attrition mills, it may be screened to remove coarse fiber bundles, knots, and slivers. Some of the coarse material can be returned to the system for further breakdown. Modern equipment can produce a pulp which does not require screening.

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There are various attrition mills on the market for the preparation of pulp. Some of the better known ones are described in some detail in references (12) and (13). However, brief reference is made here to the Asplund method (12) which has been used extensively for preparation of stock for hardboard mills. This involves the use of a single rotating disc and has the feature of combining the steaming and defibering in one unit in a continuous operation. The entire operation is carried out under pressure and has the advantage that no cooling of the steamed chips takes place prior to defibering, and foaming difficulties are substantially reduced. A unit may be expected to process 9 to 45 metric tons (10 to 50 tons) of dry wood per day, depending on the type of wood and the degree of defibering required. For hardboard stock, slight refining may be desirable, especially for the removal of slivers. When using modern refining equipment subsequent screening may be unnecessary. However, when screening is considered necessary a vibratory or rotary-type screen may be used.

The American Hardboard Association (14) describes the remaining processes in the following way.

Forming Hardboard

The manufacture of hardboard consists basically of reducing trees to fibers and putting them back together in the form of sheets or boards having properties and characteristics not formerly attainable in the natural wood. Before board formation is started, it is often desirable to introduce certain chemical additives to pulp which increases the strength, water resistance, and other desirable properties of hardboard. The additives to be used and the amounts depend on the species of wood, degree of refining, and the final properties desired. After the inclusion of additives to the refined pulp, which may be in the form of either a wet slurry or a dry fluff, the pulp is ready for delivery to the board former to begin the process of reassembling fibers into hardboard. The formation or felting of fibers to form a mat may be done by either the wet-felting process or the dry-felting (air-felting) process.

Wet-Felting: In the wet process the mat is usually formed on a fourdrinier type machine such as those used in making paper. Refined pulp is pumped to the head box of the machine and diluted with large quantities of water, until the mixture, called "stock," contains only about one and one-half percent pulp. The stock flows rapidly and smoothly from the bottom of the head box onto an endless traveling wire screen. Special

devices control the flow of stock allowing it to spread evenly on the screen as an interlaced fibrous blanket which may be several inches thick depending upon the desired thickness of the finished hardboard. The screen, kept level by tension, and a number of rollers carry stock onward for about 9 meters (30 feet) while water is withdrawn through the wire screen. The water is first removed by gravity and as the screen advances additional water is removed when the screen passes over one or more suction boxes. At this point, stock has felted together into a continuous fibrous sheet called "wetlap." The forming screen extends between a number of pairs of press rollers which also have an endless screen travelling around a series of the paired rollers. Here more water is removed as the press rollers gradually apply pressure to the wetlap, a process which is similar to the wringing action of a washing machine.

When the wet mat emerges from press rollers it is still quite wet (50 to 75 percent moisture) but yet strong enough to support its weight over a small span. At this point, it leaves the forming screen and continues its travel over a conveyor. The wet mat is then trimmed to width and cut off to length by a travelling saw which moves across the travelling mat on a bias making a square cut without the necessity of stopping the continuous wetlap sheet. The thickness of wet mat is normally three or four times the finished thickness of the hardboard to be produced. It still contains a great deal of water which must be removed before the hardboard manufacturing process is complete. The wet mat may be delivered directly to a platen press where water is removed by a combination of pressing and heating or it may be conveyed to a heated roll dryer where water is evaporated by heating alone. The direct pressing method is used to produce smooth one-side hardboard (S1S). The evaporative drying method is used in the production of smooth two-side hardboard (S2S). These operations will be described later.

Dry-Felting: The main difference between the dry, or air-felting process, and the wet-felting process is that in the dry process fibers are suspended in air rather than in water as is the case in the wet-felting process. The unit developed for laying down a continuous mat of dry fibers is called the felter. The prepared fibers are fed by volumetric feeders to the felting unit at a controlled rate. A nozzle in the unit distributes fibers to the top of the felter chamber and the fibers fall to the floor of the felter similar to a heavy snow storm. The effects of this snowing action produce an interwoven mat of fibers. The floor of the felter is a moving screen which is synchronized with the volumetric feeders.

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Air is sucked through the screen to aid in the felting. As the mat emerges from the felting chamber, it has attained the height necessary for the thickness of the board desired.

When a finished board of 3.2 millimeters (one-eighth inch) is desired, the height of the mat as it emerges from the felting chamber may be as much as 10 to 15 centimeters (4 to 6 inches). Once the mat is formed, the procedure of compressing, trimming, and sawing of the mat is similar to that for the wet process. However, air-formed mats prior to pressing are always thicker and softer than wet-formed mats and usually require more care in loading the hardboard press.

Hardboard Press

The heart of every hardboard process is the press. Here the reassembly of wood particles is completed and fibers are welded together into a tough, durable grainless board. Hardboard presses are massive, consisting of heavy steel heads and bases, each of which may weigh 45 metric tons (50 tons) or more, held together by steel columns 25 to 30 centimeters (10 or 12 inches) in diameter and as long as 9 to 12 meters (30 to 40 feet). Between the head and the base of the press are suspended a number of steel platens which are drilled internally to provide circulating passages for high pressure steam or water which is used to provide heat necessary to help weld the fibers together. Several hydraulic rams with a movable head are placed below the platens and on top of the base to apply pressure upwards toward the head of the press. When open, the hydraulic rams are at their lowest position. Each platen, except the top and bottom platens which are fastened firmly to the press head and moving base respectively, is individually suspended, allowing an air space of 8 to 25 centimeters (3 to 10 inches) between platens. The unpressed mats are placed one on top of each platen so that there is an equivalent of a multi-deck sandwich with the mat located between the steel platens. When the press is loaded, hydraulic pressure is applied to the rams. This operation forces the platens up against the head of the press, squeezing the mats down to a fraction of their former thickness. Pressures exerted may vary from 35 to 100 kilograms per square centimeter (500 to 1,500 psi) depending on the process and density desired in the finished board. Most hardboard presses have 20 openings and 21 platens, so that 20 boards may be pressed at the same time. Some presses have as few as ten openings and some as many as 30. Press sizes vary, but include 1.2 meters by 4.9 meters (four feet by 16 feet), 1.2 meters by 2.4 meters (four feet by eight feet), 1.2 meters by 5.5 meters (four feet by 18 feet), and 1.5 meters

by 4.9 meters (five feet by 16 feet). The 1.2 meters by 4.9 meters (four feet by 16 feet) is the most common production size. The combination of heat and pressure applied to mats in the press welds the fibers back together and produces properties which are unattainable in natural wood. The amount of time required for pressing and the details of temperature and pressure vary widely, depending upon the process and physical properties in the particular hardboard being produced.

To facilitate loading and unloading the board in the press, most presses are equipped with loading and unloading racks, which usually take the form of multi-deck elevators, with one deck for each opening in the hardboard press. Mats are loaded on all decks of a loading rack. When the hardboard press is open, unpressed mats are fed into the press at the same time pressed mats are removed at the other end of the press and placed into an unloading rack. Then, while the new boards are under pressure, unpressed mats are placed into the loading rack and pressed mats are discharged one at a time from the loading rack and conveyed to subsequent operations.

Pressing Operation: There are two basic types of hardboard, smooth one-side (S1S) and smooth two-sides (S2S). In making S1S hardboard, the cut-to-size mat is delivered from the board former onto a piece of screen wire slightly larger in overall dimensions than the piece of wet mat. The wires carrying wet mats are loaded into the decks of the press loading racks and are loaded into the press openings. When the press is closed and pressure applied, a large portion of water is removed. The remaining water must be evaporated by the heat of the press platens. Temperatures used in the production of S1S board are around 190°C (380°F). The entire process of pressing the board is carefully controlled by automatic electrical equipment.

When a wet-formed mat is to be used to produce S2S hardboard, it is delivered from the forming machine into a hot air dryer where surplus moisture is evaporated. This may require from one to four hours depending upon the weight of board being produced. At this stage the mat is in large pieces, usually two or three times as wide as the hardboard which will ultimately be pressed. The mat is trimmed to the desired length and width (usually slightly larger than 1.2 meters by 4.9 meters [four feet by 16 feet]) and delivered to the S2S hardboard press. At this point, the board may have less than one percent moisture content, and it is strong and rigid enough to support its own weight. Thus, board can be delivered

directly into the press openings and pressed with smooth platens, or caul plates, directly against both sides. Since moisture does not have to be squeezed and evaporated, the press cycle, which is from one to four minutes for common thickness, is much shorter than for comparable thicknesses of S1S board, which requires a 4 to 12 minute pressing time. The dried board is much harder to compress than the soft, wet S1S; consequently, hydraulic pressures three times greater must be applied. Press temperatures in excess of 288°C (550°F) must also be attained.

Dry-formed mat may also be used to produce S2S hardboard. When this is done, the fibers must be reduced to a desired low moisture content prior to the board formation. Most dry air-formed mats are deposited directly on traveling caul plates and delivered into the press. These traveling caul plates are necessary because the air-formed mat is too fragile to support its own weight before pressing. However, once in the press the combination of heat, pressure, and time consolidates the soft, fluffy material into a tough, durable piece of hardboard.

Oil Tempering

After being discharged from the press, a certain amount of hardboard is selected to receive a special treatment called tempering. Tempering consists of impregnating the sheets of hardboard by dipping or roller-coating them in a bath composed of drying oils and various drying resins derived from petroleum.

As sheets are removed from the oil bath, they are passed through a series of pressure rollers which aid in permeating the oils and removing any excess. The oil is then stabilized by baking the sheet from one to four hours at temperatures ranging from 143° to 171°C (290° to 340°F). Tempering hardboard increases the hardness, strength, and water resistance, thus making the board more resistant to abrasion and weathering.

Humidification

When sheets of hardboard are removed from the press, or the tempering oven, they are very hot and dry. The boards must be subjected to a seasoning operation called "humidification," otherwise they may tend to warp and change dimensions. Humidification is carried out by conveying boards through a long tunnel humidifier, or charging them in racks which enter a chamber where a high relative humidity is maintained. The boards are retained in the humidifier until they reach the proper moisture content. Although hardboards are humidified, they should be allowed to adjust to local atmospheric conditions before being installed.

Further Processing

The final operation includes trimming the board to length and width. Sheets of hardboard may be cut into any size a customer desires. Also, hardboard may be fabricated in a variety of ways. Some of the finishing processes include simulating wood grain finishes, applying paint for a variety of uses, embossing, and scoring.

After all operations have been completed and the sheets of hardboard pass their final rigid inspection, they are wrapped or packaged and sent to the warehouse for shipment to customers.

Table 12 shows the proposed voluntary classification of hardboard by surface finish, thickness, and physical properties.

PROCESS DESCRIPTION-WOOD PRESERVING

Treatments are applied by the industry to round and sawn wood products by injecting into them chemicals previously described that have fungistatic and insecticidal properties, or that impart fire resistance. Treatment is accomplished by either pressure or non-pressure processes. Pressure processes for treating wood with preservatives employ a combination of air and/or hydrostatic pressure and vacuum. Differences among the various pressure treating processes used are based mainly on the sequence of application of vacuum and pressure. The particular process used does not significantly affect either the quantity or the quality of wastewater discharged by a plant. Non-pressure processes utilize open tanks and either hot or cold preservatives in which the stock to be treated is immersed. Employment of this process on a commercial scale to treat timbers and poles is largely confined to the Rocky Mountain and Pacific regions, particularly the latter. It is used to treat lumber and posts in the East.

The effect of species of wood on the waste stream is significant only to the extent that it determines the conditioning method that must be employed to prepare stock for preservative treatment. Some species, such as the southern pines, are conditioned by a process in which the stock is steamed at approximately 118°C (245°F) for periods of from 1 to 16 hours preparatory to preservative treatment. This process, which is normally carried out in the same retort in which the actual injection of preservative is subsequently performed, has as its purpose to reduce the moisture content of green wood and to render the wood more penetrable, thus improving the quality of the preservative treatment. Other species, i.e., Douglas fir, are conditioned for the same purposes

TABLE 12

CLASSIFICATION OF HARDBOARD BY SURFACE FINISH, THICKNESS, AND PHYSICAL PROPERTIES (15)

Class	Surface	Nominal Thickness	Water Resistance (max av per panel)				Modulus of Rupture (min av per panel)	Tensile Strength (min av per panel)	
			Water		Thickness			Parallel to Surface	Perpendic- ular to Surface
			Absorption based on Weight		Swelling				
			S1S	S2S	S1S	S2S			
		mm	percent	percent	percent	percent	-Kilo-Newton per square meter-		
1	S1S and S2S	2.1	30	--	25	--	1015	507.5	21.75
		2.5	20	25	16	20			
		3.2	15	20	11	16			
		4.8	12	18	10	15			
		6.4	10	12	8	11			
		7.9	8	11	8	10			
		9.5	8	10	8	9			
2	S1S and S2S	2.1	40	40	30	30	725	362.5	14.5
		2.5	25	20	22	25			
		3.2	20	25	16	18			
		4.8	18	25	14	18			
		6.4	16	20	12	14			
		7.9	14	15	10	12			
		9.5	12	12	10	10			
3	S1S and S2S	3.2	20	25	15	22	625.5	290	14.5
		4.8	18	20	13	18			
		6.4	15	20	13	14			
		9.5	14	18	11	14			

Note: 1: Tempered
2: Standard
3: Service-Tempered

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TABLE 12 CONTINUED

CLASSIFICATION OF HARDBOARD BY SURFACE FINISH, THICKNESS, AND PHYSICAL PROPERTIES (15)

Class	Surface	Nominal Thickness	Water Resistance (max av per panel)				Modulus of Rupture (min av per panel)	Tensile Strength (min av per panel)		
			Water		Thickness			Parallel to Surface	Perpendic- ular to Surface	
			Absorption based on Weight		Swelling					
			S1S	S2S	S1S	S2S				
		mm	percent	percent	percent	percent	-Kilo-Newton per square meter-			
4		3.2	30	30	25	25	435	217.5	10.875	
	S1S and S2S	4.8	25	27	15	22				
		6.4	25	27	15	22				
		11.1	25	27	15	22				
		12.7	25	18	15	14				
		15.9	--	15	--	12				
		17.5	--	15	--	12				
	S2S	19.1	--	12	--	9				
		20.6	--	12	--	9				
		22.2	--	12	--	9				
		25.4	--	12	--	9				
		S1S and S2S	9.5	25	25	20				20
			11.1	25	25	20				20
			12.7	25	25	20				20
	15.9		--	22	--	18				
17.5	--		22	--	18					
S2S	19.1	--	20	--	16					
	20.6	--	20	--	16					
	22.2	--	20	--	16					
	25.4	--	20	--	16					

Note: 4: Service
5: Industrialite

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by a process called Boultonizing in which the wood is heated under vacuum in the preservative at 82° to 104°C (180° to 220°F) prior to preservative injection. Boultonizing is not used where the preservative is of the water-borne type.

Wastewater generated in steam conditioning is composed of both steam condensate and water removed from the wood. Wastewater from the Boultonizing process is composed only of water removed from the wood. Both waste streams are contaminated by the preservative used, and, where the same preservative is used, the difference between them is primarily a quantitative one.

A process flow diagram for a typical plant using steam conditioning is shown in Figure 14.

INDUSTRY CATEGORIZATION

The general objective of industry categorization is to subdivide the industry in order that separate effluent limitations and standards may be developed for such categories, if it is determined that separate regulation is necessary. A further necessary consideration, however, has to be based on whether differences in segments of the industry require separate technical analyses, even if the results of the analyses should lead to the same regulations.

The Environmental Protection Agency preliminarily categorized the timber products industry according to Standard Industrial Classification (SIC) codes. In Phase I of this study, veneer and plywood, hardboard, and wood preserving are covered. Due to the extreme differences among the three industries, the categorization is maintained.

VENEER AND PLYWOOD-SUBCATEGORIZATION

The veneer and plywood industry has been assigned two SIC codes: SIC 2435 includes hardwood veneer and plywood, and SIC 2436 includes softwood (16). It has been concluded that due to the applicability of treatment and control technology to the industry and due to other factors, hardwood and softwood veneer and plywood mills can be treated as one category without further subcategorization. Representatives of the industry have concurred with this conclusion.

Raw Materials

Numerous species of wood are used to cut veneer and produce plywood. Wastewater characteristics vary widely with raw material. For example, it is known that softwoods in contact with water, particularly hot water, release more wood sugars than do hardwoods.

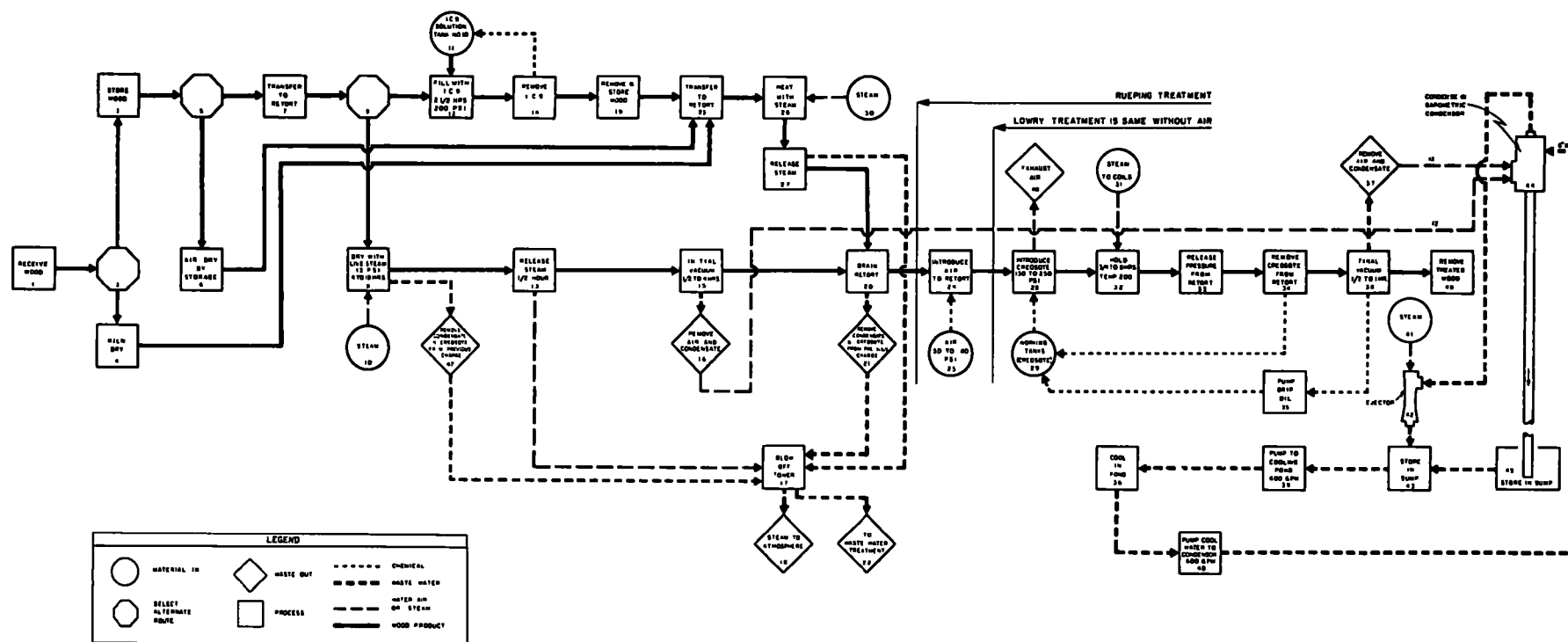


FIGURE 14 - PROCESS FLOW DIAGRAM FOR A TYPICAL WOOD-PRESERVING PLANT
(COURTESY OF ALBERT H. HALFF ASSOCIATES, INC., DALLAS, TEXAS)

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Within the broad categories of softwood and hardwood there are also many species with varying leaching characteristics. In addition, it is known that variations in process are often dictated by the raw materials. For example, hardwoods require log conditioning while some species of softwood do not.

While it would be expected that different wastewater characteristics result from different raw materials, it is observed that volumes of wastewaters vary only with process variations. In addition, the control and treatment technology applied to the industry consists almost exclusively of recycle and containment and is more a function of wastewater volume than of pollutant concentration. Differences according to species do not significantly affect the degree to which wastewaters can be treated or controlled and, therefore, are rejected as possible elements for subcategorization.

Type Of Product

The type of product manufactured is not directly related to wastewater volumes or concentrations and is, therefore, considered ineffective as a basis for subcategorization.

Size And Age Of Facility

The veneer and plywood industry is an old industry and contains a number of old mills. The softwood plywood industry, however, has been experiencing substantial growth for the past 20 years, and numerous new facilities have been constructed. The southeastern United States, the main area for new development, contains many of the newer plywood plants. Even though the ages of plants vary, the ages of various components of a plant are not necessarily reflected in total installation age; equipment is constantly being replaced. Plant age is therefore rejected as a possible element for subcategorization.

The size of mills can also vary drastically from a backyard operation producing 200,000 square meters (two million square feet) of plywood per year to a large plywood mill producing 50 million square meters (600 million square feet) per year. Since the volume of wastewater produced by a mill is largely proportional to the size of the mill, control and treatment are similarly proportional. While some special considerations based on economics may be necessary for extreme cases, plant size is rejected as a possible element for subcategorization.

Process Variation

As suggested above, there are many process variations in the veneer and plywood industry. These variations can be due to a number of factors, including: raw materials, climate, type of product, and personal preference.

Earlier in this section, process variations were described in detail. A mill may or may not condition logs; it may have wet or dry decking; it may remove the bark with or without water; it may or may not dry the veneer. Also, log conditioning may be accomplished in steam vats or hot water vats; dryers may have to be cleaned weekly, bi-weekly, or not at all. Most of these differences are dictated by the factors previously listed, while in some cases it is merely a matter of personal preference.

Even though there are a number of variations, particular unit processes are basically similar from plant to plant. It was therefore concluded that a feasible approach would be to characterize each unit operation rather than entire mills, and then to assemble these unit operations accordingly to determine the characteristics of a particular plant.

The variations in process are quite numerous, as might be expected in an industry composed of about 500 installations; however, with few exceptions, all variations can comply with regulations based on a single category encompassing all veneer, plywood, and veneer-plywood installations.

Land Availability

Since most treatment technology requires some amount of land, and since one of the more economically attractive treatment alternatives considered is containment of the wastes, land availability must be considered. Most veneer and plywood mills have sufficient land availability. However, there are certain plants located in urban areas which have a decisive lack of available land. While it is likely that most of these will have the opportunity to use municipal sewers; they will require specific consideration. With this stipulation, land availability is rejected as a parameter for subcategorization.

HARDBOARD INDUSTRY-SUBCATEGORIZATION

In developing Effluent Limitations Guidelines and Standards of Performance for new sources for a given industry, a judgment must be made as to whether effluent limitations and standards are appropriate for different segments (subcategories) within the industry. The factors considered in determining whether such subcategories are justified are:

- (1) Raw materials
- (2) Manufacturing process
- (3) Plant size
- (4) Plant age
- (5) Product
- (6) Plant location
- (7) Air pollution control equipment
- (8) Waste generated
- (9) Treatability of wastewaters

After extensive review of the above factors, involving plant inspections, discussions with industry representatives, and review of literature, it was concluded that the hardboard industry should be broken into two subcategories which are (1) dry process hardboard and (2) wet process hardboard.

Raw Material

Raw materials in the hardboard industry consist mainly of wood fiber and quantities of additives such as phenolic formaldehyde, urea formaldehyde, alum, ferric chloride and petroleum waxes. The type of wood fiber utilized will depend upon many variables including plant location, availability of raw material, and product to be made. The species of wood and even the season of harvest will have an effect on wastewater characteristics.

Composition changes in the binders are being made at different times by the industry to reduce raw materials cost, to improve the final product, and to reduce wastewater concentrations. Each mill has its own characteristics; however, in general, the waste characteristics for dry process hardboard mills and wet process hardboard mills are similar. Therefore, raw materials is not a basis for subcategorization.

Manufacturing Process

There are two different manufacturing processes in the hardboard industry which affect wastewater flow and composition. These are the dry-felting process and the wet-felting process. In

the dry-felting process the fibers are suspended in air as compared with the wet-felting process where the fibers are suspended in water. There is little or no process wastewater discharge from the dry-felting process, while there is a continuous and substantial wastewater discharge from the wet-felting process. One of the dry process mills which adds water to the mat after dry forming has a discharge from the press. This mill should be considered a special case and be given special consideration.

Wet-felting (wet process) hardboard mills may press board either dry or wet. If the board is to be pressed dry it is oven dried before pressing. Since there is only one existing hardboard mill which produces hardboard alone by wet-felting, dry pressing, it is not sufficient cause for a separate category. The wastewater from this particular mill is somewhat higher than a typical wet process mill; therefore, it should be considered a special case and given individual consideration.

There are several insulation board mills which produce hardboard by the wet process followed by dry pressing. Because insulation board mills will be considered in Phase II and because of the unknown interrelationship between the manufacture of insulation board and hardboard, these mills will also be surveyed in Phase II.

In the wet process hardboard mills, fiber preparation is a major factor affecting wastewater characteristics. Two mills utilize the explosion process for fiber preparation which causes substantially more BOD to be released. However, both of these mills have installed evaporators to handle this high BOD process wastewater and their overall waste discharge is as low or lower than other wet process mills. The degree of fiber preparation will depend upon many factors including wood species, inplant processes, and final product. There are even separate fiber preparation lines for boards that are made up in layers with the degree of fiber preparation for each layer dependent upon the product to be produced. The effect of fiber preparation on wastewater flow and composition is not sufficient in itself to be used as grounds for subcategorizing the industry.

Plant Size

It has been determined from existing data and from on-site inspections that, other than in volumes of water, plant size has no effect upon the wastewater characteristics and, therefore, should not be taken into consideration. Plant size will only affect costs of treatment as treatment cost for

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larger plants will generally be less per unit basis than for small plants.

Plant Age

A review of the data shows that plant age has no significant effect on wastewater discharge. The major effects of plant age are the higher maintenance cost and difficulty involved in installing recycle systems, not in wastewater flow or concentration. Therefore, plant age is not an appropriate basis for subcategorization.

Product

The type of hardboard produced in any one mill does not necessarily determine the inplant processes used to make that product. In the hardboard industry the product itself is not sufficient justification for subcategorizing the industry, as similar products can be produced by a combination of different inplant processes. It is the inplant processes which affect the wastewater characteristics rather than the product resulting from the processes.

Plant Location

Geographical location of hardboard mills affects wastewater characteristics mainly due to the type of available raw materials. Variation in raw materials has already been rejected as grounds for subcategorizing the industry. Plant location will affect the weather conditions experienced and the effect of low temperatures on biological treatment systems should be given special consideration. Plant location in itself is not sufficient grounds for subcategorization.

Air Pollution Control Equipment

Air pollution control is a major problem in the dry process hardboard industry and the industry is just beginning to take steps to control the problem. Air pollution control equipment is not a major factor affecting wastewater discharge in the hardboard industry, therefore, the industry subcategorization should not be affected by air pollution equipment.

Wastes Generated

Variation in waste generated in the hardboard industry is directly related to the two different manufacturing processes utilized in making hardboard, the wet-felting process and the dry-felting process. The wastewater flow, excluding cooling water, from a typical dry process hardboard mill will consist of a discharge of less than 1,890 liters per day (500 gallons per day). This compares

with a wastewater flow of 1,430,000 liters per day (378,000 gallons per day) from a typical wet process hardboard mill. Therefore, there is justification for subcategorizing the industry into the wet process and dry process hardboard mills.

Treatability of Wastewaters

Treatability of wastewaters is not a justified basis for subcategorization. Wastewaters from all wet process hardboard mills are difficult to treat; however, there is not sufficient variation to subcategorize the hardboard industry base on treatability of wastewater alone.

WOOD PRESERVING INDUSTRY-SUBCATEGORIZATION

The wood preserving industry is defined as the treatment of round and sawn wood products by injecting them with chemicals which protect the wood from insect or microorganism attack or provide fire resistance.

Factors Considered

With respect to identifying any relevant, discrete categories for the wood preserving industry, the following factors or elements were considered in determining whether the industry should be subdivided into subcategories for the purpose of the application of effluent limitations guidelines and standards of performance:

- (1) Raw materials
- (2) Products produced
- (3) Production processes or methods
- (4) Size and age of production facilities
- (5) Wastewater constituents
- (6) Treatability of wastes.

After considering all of these factors, it was concluded that the wood preserving industry should be subcategorized based on the method of conditioning the stock, type of preservative employed, and type of process involved. The wood preserving industry may be divided into four subcategories as follows:

<u>Subcategory</u>	<u>Description</u>
1	Pressure processes employing oily preservatives in which the predominant method of conditioning green stock is by steaming or vapor drying

<u>(Subcategory)</u>	<u>(Description)</u>
2	Pressure processes employing oily preservatives in which the predominant method of conditioning green stock is by Boultonizing
3	Pressure processes employing water-borne salts
4	Non-pressure sources.

These categories subdivide the industry by major process, either pressure or non-pressure, and by type of preservative used, either oil-type or water-borne. It further subdivides pressure processes that employ oil-type preservatives into two groups based on the method of conditioning green wood preparatory to preservative treatment.

Categorization based on treatment process, preservative used, and method of conditioning is necessary because of the effect of these variables on wastewater volume and on the opportunity for recycling waste, thus limiting or, in some instances, curtailing discharges. The specific considerations that dictated the selection of the categories shown are summarized below:

- (a) Because of the processing methods used, pressure treatments require the use of water, some of which comes into contact with the product. Non-pressure treatments generate no process water. Contamination of water which occurs in the latter process is due directly or indirectly to precipitation, and can generally be avoided.
- (b) Technology is currently available that makes practical the recycling of wastewater from salt-type treatments. This is not necessarily the case for wastewater from treatments which employ oily preservatives.
- (c) The volume of wastewater generated during conditioning of green stock preparatory to preservative treatment is several times greater by steaming than by Boultonizing.

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Subcategories 1 and 2 will apply principally to plants which treat southern pine and Douglas fir, respectively, with creosote and/or pentachlorophenol in the various forms in which they are used. As such, they will cover the majority of the plants in the industry.

Subcategory 3 will apply both to plants which treat only with water-borne preservatives and fire-retardants and to that portion of the production equipment used to apply salt-type treatments at plants which also treat with oily preservatives.

Subcategory 4 will apply to all non-pressure processes regardless of type, preservative used, and the products treated.

SECTION V

WATER USE AND WASTE CHARACTERIZATION

PART A: VENEER AND PLYWOOD

Water usage varies widely in the veneer and plywood industry depending on types of unit operations employed and the degree of recycle and reuse of water practiced. In general, total water usage is less than 3.15 liters per second (50 gallons per minute). There are some veneer and plywood plants that do not discharge wastewater into navigable streams, but all use fresh water to some extent. While there are plants presently being designed to recycle all wastewater, none are now in operation and the practicability of doing so has not been established. It is observed, however, that considerable effort can be made to reduce the amount of wastewater to be discharged or contained. The amount of information available on volumes and characteristics of wastewaters from the industry is minimal; however, its problems are also dwarfed when compared to that of most other industries. Data used in wastewater characterization is based mostly on data from the literature, information supplied by individual mills, and sampling and analyses conducted for the purposes of this study. Since the volumes that are involved are small, attention has been directed to finding methods for reducing the volumes and ways of handling in such a way as to eliminate discharges.

When wood comes in contact with water, there can occur various chemical effects which cause leaching and dissolution of various compounds into the water. Wood is exceedingly difficult to define chemically because it is a complex heterogeneous product of nature composed of interpenetrating components, largely of high molecular weight. The principal components generally are classified as cellulose, lignin, hemicellulose, and solvent-soluble substances (extractives). The paper industry (7) reports the amounts present to be in the range of 40 to 50 percent, 15 to 35 percent, 20 to 35 percent, and 3 to 10 percent, respectively.

The yield, composition, purity, and extent of degradation of these isolated components depend on the exact conditions of the empirical procedures employed for their isolation. By far the most important factor relative to the values obtained in chemical analysis for wood components is the tree species.

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At normal temperatures wood has remarkable resistance to degradation by chemicals and solvents. This may be attributed to the penetrating network structure of wood comprised of polymers with widely differing properties. Also, the high crystallinity of the carbohydrate system reduces the accessibility of the wood components to reagents.

Water at room temperature has little chemical effect on wood, but as temperature rises and pH decreases because of the splitting off of acetyl groups, wood becomes subject to rapid acid hydrolysis with the dissolution of carbohydrate material and some lignin. At temperatures above 140°C (220°F) considerable and rapid removal of hemicellulose occurs (7). Fortunately, cellulose resists hydrolysis better than hemicellulose fractions. Table 13 relates properties and composition of many common woods used in this country.

In veneer and plywood mills, water is used in the following operations:

- (1) Log storage
- (2) Log debarking
- (3) Log conditioning
- (4) Cleaning of veneer dryers
- (5) Washing of the glue line
and glue tanks
- (6) Cooling

Figure 9 (Section IV), presented a detailed process flow diagram. The water use and waste characteristics for each operation are discussed below.

LOG STORAGE

As described in Section IV, Process Description and Industry Categorization, there are three methods of storing logs, and two of these, log ponds and wet-decking, depend on the use of water.

Log Ponds

There are hundreds of log ponds throughout the country. Some of these are in conjunction with veneer and plywood operations, but many more are part of logging operations, saw mills, hard-board plants, paper mills, and other operations in the timber products industry. Log ponds can take a number of forms. As discussed in Section IV, they can be in an estuary, river, lake,

TABLE 13 (17)

SOME PROPERTIES OF CERTAIN UNITED STATES WOODS

	Specific gravity	Shrink- age, %	Bark, %	Hardness		Cellulose, %	Lignin, %	Solubility, %	
				Side	End			Hot water	Ether
Conifers									
Spruce									
Engelmann	0.31	10.4	11.1	240	250	60.5	27.9	1.7	0.5
Red	0.38	11.8	—	350	410				
Sitka	0.37	11.5	—	350	430	60.5	29.6	5.0	0.8
White	0.37	13.7	12.4	320	350	60.4	29.0	2.9	1.2
Fir									
Alpine	0.31	9.0	—	220	280				
Balsam	0.34	10.8	—	290	290				
Grand	0.37	10.6	9.1	360	420	63.0	27.0	2.3	0.9
Noble	0.35	12.5	—	290	330				
Silver	0.35	11.1	15.9	310	360	60.8	28.2	3.2	0.9
White	0.35	9.4	—	330	380				
Douglas fir, coast type	0.45*	11.8	10.6	480	510	59.7	30.3	5.6	0.9
Pine									
Jack	0.39	10.4	9.8	370	380	58.7	28.5	3.7	2.2
Loblolly	0.47	12.3	10.5	450	420	58.7	28.3	1.8	1.9
Lodgepole	0.38	11.5	7.5	330	320	57.6	25.9	3.6	1.3
Longleaf	0.54	12.2	11.6	590	550	58.6	30.8	3.1	2.1
Ponderosa	0.38	9.6	—	310	330	58.0	27.2	4.8	6.8
Red	0.44	11.5	—	340	360				
Shortleaf	0.46	12.3	11.9	410	410	58.8	29.0	2.6	2.0
Slash	0.56	12.2	15.6	630	600	59.8	27.6	3.6	3.3
Sugar	0.35	7.9	—	310	320				
White eastern	0.34	8.2	12.5	310	310	60.0	27.5	4.6	3.0
White western	0.36	11.8	—	310	310	59.7	26.4	4.5	4.3
Hemlock									
Eastern	0.38	9.7	18.9	400	500	54.4	34.1	3.7	0.6
Western	0.38	11.9	9.7	430	520	59.6	30.2	3.0	0.7
Larch									
Tamarack	0.49	13.6	—	380	400				
Western	0.48	13.2	8.8	450	470	57.8	—	12.6	0.81
Cypress, bald	0.42	10.5	—	390	440				
Hardwoods									
Ash, white	0.55	13.3	—	960	1,010	51.0	26.4	6.9	0.5
Basswood	0.32	15.8	—	250	290	61.2	—	4.1	1.9
Beech	0.56	16.3	—	850	970				
Birch									
Paper	0.48	16.2	13.2	560	470	60.6	25.7	2.7	1.0
Yellow	0.55	16.7	—	750	810	61.3	—	4.0 ^a	0.6
Butternut	0.36	10.2	—	390	410				
Chestnut	0.40	11.6	—	420	530				
Cucumber tree	0.44	13.6	—	520	600				
Elm, American	0.46	14.6	9.6	620	680	58.3	24.3	3.6	0.4
Gum									
Black	0.46	13.9	12.4	640	790	56.7	28.4	4.0	0.1
Sweet	0.44	15.0	—	520	630	59.6	20.5	2.8	0.8
Maple									
Red	0.49	13.1	—	700	780				
Silver	0.41	12.0	—	590	670				
Sugar	0.56	14.9	13.7	970	1,070	60.8	23.2	4.1	0.3
Poplar									
Quaking aspen	0.35	11.5	18.1	300	280	65.5	23.4	3.0	1.1
Balsam	0.30	10.5	—	230	210				
Eastern cottonwood	0.37	11.1	11.7	310	380	63.2	23.6	2.0	0.1
Large tooth aspen	0.35	11.8	—	370	400				
Sycamore	0.46	14.2	—	610	700				
Yellow poplar	0.35	12.3	—	310	390	61.7	20.0	2.0	0.2

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or they can be in the form of man-made impoundment. The data available in the literature along with that obtained by sampling are based on man-made impoundments which are the most common in the veneer and plywood industry. All of these are based on the state of Oregon where log ponds abound.

In order to characterize the quality of water leaving a log pond, there are many factors that must be considered. These include:

- (1) Type of logs in pond
- (2) Number of logs in pond
- (3) Age of logs
- (4) Detention time of logs
- (5) Size of pond
- (6) Hydraulic detention time
- (7) Quality of water entering pond

While the first five factors can usually be approximated with sufficient accuracy, the last two can be elusive. Both the hydraulic detention time and the quality of water entering the pond are a function of the quantity and frequency of rain as well as drainage area and runoff characteristics. In western Oregon, for example, the average yearly rainfall is approximately 137 centimeters (54 inches), but almost all of the rain occurs in the winter months of November through April. In general, in western Oregon log ponds do not discharge during the summer, and the concentrations accumulate until the winter rainy season when the ponds begin to overflow. At the end of the rainy season the quality of water in the log ponds is usually at its best. A variable discharge, as is common in Oregon, makes the task of characterization an exceedingly difficult one. In fact, in order to accomplish a reasonable characterization, it would be necessary to monitor several log ponds over at least a one-year period.

The data used to characterize log ponds in this study are based on samples collected in the winter of 1973 and on additional samples collected under Environmental Protection Agency Project Number NP01320, by Doctor Frank D. Schaumburg (18), in the summer of 1972. From this data it is possible to formulate an approximation of the characteristics of man-made log ponds in Oregon and to obtain some idea of the waste loads that these might represent.

Tables 14 and 15 characterize the water from various log ponds in terms of concentration. From this data it can be seen that there are significant differences in concentration from summer to winter.

TABLE 14
WINTER CHARACTERISTICS OF OREGON LOG PONDS*
PART A: CHEMICAL CHARACTERISTICS

Pond	BOD ₅	COD	DS	SS	TS	Turb.	Phenols	Color	Kjld-N	T-PO ₄ -P
A-1	5	57	81	31	112	12	0.03	18	2.30	0.02
A-2	10	64	90	579	669	40	0.03	9	0.34	0.02
A-3	2	47	69	11	80	8	0.03	14	1.40	0.02
A-4	3	67	130	21	151	6	0.01	9	1.33	0.02
A-5	7	46	120	42	162	28	0.08	12	2.82	0.025
A-6	3	78	271	26	297	4	0.06	13	0.45	0.02

Note: Turbidity in JTU; color in Pt.-Cobalt units; all others in mg/l.

TABLE 14 (CONTINUED)

WINTER CHARACTERISTICS OF OREGON LOG PONDS*
PART B: PHYSICAL CHARACTERISTICS

Pond	Surface Area (Hectares)	Average Depth (Meters)	Volume (Cu.M)	Type of Log	Log Detention	Water Source	Remarks and Approximate Eff.
A-1	23	1.5	345,192	65% Doug.fir 35% Hemlock	44 Days	Reservoir	Overflow in Nov. to Mar.=about 1,635 Cu.M/Day
A-2	1.2	1.8	22,937	40% Doug.fir 60% Hemlock	3 Hours	Creek	Impounded creek Overflowing Nov. to Mar.=about 489,400 Cu.M/Day
A-3	23	1.4	314,912	90% Doug.fir	60 Days		Overflow in Nov. to Mar.=about 1,635 Cu.M/Day
A-4	17	1.2	207,039	100% Doug.fir	126 Days	Another Pond	Overflow in Nov. to Mar.=about 1,643 Cu.M/Day

*Based on Environmental Science and Engineering, Inc. sampling from March 2 to March 6, 1973.

TABLE 15

SUMMER CHARACTERISTICS OF OREGON LOG PONDS (18)
PART A: CHEMICAL CHARACTERISTICS

Pond	TS	SS	DO	Temp.	pH	COD	BOD ₂₀	BOD ₅	$\frac{BOD_5}{COD}$	Kj1d-N	NO ₃ -N	PO ₄
B-1	254	43	0.1	22	6.9	116	48	29	0.25	2.4	0.6	0.5
B-2	747	180	0.3	21.5	7.1	504	167	54	0.11	10.4	1.5	1.2
B-3	356	4	1.5	23	7.5	23	10	6	0.25	1.0	0.1	0.1
B-4	606	122	0.7	21.5	7.4	353	116	68	0.19	4.9	0.7	2.0

Note: All concentrations in mg/l except temperature in degrees Centigrade and pH

TABLE 15 (CONTINUED)

SUMMER CHARACTERISTICS OF OREGON LOG PONDS (18)
PART B: PHYSICAL CHARACTERISTICS

Pond	Area (Hectares)	Depth (Meters)	Pond Age (Years)	Type Logs Stored	Length of Storage	Water Source	Remarks
B-1	10.5	2.44	11	Doug.fir	1-3 years	stream	Non-everflowing except during high runoff periods; Sanitary wastes dumped into pond.
B-2	8.09	1.85 to 2.44	14	Doug.fir	80% of logs about 1 week	wells	Non-overflowing except during high runoff periods; Sanitary wastes from plywood dumped into pond.
B-3	1.01	3.66	19	85% Pond- erosa pine 15% Doug.fir	2 weeks	stream	Overflowing at about 25.2 liters per second
B-4	1.21	1.22 to 1.52		Over 90% Ponderosa pine	1 week	spring; irriga- tion	Overflowing at about 1.01 liters per second.

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In the winter, BOD values range from two to ten milligrams per liter and in the summer from six to 68 milligrams per liter. COD values are from six to 26 times larger than BOD values in the winter and from four to ten times larger in the summer. Log ponds with higher hydraulic loads also have higher solids concentration. Total solid concentrations vary from about 80 to 700 mg/l.

All of the log ponds have a distinct brown coloration which has been credited by Schaumburg (18) to leached tannins from the bark of the logs. The Pearl Benson Index has often been used as a measure of color producing substances, but COD has also been found by Schaumburg to correlate satisfactorily.

Table 16, below, presents approximate waste loads from ponds sampled during this study. Three of the four ponds presented in this table show good correlation; however, the other carries much greater loads. The greater loads may be partly due to the greater hydraulic loads and partly to the shorter detention time of the logs - factors favoring greater leaching.

Wet-Decking

Since wet-decking is the most acceptable alternative to traditional log-ponding, it is necessary to determine the waste characteristics from such operations. Schaumburg's study (18) on log handling includes the results of field work conducted to obtain leaching data from wet-decking. This data is shown in Table 17. It appears that the amount of waste transferred from the logs to the water is about the same regardless of whether the logs are stored in ponds or wet-decked.

TABLE 16

WINTER WASTELOAD FROM OREGON LOG PONDS

Pond	BOD ₅	COD	DS	SS	TS	Phenols	Kjld-N	T-PO ₄
A-1	23	262	367	144	516	0.138	10.6	<0.092
A-2	2027	13600	912	121000	120000	6.587	74.3	<4.36
A-3	20	477	701	112	814	0.306	14.2	<0.202
A-4	12	258	502	81	583	-0.039	-0.277	--

Note: Units are in kilograms per million cubic meters

TABLE 17
PONDEROSA PINE WET DECK DATA (18)

<u>Parameter</u>	<u>Sampled Value</u>
Mean log diameter	49 cm
Mean log length	9.9 m
Estimated number of logs	24,400
Estimated surface area	371,600 sq.m
Mean BOD of runoff	19 mg/l
Flow	1,612 cu.m/day
BOD per day	30.6 kg/day

TABLE 18
ANALYSIS OF SAMPLE TAKEN FROM A WET DECKING RECYCLE POND

BOD	16 mg/l
COD	323 mg/l
Total Solids	544 mg/l
Suspended Solids	104 mg/l
Dissolved Solids	440 mg/l
Total Phosphorus	2.0 mg/l
Kjeldahl Nitrogen	2.7 mg/l
Turbidity	80 JTU
pH	8.16

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However, collection and recycling of sprinkling water makes zero discharge from wet-decking more feasible than from log ponds. The main advantage of wet-decking is that the volume of wastewater produced is more easily controlled due both to the operation and to the fact that sprinkling enhances evaporation. The increased evaporation partially offsets the effect of rainfall runoff on wastewater volume.

A small hardwood and veneer plywood plant with a wet-decking operation recycles the sprinkled water by collecting it into two small ponds of less than two hectares (one acre) where solids are allowed to settle. The effluent from these ponds is pumped back to the sprinklers through a coarse screen. One of these ponds was sampled and the results of analyses are presented in Table 18. No significant accumulation of BOD and COD is observed when this data is compared with the data in Table 17. The major concern of such a recycling system is the accumulation of solids and particularly of colloidal solids. While there are problems associated with recycling, these are operational problems that vary from plant to plant and also vary with location, soil conditions, and other such factors. These problems can be solved in most cases. There are now several plants within the industry that recycle sprinkling water successfully.

LOG BARKING

Logs can be barked with or without water. A typical mill barks logs without water and it appears that the trend will be for all barking to be accomplished without water (mechanically). A very small amount of water may be used to control dust and small wood particles; however, no discharge is necessary. Nevertheless, there are still some applications, such as with very large logs, which make wet barking necessary.

Since wet barkers are being phased out in the veneer and plywood industry, no effort is being made to verify the characterization of the wastewaters associated with it. The following is based on results of Environmental Protection Agency Contract Number 68-01-0022 and 68-01-0012 (8).

As discussed in Section IV, Process Description and Industry Categorization, there are three types of wet barkers: (1) drum barkers; (2) pocket barkers; and (3) hydraulic barkers. Drum and hydraulic barkers are the most common. In any case, a wet barking operation requires a number of steps to separate the bark from the water. The bark is usually pressed to remove water and then sent to a boiler where it

is used as a source of fuel. Figure 10 in Section IV presented a typical process flow diagram for wet barking.

Results of an analysis of the effluent from a hydraulic barking process are shown in Table 19. The water employed in hydraulic barking must be free of suspended solids to avoid clogging nozzles. It can be concluded that the total suspended solids content in the discharge from hydraulic barking ranges from 521 to 2,362 mg/l, while BOD values range between 56 and 250 mg/l.

Results of an analysis of the effluent from a drum barker is also given in Table 19. Total suspended solids concentrations are only slightly higher in a drum barker than in a hydraulic barker, but BOD values are significantly higher. Drum barking often involves recycling, which accounts for part of the increase. The high BOD values are also due to a longer contact between the bark and the water and to the grinding action which is absent in hydraulic barking.

BOD values are also affected by the species of wood barked and by the time of the year in which the log is cut.

LOG CONDITIONING (STEAMING)

The industry uses two distinct types of log steaming systems. These are discussed in Section IV; Process Description and Industry Categorization, and are referred to as steam vats and hot water vats. In the South about 50 percent of the plants use steam vats and 50 percent use hot water vats. In the West, however, only about 30 percent of the plants use any kind of conditioning and these use steam vats almost exclusively.

The only wastewater from a steam vat is condensed steam. This water carries leachates from the logs as well as wood particles. Table 20 presents the results of analyses of wastewaters from steam vats. The magnitudes of these flows vary according to the size and number of vats. A plant producing 9.31 million square meters (100 million square feet) of plywood on a 9.53 millimeter (three-eighths inch) basis has an effluent of about 1.58 to 3.15 liters per second (25 to 50 gallons per minute). A southern plywood mill produces a BOD load of 2,500 kilograms per million square meters (515 pounds per million square feet) of board on a 9.53 millimeter (three-eighths inch) basis, and a total solids load of 29,200 kilograms per million square meters on a 9.53 millimeter basis (6,000 pounds per million square feet on a three-eighths inch basis) of board.

TABLE 19
CHARACTERISTICS OF DEBARKING EFFLUENTS (8)

Mill	Type of Debarking	Total Suspended Solids (mg/l)	Non-Set. Solids (mg/l)	BOD ₅ (mg/l)	Color Units
1	Hydraulic	2,362	141	85	Less than 50
2	Hydraulic	889	101	101	Less than 50
3	Hydraulic	1,391	180	64	Less than 50
4	Hydraulic	550	66	99	Less than 50
5	Hydraulic	521	53	121	Less than 50
6	Hydraulic	2,017	69	56	Less than 50
7	Hydraulic	2,000	<200	97	-----
8	Hydraulic	600	41	250	35

9	Drum	2,017	69	480	20
10	Drum	3,171	57	605	Less than 50
11	Drum	2,875	80	987	Less than 50

TABLE 20
CHARACTERISTICS OF STEAM VAT DISCHARGES

Plant	Concentrations									
	BOD	COD	DS	SS	TS	Turb.	Phenols	Kjld-N	T-PO ₄ -P	pH
A	470	8,310	2,430	2,940	5,370	450	0.69	56.8	5.70	4.12
B	3,117	4,005	--	86	--	--	--	16.5	14	4.1-6.1
C	2,940	8,670	5,080	370	5,450	245	0.57	39.3	--	5.38
D	1,499	3,435	2,202	389	2,591	249	--	--	--	5.3
E	1,298	3,312	2,429	107	2,536	30	0.30	1.87	.173	
F	476	1,668	917	74	991	28	0.20	4.73	1.93	

Note: All units are in mg/l except Turbidity, which is in JTU's and pH.

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A hot water vat conditions the log with hot water heated either directly with steam or by means of heating coils with steam, oil or other heat sources. When the vat is heated indirectly, there is no reason for a constant discharge. Steam vats regardless of heating method are usually emptied periodically, and the water is discharged and replaced with clean water. Some plants settle spent wastewater and pump it back into the vats. Chemical characteristics for hot water vats for a series of veneer and plywood plants are given in Table 21.

DRYER WASHWATER

Veneer dryers accumulate wood particles. Volatile hydrocarbons will also condense on the surface of dryers to form an organic deposit which is called "pitch." In order to avoid excessive buildup of these substances, dryers must be cleaned periodically. Wood particles can be removed either by flushing with water or by blowing with air. While some of the pitch can be scraped off, generally a high pH detergent must be applied to dissolve most of the pitch and then it must be rinsed off with water.

The nature of the dryer wash water varies according to the amount of water used, the amount of scraping prior to application of water, condition of the dryer, operation of dryer, and, to some extent, the species of wood that is being dried.

The amount of water used varies from plant to plant and from operator to operator. One drying operation was observed to use about 23,000 liters (6,000 gallons) of water per dryer over a period of 80 hours. At this plant there were six dryers and they were washed every three weeks. The washing operation consisted of removing the bulk of the wood residue by blowing it out with air and hauling it away, and then washing the dryer with water for about three-quarters of an hour to remove more wood particles. After this water cleaning, the caustic detergent was applied. Finally, the detergent was rinsed off with water for another three-quarters of an hour. Samples of spent water were taken during both applications of water, and the analyses of these samples are shown in Table 22-A. The effluent from this washing operation was averaged over a seven-day period and expressed in terms of a unit of production basis as shown in Table 22-B.

One thing that is emphasized by various experts in the veneer and plywood industry is that pitch build-up can be minimized by proper maintenance of the dryers. In addition, the volume

TABLE 21

CHARACTERISTICS OF HOT WATER STEAM VAT DISCHARGES

Plant	Concentrations									
	BOD	COD	DS	SS	TS	Turb.	Phenols	Kjld-N	T-PO ₄ -P	pH
A	4,740	14,600	3,950	2,520	6,470	--	0.40	26.4	--	5.4
B	3,100	9,080	1,570	460	2,030	--	--	23.4	--	3.8
C	326	1,492	1,948	72	2,020	800	<1.0	16.2	<1.0	6.9
D*	1,000			160	1,000					4.5
E*	1,900	4,000	319	1,462	1,781					4.4

Note: All units are in mg/l except Turbidity, which is in JTU, and pH

*Analyses for plants 'D' and 'E' were provided by the respective plants, and figures for plant 'E' represent an average for several mills owned by one company.

TABLE 22^a

ANALYSIS OF DRIER WASHWATER

Plant	BOD	COD	DS	SS	TS	Turb.	Phenols	Color	Kjld-N	T-PO ₄ -P
<hr/>										
A										
Part I	210	1,131	643	113	756	19	1.31	32	17.7	1.93
Part II	840	6,703	1,095	5,372	6,467	50	0.20	43	211	11.0
B										
	60	1,568	1,346	80	1,426	6	4.68	51	2.91	0.495
<hr/>										

Note: All units are concentrations in mg/l except for Turbidity in JTU's and Color in Pt-Cobalt units.

TABLE 22^b
WASTE LOADS FROM VENEER DRIERS

Plant	BOD	COD	DS	SS	TS	Phenols	Kjld-N	T-PO ₄ -P
A	60.94	412	99.7	319	418	0.018	13.2	0.18
B	2.33	60.6	52.3	3.09	55.2	0.014	0.112	0.019

Note: all units are in kilograms per million square meters.

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of water necessary to wash the dryers can be greatly reduced. For example, one Oregon plant of about one-half the size of the one described previously was observed to use one-twelfth as much water per week to clean its dryers. Wastewater characteristics from this plant are also given in Tables 22-A and 22-B. It must be noted, however, that this plant provides settling and screening for the spent wash water before discharge, and samples were taken at the discharge.

Most dryers are equipped with deluge systems to extinguish fires that might be generated inside the dryer. Fires in dryers are actually quite common, especially in those that are poorly maintained. This water is usually handled in a similar manner to dryer wash water, and many plants actually take advantage of fires to clean the dryers. Fire deluge water can add significantly to the wastewater problems in some cases.

In addition to the two wastewater sources from veneer dryers that have been mentioned, water is occasionally used for flooding the bottom of the dryers. Many operators question the logic behind this practice, while some claim that it prevents fires and reduces air pollution problems. In any event, this water does not have to add to the wastewater problems of a mill. Several plants recycle all flood, wash, and fire water, and because the flooding results in substantial evaporation of water, these plants have found that fresh water can be used to clean the dryers and still keep the system closed.

GLUE SYSTEM

Presently there are three types of glues in use in the veneer and plywood industry: (1) phenolic formaldehyde resin; (2) urea formaldehyde; and (3) protein glue. Protein glues are slowly being phased out of the industry, while phenolic glues are becoming more widely used. The main source of wastewater from a glue system results from the washing of the glue spreaders and mixing tanks.

The most extensive study of wastewater from glue systems in the veneer and plywood industry was made by the Environmental Protection Agency and carried out by Bodien (10). Table 10, found in Section IV, shows a list of the typical ingredients of the three categories of glues already established. The specific quantities of these ingredients may vary slightly. Table 23-A lists the results of chemical analyses of typical mixtures of the different glues. The wastewaters from the washing operations are diluted at a ratio of about twenty

TABLE 23-A

AVERAGE CHEMICAL ANALYSIS OF PLYWOOD GLUE (10)

Analysis and Units	Phenolic Glue ^a	Protein Glue ^b	Urea Glue ^c
COD, mg/kg	653,000	177,000	421,000
BOD, mg/kg	---	88,000	195,000
TOC, mg/kg	176,000	52,000	90,000
Total Phosphate, mg/kg as P	120	260	756
Total Kjeldahl Nitrogen, mg/kg as N	1,200	12,000	21,300
Phenols, µg/kg	514,000	1,810	
Suspended Solids, mg/kg	92,000	59,000	346,000
Dissolved Solids, mg/kg	305,000	118,000	240,000
Total Solids, mg/kg	397,000	177,000	550,000
Total Volatile Suspended Solids, mg/kg	84,000	34,000	346,000
Total Volatile Solids, mg/kg	172,000	137,000	550,000

^aBorden's Cascophen 31 which is similar to Borden's Cascophen 382^bBorden's Casco S-230^cBorden's Casco Resin 5H

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to one with water to yield concentrations shown in Table 23-B. Samples of two phenolic and one urea formaldehyde wastewater were collected and are shown in Table 23-C. These are in the same range as those in Table 23-B, so it is reasonable to assume a twenty to one dilution with water. This ratio varies considerably, however, according to frequency of cleaning and amount of water used.

Wastewaters from glue systems are presently being handled by: (1) direct discharge; (2) lagooning and discharge; (3) evaporators; (4) partial incineration; and (5) reusing the wash water.

Several studies have been made of wastewater flow and reuse in gluing operations to determine the possibility of complete wastewater recycling. Most plywood mills add about 20 percent water by weight, and the use of some wash water in the glue mix is, therefore, possible. Table 23-D shows a list of southern plywood mills along with the wastewater generated and the water needed in glue makeup. Table 23-E shows measurement of wastewaters generated by four Oregon plywood plants. It is obvious from this data that in order to use all of the wash water as glue makeup, significant reductions must be made in the wastewater generated. These reductions, however, are feasible and many plants currently operate with complete recycle.

Cooling Requirements

A veneer and plywood mill requires a certain amount of cooling water to dissipate heat from the air compressor as well as from machines such as the press and the lathe. A mill producing 9.3 million square meters (100 million square feet) of plywood per year on a 9.53 millimeter (three-eighths inch) basis needs to dissipate about 55,000 kilo-calories (217,000 BTU) (20) per hour from the compressor and 101,000 kilo-calories (400,000 BTU) (20) per hour from the rest of the plant, for a total of 156,000 kilo-calories (617,000 BTU) per hour.

Mass Water Balance in a Veneer and Plywood Mill

An account of water gains and losses that occur in a typical mill is given in this section. A schematic diagram of water balance is given in Figure 15.

A veneer and plywood mill with an annual production of 9.3 million square meters (100 million square feet) of plywood on a 9.53 millimeter (three-eighths inch) basis is used as a basis for the development of the water balance. Such a mill would

TABLE 23-B

AVERAGE CHEMICAL ANALYSIS OF PLYWOOD GLUE WASHWATER (10)
(assuming a 20:1 dilution with water)

Analysis and Units	Phenolic Glue ^a	Protein Glue ^b	Urea Glue ^c
COD, mg/kg	32,650	8,850	21,050
BOD, mg/kg	~25,000	440	9,750
TOC, mg/kg	8,800	2,600	4,500
Total Phosphate, mg/kg as P	6.00	13	37.8
Total Kjeldahl Nitrogen, mg/kg as N	60	600	1,065
Phenols, µg/kg	25,700	90.5	
Suspended Solids, mg/kg	4,600	2,950	173,000
Dissolved Solids, mg/kg	15,250	5,900	10,300
Total Solids, mg/kg	19,850	8,850	27,500
Total Volatile Suspended Solids, mg/kg	84,000	1,700	17,300
Total Volatile Solids, mg/kg	172,000	6,850	27,500

^aBorden's Cascophen 31 which is similar to Borden's Cascophen 382

^bBorden's Casco S-230

^cBorden's Casco Resin 5H

TABLE 23-C
CHARACTERISTICS OF GLUE WASHWATER

Plant	BOD	COD	TS	DS	SS	Kj1d-N	T-PO ₄ -P	Phenols	pH
A	15,900	16,700	7,910	6,850		21.8	2.46	4.16	9.77
B			8,880	6,310		1,640	20.2	0.14	5.25
C	710	5,670	5,890	3,360	2,530				10.8

Note: Plants A and C utilize phenolic glue and Plant C uses urea glue.

TABLE 23-D

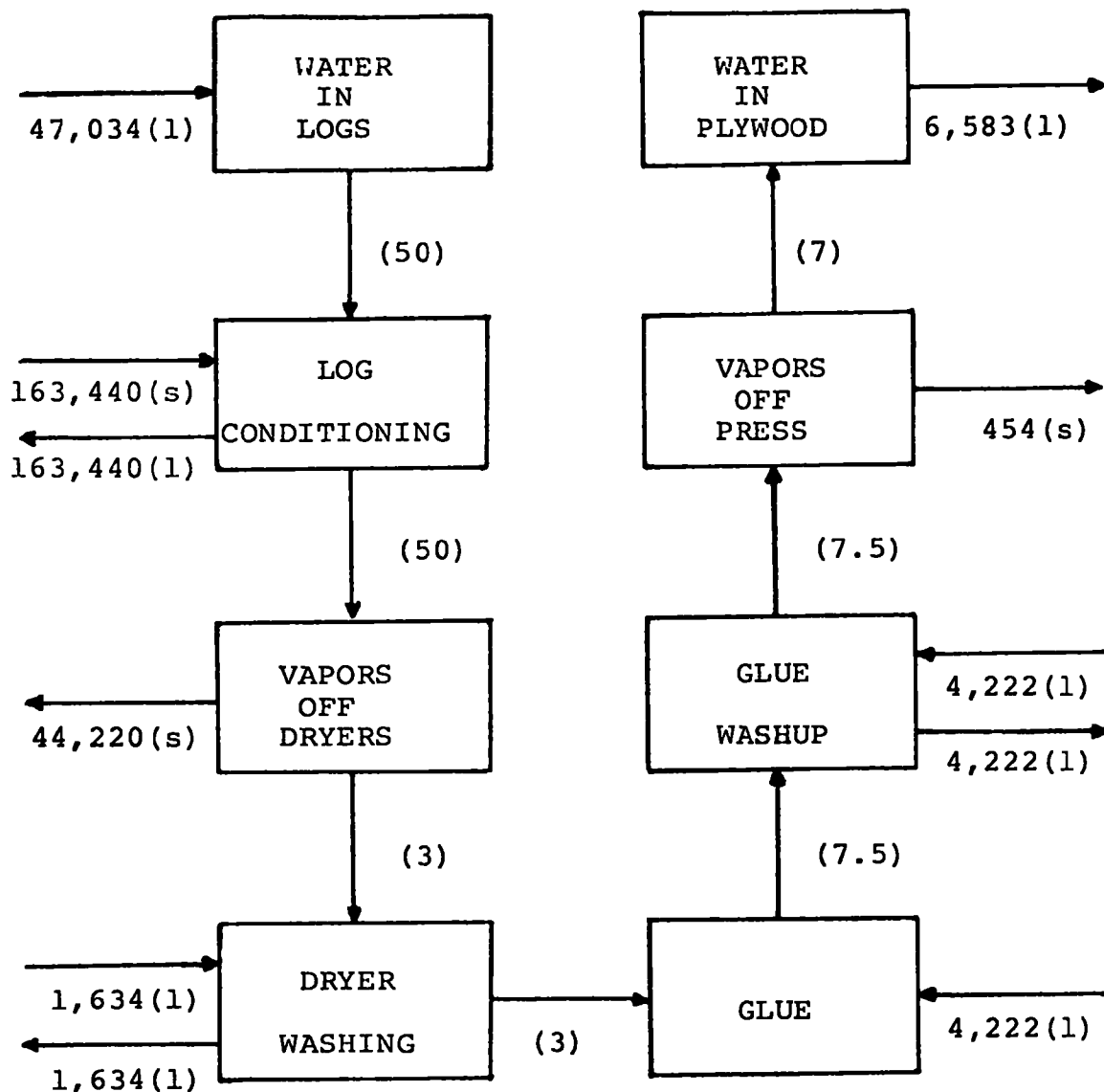
AMOUNT OF ADHESIVE WASHWATER GENERATED IN SOUTHERN PINE PLYWOOD PLANTS (19)

Plywood Plant Production (million sq. meters/year) 9.53mm basis	Weekly Adhesive Use	Amount of Washwater Produced (liters)				Amount of Adhesive per week
		Glue Mixers	Glue Hold Tanks	Glue Spreaders	Total	
2.7	38,590	9,286	948	6,633	16,866	7,364
3.6	51,454	9,286	1,895	13,265	24,446	9,820
4.5	64,316	9,286	1,895	13,265	24,446	2,276
5.4	77,180	11,939	1,895	13,265	27,099	14,732
6.3	90,044	23,877	1,895	19,898	45,670	17,188
7.2	102,906	23,877	2,843	19,898	45,670	19,640
8.1	115,770	23,877	2,843	26,530	53,250	22,096
9.0	128,634	23,877	2,843	26,530	53,250	24,552

TABLE 23-E

GLUE WASTE DISCHARGE MEASUREMENTS

Plant	Days Measured	Average Discharge for Days Measured (l/sec)	1966 Production (sq.M - 9.53mm basis)	Number of Spreaders
1	212	0.814	9,000,000	4
2	49	1.54	12,150,000	3
3	42	1.13	9,000,000	4
4	42	3.36	6,300,000	2



(1) - liquid water
 (2) - steam
 (XX) - % of moisture by weight
 based on dry wood

Water in = 485,800
Water out = 485,800

All units in $\frac{\text{Kg of water per Day}}{(\text{lb. of water per Day})}$

FIGURE 15 - WATER BALANCE FOR A PLYWOOD MILL PRODUCING
 9.3 MILLION SQUARE METERS PER YEAR
 ON A 9.53mm BASIS

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be producing plywood equivalent to 93,980 kilograms (207,000 pounds) per day or 95 metric tons (104 tons) per day on a dry wood basis.

Water Gains

Water gains from a typical mill include water from the logs and glue from various freshwater intakes that are used throughout the process without the water becoming incorporated into the wood.

The moisture content of incoming logs varies according to species. For the purpose of these calculations, 50 percent moisture is assumed. Water from incoming logs is thus 47,000 kilograms per day or 500 kilograms per metric ton (1,000 pounds per ton). The amount of water that is applied to plywood glue is estimated to be 4,200 kilograms per day or 43 kilograms per metric ton (85 pounds per ton) of dry plywood.

The freshwater sources of water vary with operation. Based on data previously given, the following quantities can be estimated: about 163,000 kilograms (360,000 pounds) per day or 1,750 kilograms per metric ton (3,500 pounds per ton) of steam is used in log conditioning; about 1,620 kilograms (3,570 pounds) per day or 17.5 kilograms per metric ton (35 pounds per ton) of water is used to wash veneer dryers; and about 4,200 kilograms (9,300 pounds) per day or 45 kilograms per metric ton (90 pounds per ton) of water is used to wash the glue system.

Water Losses

Water losses from a typical mill include the water in the finished plywood, vapor losses from the pressing, and spent water from log conditioning and washing operations.

The amount of water that is in the finished plywood can be calculated to be 6,600 kilograms per day (14,500 pounds per day or 140 pounds per ton) based on a seven percent moisture content.

Vapor losses occur in the dryers and in the press. Based on three percent moisture content in dried veneer, approximately 44,000 kilograms per day (97,400 pounds per day or 940 pounds per ton) of steam must be released. Similar calculations indicate a steam discharge of 450 kilograms per day (1,000 pounds per day or 10 pounds per ton) from the press.

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Wastewater discharged from log conditioning equals the amount of steam applied, if coils are not used. This would be equivalent to a discharge of 163,000 kilograms per day (360,000 pounds per day or 3,500 pounds per ton).

Wastewater discharges from the washing operations are equal to the respective water usage. Dryer wash water is approximately 163,000 kilograms per day (3,600 pounds per day or 35 pounds per ton), and glue wash water is approximately 4,200 kilograms per day (9,300 pounds per day or 90 pounds per ton).

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PART B: HARDBOARD

DRY PROCESS HARDBOARD

Specific Water Uses

There are several processes in the dry process hardboard industry where water might be used. However, due to a wide variety of raw material handling techniques and inplant processes and housekeeping practices, no single dry process hardboard mill uses water in all of the following processes:

- Log Washing
- Chip Washing
- Resin System
- Caul Washing
- Housekeeping
- Humidification
- Fire Fighting
- Cooling

The quantity of water utilized in any dry process hardboard mill depends upon water uses in raw material handling and inplant processes, recycle system utilized, housekeeping practices, and many other factors. Table 24 shows wastewater flows from 11 of the 16 existing dry process hardboard mills. The quantity of process water utilized in a typical mill would be approximately 18,925 liters (5,000 gallons) per day. Most of this water is either evaporated in the press or becomes a part of the final product. A typical wastewater flow from a dry process mill should be less than 1,900 liters (500 gallons) per day. Cooling water usage varies widely from mill to mill but rarely exceeds 280,000 liters (75,000 gallons) per day. Therefore, it can be seen that the water usage in a dry process hardboard mill is exceedingly low and wastewater discharges minimal.

Log Washing

Log washing is practiced by a minority of mills and not necessarily on a continuous basis. Log washing is used to remove dirt and sand from the log surface, the quantity of which varies according to harvesting and storage techniques. Weather conditions are a factor in the need for log washing as wet conditions may cause excessive quantities of mud to adhere to the logs when harvested. Since mills store both whole logs and

TABLE 24
WASTEWATER FLOW AND SOURCE

MILL	LOG WASH	CHIP WASH	RESIN* WASH	CAUL* WASH	HOUSEKEEPING*	COOLING WATER	HUMIDIFICATION
A	0	0	0	0	20,000	320,000	0
B	0	0	0	570	380	81,650	11,340
C	0	0	38	110	0	227,000	0
D**	YES	0	0	300	YES	YES	0
E	81,650	0	0	0	—	YES	0
F	0	0	0	380	0	—	0
G	0	0	5,670	0	0	189,000	0
H	0	0	3	750	0	125,000	0
I	0	0	0	0	0	160,650	0
J**	0	0	570	0	0	283,500	0
K	0	0	0	0	—	0†	0

Note - All flows given in liters per day
 * Actual Intermittant Flow Averaged Daily
 ** Total Waste Contained on Site
 † Cooling Water Used for Boiler Makeup

chips on site and the ratios of logs purchased as compared with chips vary, the quantity of water utilized will vary accordingly. Fresh water can be utilized for log washing. Cooling water from the inplant processes may also be used. Quantities of water utilized for log washing can be expected to vary from 400 liters per metric ton (100 gallons per ton) to 1,250 liters per metric ton (less than 300 gallons per ton) (8). Typical chemical analyses would include a BOD of 200 mg/l and a suspended solids of 500 mg/l.

Chip Washing

The purpose of chip washing is similar to that of washing logs. Chips that are brought in from outside sources can contain dirt and sand which cause excessive equipment wear. Chip washing serves not only to remove this unwanted matter, but also gives the chips a uniform moisture content and, in northern climates, helps thaw frozen chips. There were no dry process hardboard mills reporting the use of chip washing, but the trend is toward mills having to wash chips. As prime sources of fiber become increasingly scarce such as from whole logs, the future trend is toward whole tree utilization. This means that whole trees, or just limbs and branches, would be chipped in the forest and shipped to the mill. Due to the increased extraneous material, chip washing will become a necessity.

Fresh water may be used for chip washing or cooling water from inplant equipment might also be used. As there are presently no chip washing systems reportedly in use, there are no water usage figures or waste characteristics available in the dry process hardboard industry.

Resin System

Water is used to make up the resins which are added as binders for hardboard. The water used for making resin is not a wastewater but becomes part of the hardboard as it is evaporated in the press. Some mills claim it is necessary to clean the resin system, and available data, as shown in Table 24, indicates that there is no standard procedure for cleanup as water usage varies widely.

There are two types of resins used in the hardboard industry, phenolic formaldehyde and urea formaldehyde. These resins are essentially the same as those utilized in the plywood industry where most mills have already gone to a completely closed resin system. Table 25 shows typical chemical analysis of plywood glue.

TABLE 25 (10)

AVERAGE CHEMICAL ANALYSIS OF PLYWOOD RESIN

Analysis and Units	Phenolic Resin (a)	Urea Resin (b)
COD, mg/kg	653,000	421,000
BOD, mg/kg	--	195,000
TOC, mg/kg	176,000	90,000
Total Phosphate, mg/kg as P	120	756
Total Kjeldahl Nitrogen, mg/kg as N	1,200	21,300
Phenols, µg/kg	514,000	
Suspended Solids, mg/kg	92,000	346,000
Dissolved Solids, mg/kg	305,000	204,000
Total Solids, mg/kg	397,000	550,000
Total Volatile Suspended Solids, mg/kg	84,000	346,000
Total Volatile Solids, mg/kg	172,000	550,000

(a) Borden's Cascophen 31 which is similar to Borden's Cascophen 382

(b) Borden's Casco Resin 5H

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The chemical analysis of resin washwater will be those concentrations shown in Table 25 diluted by a factor depending upon the quantity of water used for wash up. Several hardboard mills are presently recycling this wash water as resin makeup water or simply do not wash at all, therefore, they have no discharge. Due to the small quantity of water and ease of reuse, there should be no discharge from the resin system in any hardboard mill.

Caul and Press Plate Wash Water

Another minor water usage and wastewater source for some mills is for caul and press plate wash water. After a period of use, cauls and press plates acquire a buildup of resin and organics on their surfaces. This results in sticking in the presses and blemishes on the hardboard surface. The cauls or press plates must then be cleaned to remove this buildup. The cleaning operation consists of submerging the cauls in a caustic cleaning solution for a period of time to loosen the organic matter. Press plates are also cleaned with a caustic solution in place. After soaking, cauls are removed, rinsed with fresh water, then put back in use. The tanks used for soaking the cauls are emptied as needed, normally only a few times each year. The soaking water and rinse water used in a typical dry process hardboard mill ranges from 380 to 950 liters (100 to 250 gallons) per day or approximately 4 liters per metric ton (1.0 gallons per ton) of hardboard production.

Miscellaneous Housekeeping Water

Water may be used in small quantities for various cleaning procedures. The frequency and quantity of water used for cleaning purposes is highly variable as there are generally no scheduled cleanup procedures. Information gathered from several dry process hardboard mills indicates that this water usage can be expected to range from zero to less than 1,500 liters (400 gallons) per day in a typical mill. This source of wastewater is of such a minor volume that it can easily be disposed of onsite. Several mills utilize no water for cleaning as all house cleaning is done by sweeping and vacuum cleaning.

Humidification

All dry process hardboard mills humidify their board after pressing. This consists simply of passing the boards through a room with a high humidity and temperature to bring the moisture content to a more stable level. Approximately 45 liters

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(12 gallons) of water per ton of product are used for this purpose. Most mills report no wastewater discharge from this process.

Fire Water

A major problem with the dry process for manufacturing hardboard is the problem of fires. The inside of a dry process hardboard mill can easily become coated with dry fibers and an electrical spark or excessively hot press or other piece of equipment can easily start a fire. More frequently, a fire starts in a refiner and quickly spreads through the fiber conveying system. Mills have elaborate fire fighting systems which use large quantities of water to put fires out quickly. Fires are certainly not scheduled and their frequency varies from mill to mill. Depending upon the duration and extent of the fire, the water used to control a fire will vary accordingly. Fire water should not be considered as a continuous wastewater flow because a typical mill will have a fire only a few times each year.

Cooling Water

The largest water usage in a dry process hardboard mill is for cooling water. This water is used for cooling various inplant equipment such as refiners and air compressors, and is normally not changed in quality except for the addition of heat. Although this usage is the largest volume used in a dry process hardboard mill, it is relatively small when compared with other industries. The volume of cooling water varies widely from mill to mill depending upon temperature of freshwater source and the equipment within a mill. Cooling water can be expected to range from 18,900 to 280,000 liters (5,000 to 75,000 gallons) per day with a typical mill utilizing 190,000 liters (50,000 gallons) per day. There is a potential for cooling water to become contaminated with lubricating oil and in this event the oil must be removed before the cooling water is discharged.

Scrubber Water

Air pollution from dry process hardboard mills is a major concern. One method of air pollution control is the use of wet scrubbers. Although only two hardboard mills report using a wet scrubber, the future trend is toward the use of wet scrubbers in many dry process hardboard mills. The water usage for wet scrubbing in a dry process hardboard mill will vary depending on the individual scrubber design. Since there are only

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two wet scrubbers in operation, representative data for the industry is unavailable. One of the mills using a wet scrubber reportedly achieves zero discharge by settling and filtering the scrubber water before recycle. In fact, there is need for water makeup.

Mass Water Balance in a Dry Process Hardboard Mill

An account of water gains and losses in a typical dry process hardboard mill is given in this section. A schematic diagram of the water balance (net gains and losses) for a typical dry process hardboard mill is shown in Figure 16. Water gains or losses are shown as liters of water per metric ton of dry product produced in a typical 225 metric ton per day mill.

Water Gains. Water gains in a typical dry process hardboard mill result from incoming raw materials and fresh water intake. Incoming wood normally has approximately 50 percent moisture which represents 100 percent of the final product weight.

Water from incoming wood = 1,000 liters per metric ton
(50 percent moisture) (240 gallons per ton)

The water usage within a dry process hardboard mill is highly variable depending upon water usage within an individual process and plant operation. A typical dry process mill uses water only for glue preparation, caul wash, humidification and cooling.

Water in glue = 35 liters per metric ton of
(3.5 percent of product) product (8.4 gallons per ton)

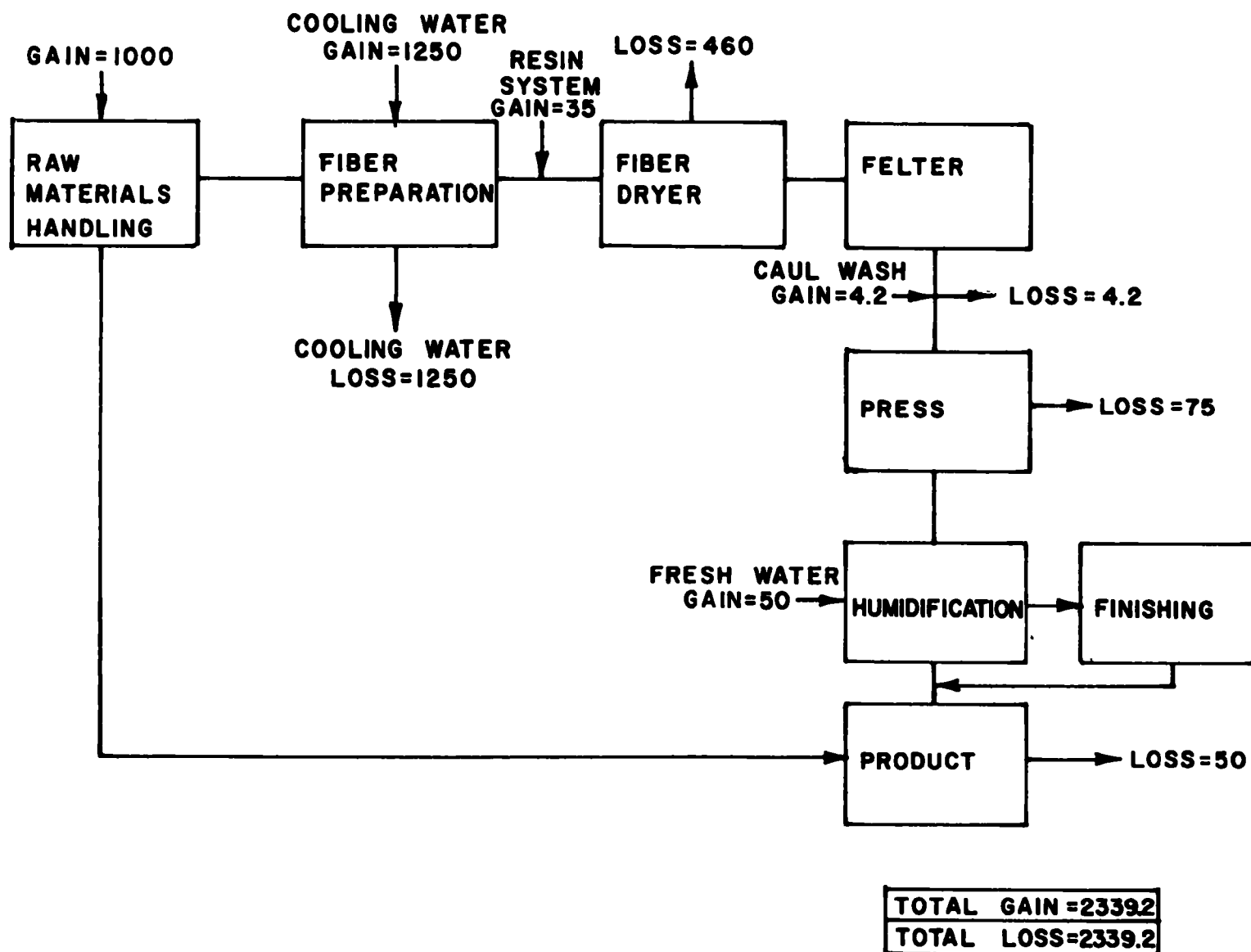
Caul wash (950 liters per day) = 4.2 liters per metric ton of
(250 gallons) product (1 gallon per ton)

Humidification (5.0 percent of product) = 50 liters per metric ton of product (12 gallons per ton)

Cooling water (284,000 liters = 1,250 liters per ton of
per day) product (300 gallons per
(75,000 gallons) ton)

Water Losses . Water losses in a dry process hardboard mill result from:

Fiber drying to 7.5 percent moisture = 960 liters per metric ton of product (230.4 gallons per ton)



* GAINS AND LOSSES SHOWN IN LITERS/TON DRY PRODUCT

FIGURE 16 - WATER BALANCE FOR TYPICAL DRY PROCESS HARDBOARD MILL*

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Press evaporation = 75 liters per metric ton of product
(0.0 percent moisture) (18 gallons per ton)

Water in product
(5.0 percent moisture) = 50 liters per metric ton of product
(12 gallons per ton)

Caul wash (950 liters per day) = 4.2 liters per metric ton
(250 gallons) (1.0 gallons)

Cooling water = 1,250 liters per metric ton of pro-
(284,000 liters per day) duct (300 gallons per day)

WET PROCESS HARDBOARD

Specific Water Uses

There are several processes in the wet process hardboard industry where water is used. Wet process mills have similar overall water uses and wastewater sources, however, due to variations from mill to mill there will be variations in water use in the following processes:

- Raw Materials Handling
- Fiber Preparation
- Mat Formation and Pressing
- Finishing
- Miscellaneous

Raw Materials Handling

There are two potential sources of water usage and waste discharge in the raw materials handling process; 1) log washing, 2) chip washing (see Figure 17 for schematic diagram of the raw materials handling processes).

Log Washing. Log washing is practiced by a minority of mills and not necessarily on a continuous basis. Log washing is used to remove dirt and sand from the log surface, the quantity of which varies according to harvesting and storage techniques. Weather conditions are a factor in the need for log washing as wet conditions may cause excessive quantities of mud to adhere to the logs when harvested. Since mills store both whole logs and chips on site and the ratios of logs purchased as compared with chips vary, the quantity of water utilized will vary accordingly. Fresh water can be utilized for log washing; or cooling water from the inplant processes

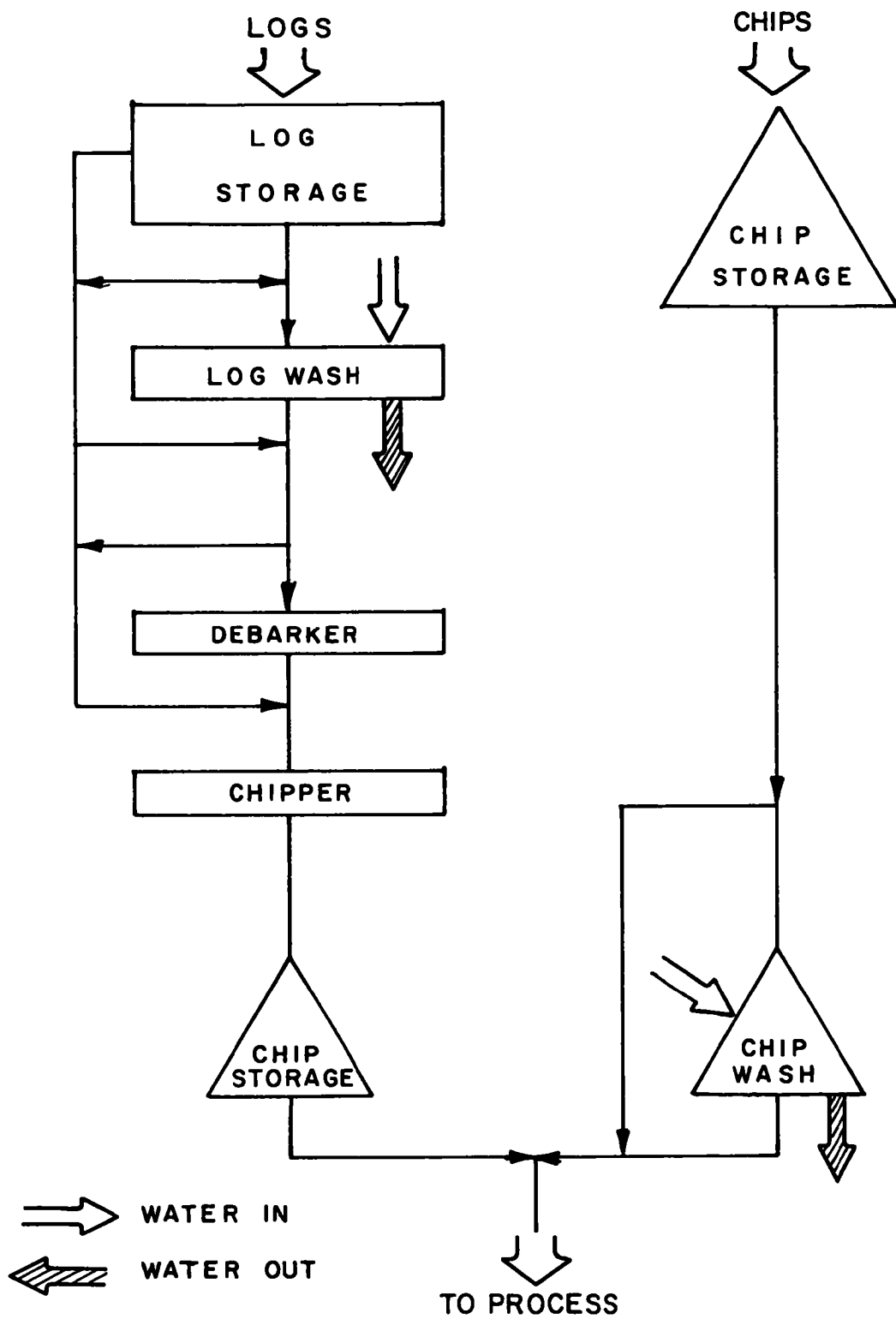


FIGURE 17 - WATER USAGE IN RAW MATERIALS HANDLING
IN THE HARDBOARD INDUSTRY

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may also be used. Quantities of water utilized for log washing can be expected to vary from 417 liters per ton (100 gallons per ton) to less than 1,250 liters per ton (300 gallons per ton) (8). Typical chemical analyses would include a BOD of 200 mg/l and a suspended solids of 500 mg/l.

Chip Washing. The purpose of chip washing is similar to that of washing logs. Chips that are brought in from outside sources can contain dirt and sand which cause excessive equipment wear. Chip washing serves not only to remove this unwanted matter, but also gives the chips a uniform moisture content and, in northern climates, helps thaw frozen chips. There is only one wet process hardboard mill reportedly using chip washing, but the trend is toward mills having to wash chips. As prime sources of fiber become increasingly scarce such as from whole logs, the future trend is toward whole tree utilization. This means that whole trees, or just limbs and branches, would be chipped in the forest and shipped to the mills. Due to the increased extraneous material, chip washing will become a necessity.

Fresh water may be used for chip washing; and cooling water from inplant equipment might also be used. There is presently only one chip washing system reportedly in use with a water usage of approximately 330 liters per ton (96 gallons per ton).

Fiber Preparation

As previously discussed, there are two principal fiber preparation processes: 1) thermal plus mechanical refining, and 2) the explosion process. Figure 13 (Section IV) shows a schematic diagram of a typical wet process hardboard mill where thermal plus mechanical refining is used for fiber preparation. All but two wet process mills utilize some variation of this process. Two mills owned by the Masonite Corporation utilize the explosion process as shown in Figure 18.

The actual water used in fiber preparation in the wet process is relatively small as compared to overall water use in a wet process mill. In general, the only water used in fiber preparation is the addition of steam into the cooker. This quantity of steam can be expected to equal one half the weight of dry chips processed or approximately 0.5 cubic meters per 1.0 ton (120 gallons per short ton).

The principal reason for significant wastewater flows and concentrations from the wet process as compared with the dry

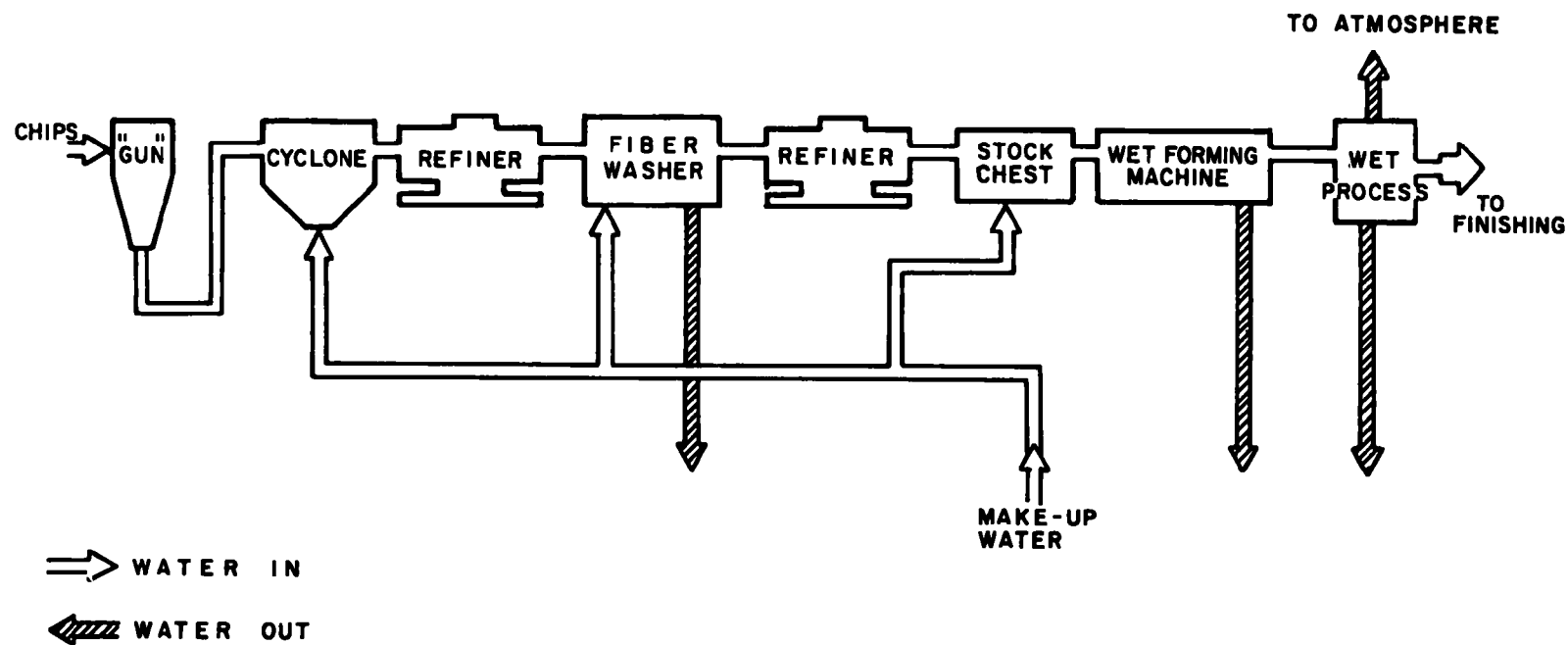


FIGURE 18 - WATER USE IN THE EXPLOSION PROCESS

process is the fact that the fiber is diluted from approximately 40 percent consistency to 1.5 percent consistency with significant quantities of water prior to forming on a wet felting machine. There are limitations on the concentrations of organics in the process water which means that most of the soluble organics released into solution during fiber preparation must be disposed of in some manner (usually discharged as wastewater) as only a portion of the solubles may be retained in the hard-board. In the dry process all solubles released during fiber preparation are retained in the board.

The interrelation between fiber preparation processes, variations of cooking time, and temperature and wood chemistry on wastewater discharge is extremely important. The following information was derived from a number of sources, the most important of which are reference numbers (7) and (17). Wood is exceedingly difficult to define chemically because it is a complex heterogeneous product of nature made up of interpenetrating components, largely of high molecular weight. The principal components generally are classified as cellulose, lignin, hemicellulose, and solvent-soluble substances (extractives). The amounts present are in the range of 40 to 50 percent, 15 to 35 percent, 20 to 35 percent, and 3 to 10 percent, respectively.

The yield, composition, purity, and extent of degradation of these isolated components depend on the exact conditions of the empirical procedures employed for their isolation. By far the most important factor relative to the values obtained in chemical analysis for wood components is the tree species. The variation in chemical composition of wood greatly influences the quantities and kinds of chemicals released during fiber preparation.

At normal temperatures wood has remarkable resistance to degradation by chemicals and solvents. This may be attributed to the interpenetrating network structure of wood comprised of polymers with widely differing properties. Also, the high crystallinity of the carbohydrate system reduces the accessibility of the wood components to reagents.

Water at room temperature has little chemical effect on wood, but as temperature rises and pH decreases because of the splitting off of acetyl groups, wood becomes subject to rapid acid hydrolysis with the dissolution of carbohydrate material and some lignin. At temperatures above 140°C considerable and rapid removal of hemicelluloses occurs. Fortunately, cellulose resists hydrolysis better than the hemicellulose fractions.

The thermal and explosion pulping processes such as the Asplund and Masonite processes make use of the effect of water on wood at high temperatures to prepare fiber for mechanical refining prior to being pressed into hardboard. The high temperatures soften the lignin-hemicellulose matrix to permit the separation of fibers with reduced power cost and fiber damage. Also, carbohydrate and lignin degradation products and the lignin softened by high temperatures facilitate bonding of the fibrous structure upon drying of the board.

Cooking wood with steam at temperatures of about 180°C causes a rapid loss in weight. Part of the loss is due to thermal decomposition and simple solution, but the acids released by the wood hydrolyze appreciable amounts of carbohydrates as well. In commercial operations, yields of pulp fall to between 75 and 90 percent, therefore, potential wastewater problems increase significantly. Wood species high in water-solubles will obviously give lower yields of pulp.

In the well-known explosion process wood chips are exposed to high-pressure steam in a "gun" or small digester fitted with a quick-opening valve that allows the chips to disintegrate when the pressure is abruptly released. In the gun the chips are steamed at 41.8 ATM (600 psi) for 1 minute, and the pressure is then increased to 69 ATM (1,000 psi) for an additional 5 seconds before the valve is opened. Differences in wood species, condition, and size of chips modify the cycle. The high temperature, high pressure treatment does not remove the lignin but makes it sufficiently plastic for the chips to burst apart on release. Hemicellulose is hydrolyzed, becoming pentose sugars, some of which are dehydrated and polymerized to form furfural resins as a result of the steaming and the subsequent high-temperature pressing and tempering involved in manufacturing boards. This process causes the release of significant quantities of organics which must be disposed of as a waste stream.

Another representative and more commonly used process uses a screw press to force compressed chips into one end of a horizontal stainless-steel tube, typically 3 meters (10 feet) long and 1 meter (3 feet) in diameter, which the chips traverse in about 30 seconds while exposed to steam at 182°C and 12.9 ATM (175 psi). At the far end they are fiberized in a single-rotating-disk mill while still hot and under pressure. From the disk mill the pulp is discharged to a cyclone, from which it goes to a surge bin followed by a second refiner for further processing. Other types of continuous or quick-cycle digesters may be substituted and give similar results. Due to the lower temperatures and

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pressures the quantity of released organics is considerably less than in the explosion process, resulting in less potential waste.

The yield, chemical composition, and physical properties of the pulps prepared by any method are dependent upon two sets of variables, i.e.:

Variables associated with the wood,

1. Species
2. Density
3. Growth factors
4. Moisture content
5. Length of storage
6. Particle size

Variables associated with the fiber preparation system,

7. Concentration of pH or liquor (water solution)
8. Temperature of digestion
9. Time of digestion

The dissolution of the wood substances takes place mainly during pre-heating and defibration process and is closely related to the kind of raw material used. It is also a function of the pre-heating temperature and the pre-heating time used.

It is rather difficult to make determinations of the yield of pulp from wood as a function of the pre-heating conditions as, in general, the pre-heating periods used in practice are fairly short in comparison to the time it takes for the chips to reach the final temperature in the pre-heater. Some attempts have been made, however, and in Figure 19 a graph for beechwood is shown, where the pre-heating period was extended to 16 minutes. These determinations were made with water as "cooking liquor," and it is clearly shown that the dissolution proceeds much faster as the pre-heating temperature is increased (21).

During the pre-heating mainly two reactions take place. One of them is the hydrolysis of hemicellulose molecules, whereby oligosaccharides are formed. These short-chain molecules are small enough to dissolve in water. The other reaction is the hydrolysis of acetyl groups, whereby acetic acid is formed, causing an increase in the hydrogen ion concentration in the raw material. The higher acidity causes the hydrolytic reactions to proceed still faster. Thus the reactions can be said to be autocatalytic. For that reason it is very difficult to calculate rates of

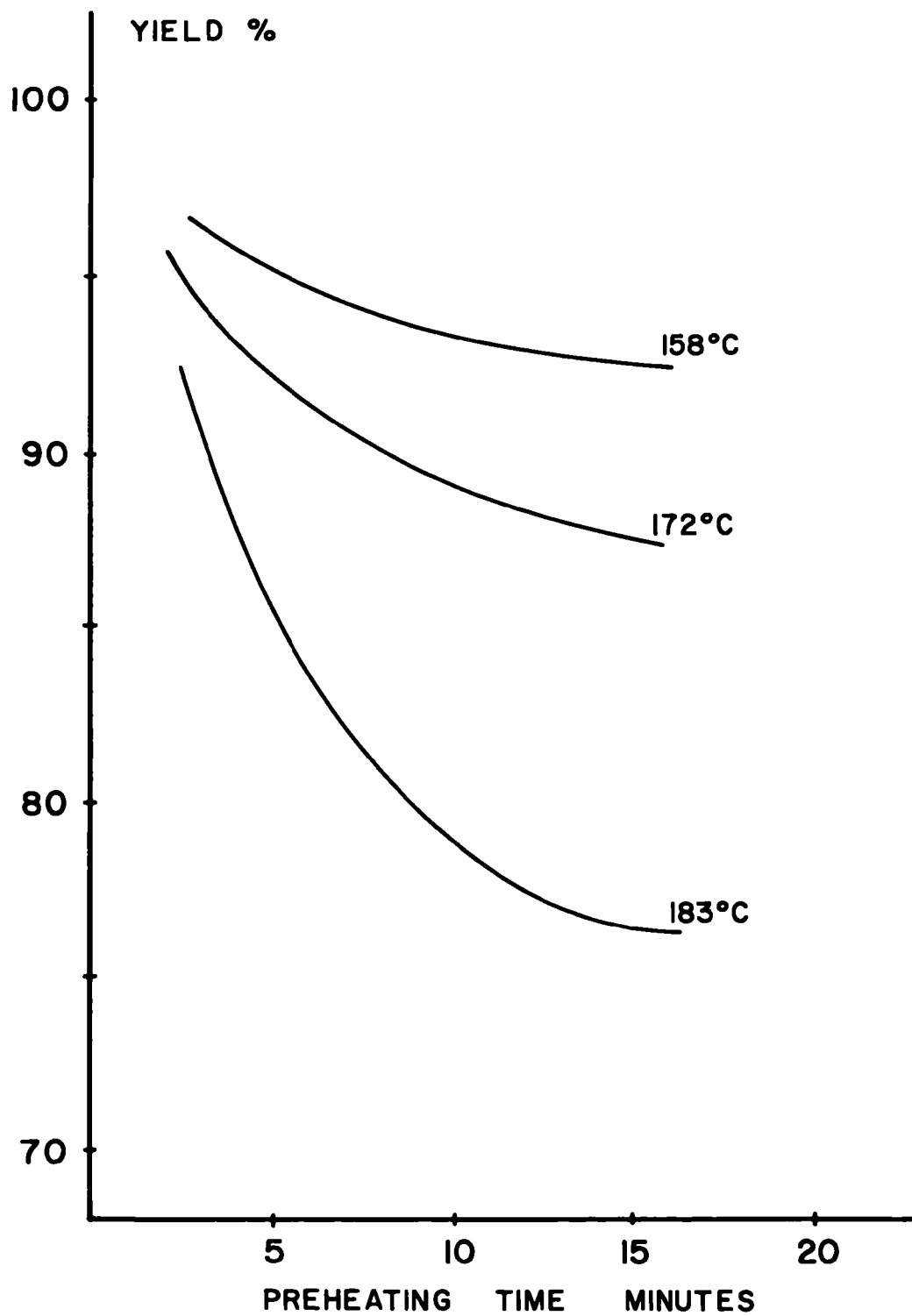


FIGURE 19 (21) - EFFECT OF PREHEATING TIME AND TEMPERATURE ON YIELD

reaction for the dissolution of wood substances during the pre-heating stage. As a rough estimation, however, the rate of reaction seems to double with an increase in temperature of about 8°C (50°F), which is normal for most chemical reactions (21).

So far no exhaustive investigations seem to have been made on the composition of the substances dissolved during the pre-heating and defibration steps. An examination of the composition of the substances dissolved in the Masonite process was made by Edhborg some fifteen years ago. The temperature in the Asplund-Defibrator process is normally about 180°C and the pre-heating time is usually from one up to a few minutes. The temperature in the explosion process, on the other hand, is increased to between 250 and 300°C, even if it is only for a few seconds. This leads to larger amounts of substances being dissolved in the latter process and also to more acidic conditions-- a pH value of about 3 was obtained in an extract from an explosion pulp whereas the pH values in extracts from defibrator pulps are usually close to 4. The acidity depends partly on volatile acids like acetic and formic acid and partly on non-volatile ones, among which uronic acid is the most frequent (21).

The investigation on dissolved substances in the explosion process was based on coniferous wood as raw material. The dissolved substances in this case consisted of about 70 percent carbohydrates, 10 percent lignin - partly modified - and 20 percent "organic resins." The carbohydrates consisted of 35 percent pentosans - mostly xylans - and 65 percent hexosans (21).

Corresponding investigations on dissolved substances in the Asplund-Defibrator process were made with beech as raw material. In this case 75 percent of the dissolved substances were carbohydrates and a few percent were lignin type substances. In addition about 10 percent acetic acid - partly free and partly bound as acetyl groups - were found. In this case about 80 percent of the carbohydrates were pentosans-- mainly xylans-- and 20 percent hexosans.

Tables 13 and 26 relate properties and composition of many common woods used in this country, and Figure 20 indicates the effects various treatments have on these components. Figure 21 depicts a general relationship of lignin dissolution versus percent of wood dissolved.

TABLE 26 (7)

ANALYSES OF SOME COMMON SPECIES OF WOOD
(Extractive-free basis, percent of dry wood)

Constituent	Douglas fir	Loblolly pine	Black spruce	Southern red oak
Ash	0.3	0.3	0.4	0.2
Acetyl	0.6	1.1	1.1	3.3
Lignin	28.4	29.5	28.0	25.2
Summation A				
α -Cellulose	57.2	55.0	51.5	45.7
Hemicellulose	14.1	15.3	17.4	23.3
Total ^a	<u>100.6</u>	<u>101.2</u>	<u>98.4</u>	<u>97.7</u>
Summation B				
α -Cellulose ^b	48.3	46.6	45.6	43.7
Mannan ^c	5.4	4.7	8.0	--
Xylan	6.2	10.1	10.5	20.0
Uronic anhydride	2.8	3.8	4.1	4.5
CH ₂ ^d	0	0.2	0.2	0.6
Total ^a	<u>92.0</u>	<u>96.3</u>	<u>97.9</u>	<u>97.5</u>

^aIncluding ash, acetyl, and lignin.

^bCorrected for mannan, xylan, and uronic anhydride.

^cBy the phenylhydrazine method; the figures are probably low.

^dCalculated from methoxyl not in lignin.

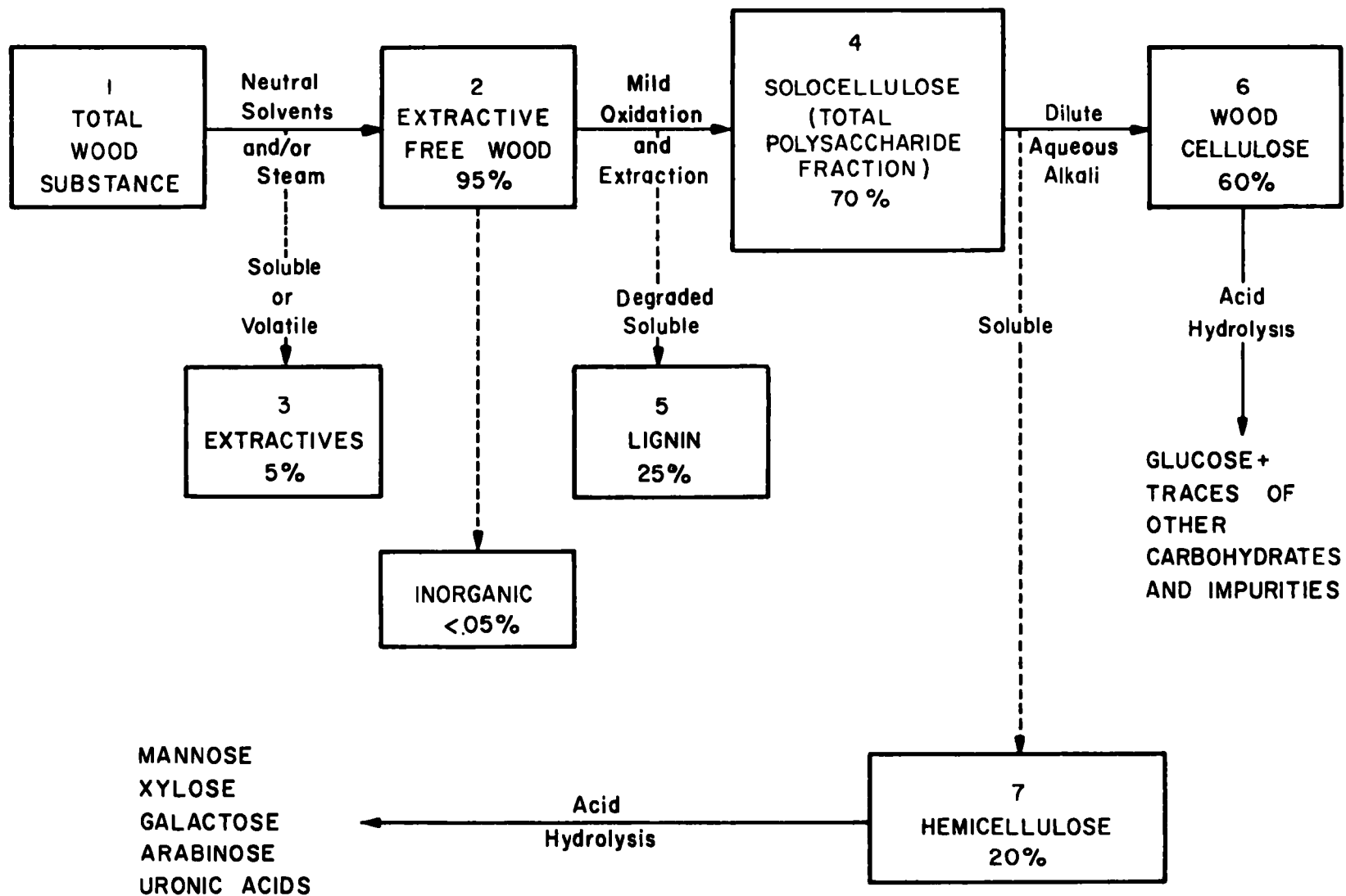


FIGURE 20 (7) - THE CHEMICAL COMPONENTS OF WOOD

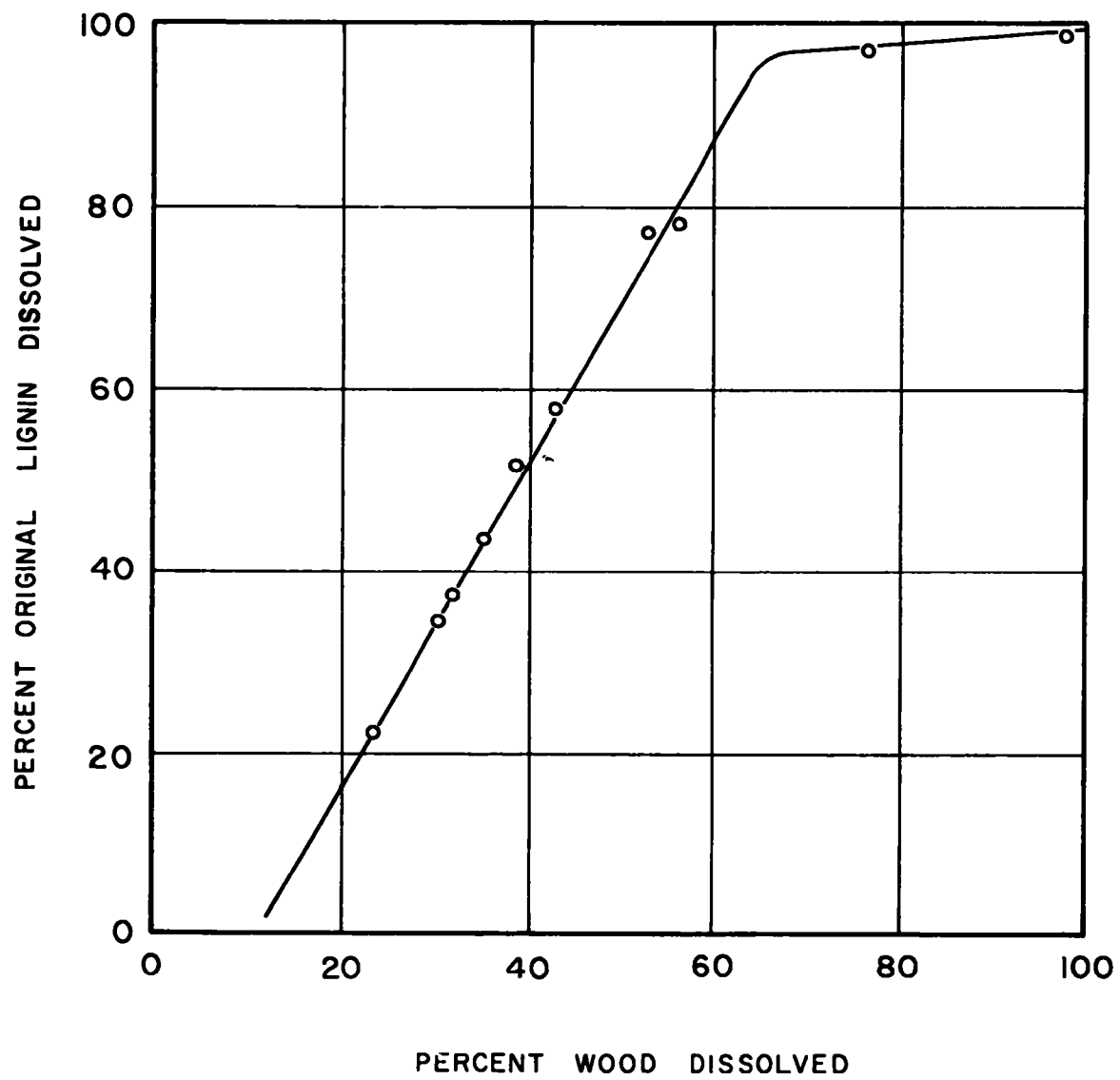


FIGURE 21 (7) - RELATION BETWEEN DISSOLVED LIGNINS AND WOOD

Mat Formation and Pressing

Figure 13 shows that from the refiner, fiber is discharged into a cyclone where the fiber is diluted with process water. Figure 22 shows a typical schematic diagram of the process water flow in the wet process. From the refiner, fiber is diluted to approximately 5.0 percent through the cyclone then diluted still further to approximately 1.5 percent fiber in the stock chest.

A mat is then formed on the wet forming machine where the fiber concentration is increased to approximately 35 percent prior to wet pressing. Water removed from the mat formation flows to a process water chest where it is recycled as process water. Water released upon pressing either evaporates to the atmosphere or flows back to the process water chest or is discharged directly as a wastewater. Process water may be recycled until the temperature, soluble organics or suspended solids become too high. Normally, fresh makeup water is added at a constant rate to control these parameters and the overflow is discharged to waste.

In the explosion process considerably more soluble organics are released. All of these plants (two) use recycle process water for fiber washing. Fiber wash water from the explosion process is a major source of wastewater. A waste load from this process alone of 40 kilograms per metric ton (80 pounds per ton) into a flow of 2.5 cubic meters per ton (600 gallons per ton) is reported. Typical wastewater characteristics of this fiber wash are shown below:

BOD = 22,620 mg/l
COD = 51,100 mg/l
TS = 32,000 mg/l
Volume = 2.5 cubic meters per metric ton (600 gallons
per ton)

Because of these high waste concentrations it has been found that it is practical to evaporate this waste stream. The resulting liquor is sold as cattle feed or incinerated (Figure 23). This is the normal procedure in both of the plants that use an explosion process.

Two other wet process mills which use the more conventional cooking processes wash fiber prior to mat formation. These mills do not evaporate this wash water separately as is done by the Masonite mills, but simply discharge it directly to waste.

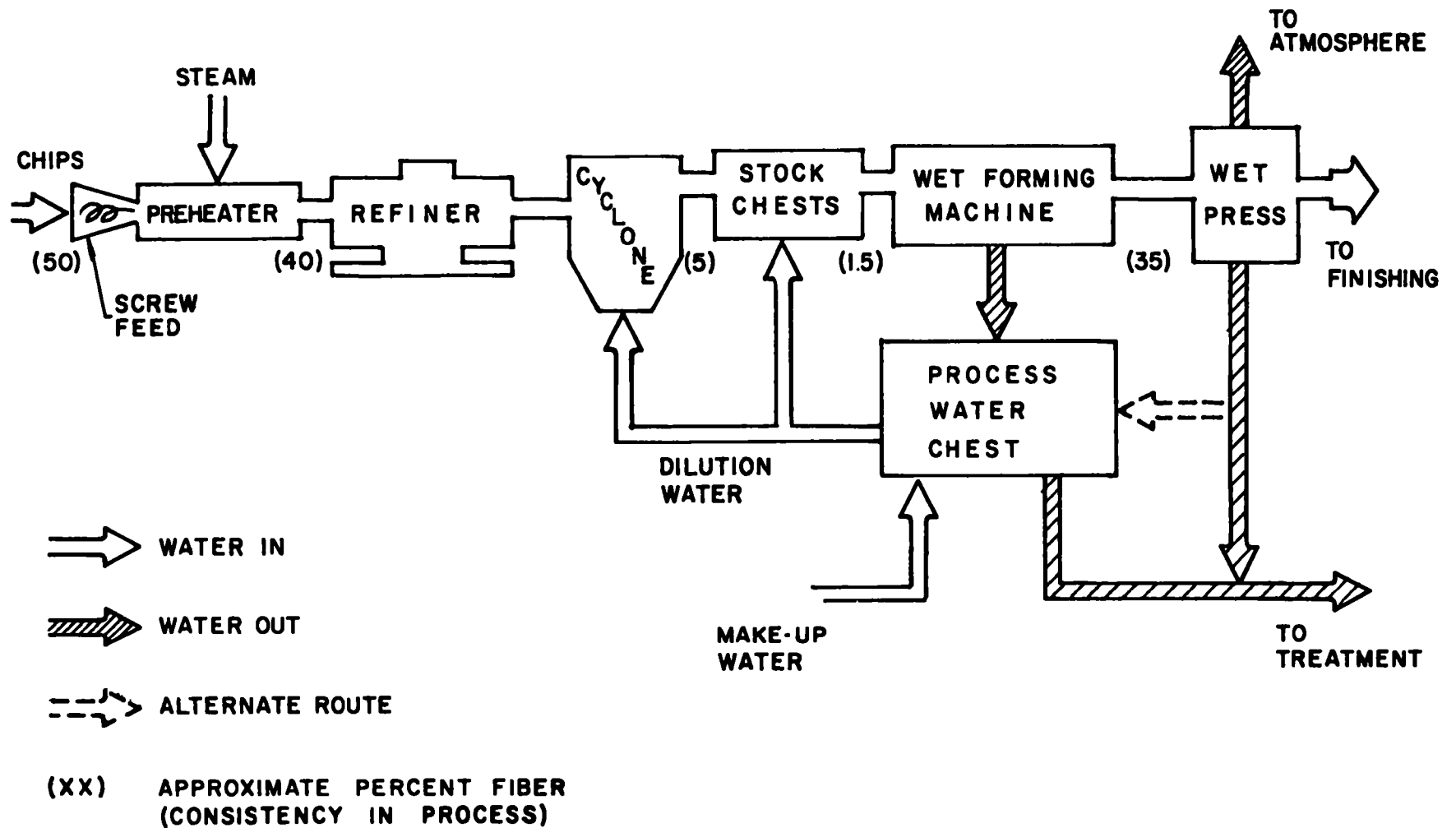


FIGURE 22 - PROCESS WATER RECYCLE IN A TYPICAL WET PROCESS HARDBOARD MILL

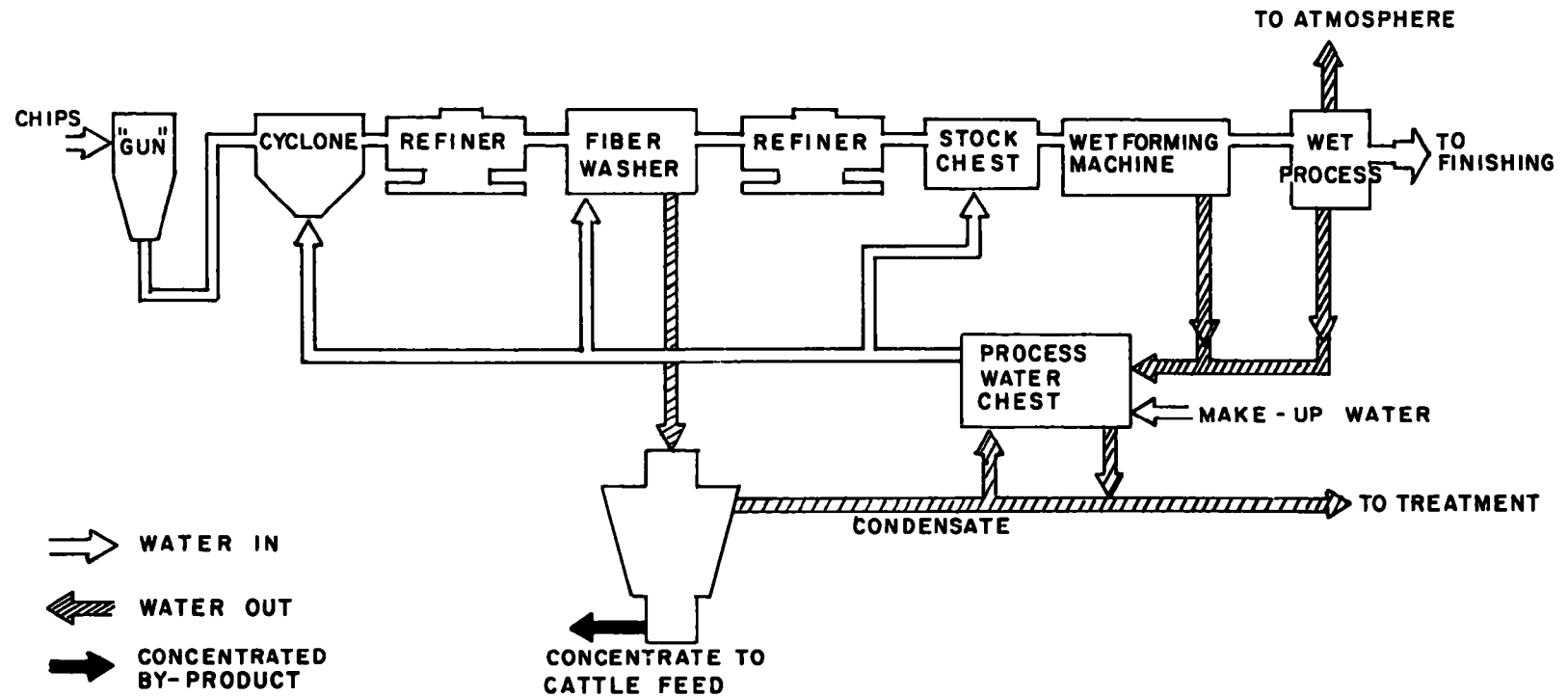


FIGURE 23 - PROCESS WATER RECYCLE IN A HARDBOARD MILL USING THE EXPLOSION PROCESS

The moisture in the chips entering the wet process is approximately 50 percent. Assuming that the mat is formed from a 1.5 percent fiber concentration and that the board coming from the press has a 0.0 percent moisture, and that there is no recycle, approximately 66.8 cubic meters per ton (16,000 gallons per ton) of process water must be disposed of in some form. While a portion of this water will be disposed of as steam, the majority will be discharged as a waste stream. The actual volume discharged is a function of the amount of recycle practiced. There are three principal factors which limit recycling of process water: temperature, suspended solids, and soluble solids.

Usually a process water temperature of a certain minimum is required to avoid excessive use of resin. At lower temperatures the naturally occurring resins in the fiber will set, thereby becoming ineffective for bonding. Furthermore, when the board is formed at low temperature, longer pressing times are required which can significantly reduce production rates. Most hardboard mills operate with a process water temperature between 30°C (100°F) and 63°C (145°F). The more the process system is closed, the higher its temperature becomes. It has been found that as temperatures increase outside of this range, certain corrosion problems are experienced. Furthermore, conditions near forming machines become very humid, making working conditions unpleasant. A certain critical temperature seems to exist after which spots will appear on the board, thereby lowering the aesthetic quality of the board. This critical temperature varies with raw material, process and product produced.

Increased recycling of process water increases the concentration of soluble organics. This increased concentration raises the risk of spot formation on the board and the chance of sticking in the hot press. This is partly due to build-up of volatilized organics on press plates. The critical concentration of soluble organics, above which process problems are encountered, is primarily a function of wood species.

The effect of suspended solids concentrations relates to the dewatering characteristics of the board. It has been reported that as suspended solids concentrations increase with recycling, a certain concentration is reached after which the board will not exhibit proper water drainage during mat formation (22). This can be attributed to a buildup of fines which cause the mat to dewater slowly. As suspended solids become too numerous in the process water they must be removed either by blowing down this highly concentrated water and diluting it with fresh water, or by removing the solids from the process water by some other means.

Miscellaneous Wastewater Sources

By far the major wastewater discharge from a wet process hardboard mill is process water from mat formation, pressing, and fiber washing where used. Other wastewater sources which may be classified as miscellaneous streams include resin system wash water, caul wash water, housekeeping water, and cooling water.

Resin Wash Water. Water is used to make up the resins which are added as binders for hardboard. The water used for making resin is not a wastewater, but is evaporated in the press. Some mills claim it is necessary to clean the glue system; and indications are that there is no standard procedure for cleanup. Several hardboard mills are presently recycling this wash water as resin makeup water or simply are not washing at all, therefore, they have no discharge.

Caul, Press Plate or Screen Wash Water. Another minor water usage and wastewater source is for caul and press plate (screen) wash water. After a period of use cauls and press plates acquire a buildup of resin and organics on their surface. This results in sticking in the presses and blemishes on the hardboard surface. The cauls or press plates must then be cleaned to remove this buildup. The cleaning operation consists of submerging the cauls in a caustic cleaning solution for a period of time to loosen the organic matter. Press plates are also cleaned with a caustic solution in place. The cauls are removed, rinsed with fresh water, then put back in use. The tanks used for soaking the cauls are emptied as needed, normally only a few times each year. The soaking water used may amount to about 4 liters per metric ton (1.0 gallons per ton) of hardboard production. Rinse water volume varies with frequency of washing of cauls or plates (approximately 1.0 gallons per ton).

Water can be used in small quantities for various cleaning procedures. The frequency and quantities of water used for cleaning purposes is highly variable as there are generally no scheduled cleanup procedures. Information gathered indicates that the volume of wastewater from this amounts to less than 8 liters per ton (2.0 gallons per ton) of board.

Total Wastewater Flow

Table 27 is a summary of the total wastewater flow from eight wet process hardboard mills. Table 28 gives a summary of the average wastewater concentrations from these same mills.

TABLE 27
WASTEWATER DISCHARGES FROM WET PROCESS HARDBOARD

Plant	Production metric tons	Wastewater m ³ /day	Wastewater m ³ /metric ton
1	91	4,164	45.9
2	77	2,952	38.2
3	1,356	16,578	12.2
4(+)	136	1,590	11.7
5	82	757	9.3
6	127	908	7.1
7	356	1,628	4.6
8*	327	833	2.6

(+) Chip Wash Included

* Projected Figures

TABLE 28

RAW WASTEWATER CHARACTERISTICS FROM WET PROCESS HARDBOARD

Plant	Discharge Flow		BOD ₅		S.S.		pH
	m ³ /D	m ³ /metric ton	mg/l	kg/metric ton	mg/l	kg/metric ton	
1	4,164	45.9	720	33	220	10	--
2	2,945	38.2	1,130	50	--	--	--
3 ^o *	16,578	12.2	1,800	23	540	6.5	5.0
4	1,589	11.7	3,000	28	1,650	19	4.5
5	757	9.3	3,500	32	430	4	4.4
6*	897	7.1	3,900	28	450	3.21	4.0
7*	1,635	4.6	--	--	--	--	--
8	840	2.6	3,350	8.5	48	0.125	--

* After Primary Treatment

^o Masonite Explosion Process

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Wastewater flows vary from about 4.2 to 45.8 cubic meters per metric ton (1,000 to 11,000 gallons per ton), depending largely upon the amount of process water recycled. BOD concentrations vary from 720 mg/l to 4,000 mg/l and suspended solids from 48 to 1,650 mg/l. A comparison of data reported as raw wastewater concentrations from mill to mill should be done with caution. Several mills report raw wastewater concentrations after primary sedimentation while others do not. These mills utilize primary clarifiers as part of their recycle systems while other mills consider primary clarifiers as part of their waste treatment system. The average discharge of BOD₅ in kilograms per metric ton (pounds per ton) ranges from 8.5 to 50 (17 to 100), while average discharge of suspended solids ranges from 0.13 to 19 kilograms per metric ton (0.25 to 38 pounds per ton).

Other representative analyses of raw wastewater discharged from a typical wet process hardboard mill are shown below:

<u>Parameter</u>	<u>Concentrations</u> <u>mg/l</u>
BOD	1,300 - 4,000
COD	2,600 - 12,000
SS	400 - 1,100
TDS	500 - 4,000
Kjld-N	0.17 - 4.0
PO ₄ -P	0.3 - 3.0
Turbidity	80 - 700
pH	4.0 - 5.0
Phenols	0.7 - 1.0

Water Balance for a Typical Wet Process Hardboard Mill

A schematic diagram of the water balance (net gains and losses) for a typical mill is shown in Figure 24. Water gains or losses are shown as liters of water per metric ton of product produced in a typical 127 metric tons (140 tons) per day mill.

Water Gains. Water gains in a typical wet process hardboard mill result from incoming raw materials and freshwater makeup. Incoming wood has approximately 50 percent moisture content which represents 100 percent of the final product weight.

The volume of miscellaneous housekeeping water, used for such things as floor and caul washing, is highly variable. There is little data as this stream is normally discharged to the treatment system with the process water without monitoring.

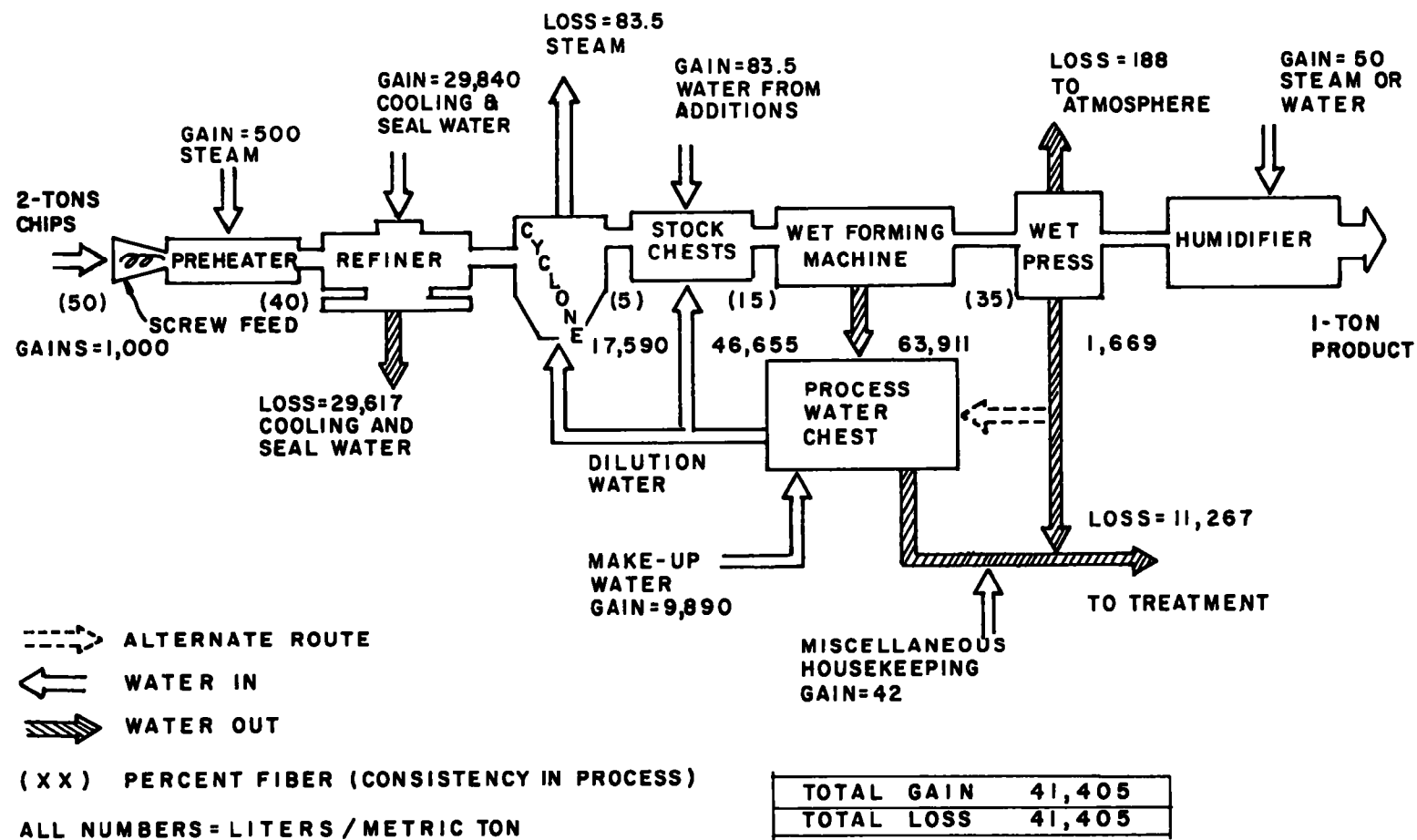


FIGURE 24 - WATER BALANCE FOR A TYPICAL WET-PROCESS HARDBOARD MILL

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Water from incoming chips (50 percent moisture)	=	1,000 liters per ton (240 gallons per ton)
Steam to preheater	=	500 liters per ton (120 gallons per ton)
Cooling and seal water	=	29,840 liters per ton (7,150 gallons per ton)
Additive dilution water	=	83.5 liters per ton (20 gallons per ton)
Process water makeup	=	9,890 liters per ton (2,370 gallons per ton)
Humidifier	=	50 liters per ton (12 gallons per ton)
Miscellaneous housekeeping	=	42 liters per ton (10 gallons per ton)

Total water gain	=	41,405 liters per ton (9,922 gallons per ton)
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Water Losses. Water losses in a wet process mill result from:

Steam off of press	=	188 liters per ton (45 gallons per ton)
Cooling and seal water discharge	=	29,817 liters per ton (7,145 gallons per ton)
Steam from cyclone	=	83.5 liters per ton (20 gallons per ton)

Discharge of excess process water (includes miscellaneous housekeeping water discharge)	=	11,267 liters per ton (2,700 gallons per ton)
---	---	---

Water in product	=	50 liters per ton (12 gallons per ton)
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Total water losses	=	41,405 liters per ton (9,922 gallons per ton)
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PART C: WOOD PRESERVING

WASTEWATERS CONTAINING ENTRAINED OILS

Wastewater characteristics vary with the particular preservative used, the volume of stock that is conditioned prior to treatment, the conditioning method used, and the extent to which effluents from the retorts are diluted with water from other sources. Typically, wastewaters from creosote and pentachlorophenol treatments have high phenolic, COD, and oil contents and may have a turbid appearance that results from emulsified oils. They are always acid in reaction, the pH values usually falling within the range of 4.1 to 6.0. The COD for such wastes frequently exceeds 30,000 mg/liter, most of which is attributable to entrained oils and to wood extractives, principally simple sugars, that are removed from wood during steam conditioning.

Effect of Closed Steaming

The characteristics of wood preserving wastewater are different for plants that practice modified-closed or closed steaming. In the former process steam condensate is allowed to accumulate in the retort during the steaming operation until it covers the heating coils. At that point, direct steaming is stopped and the remaining steam required for the cycle is generated within the retort by utilizing the heating coils. Upon completion of the steaming cycle, the water in the cylinder is discarded after recovery of oils. In closed steaming, the water in the retort at the end of a steaming cycle is returned to a reservoir, after recovery of free oils, and is reused instead of being discarded.

The principal advantage of modified-closed steaming, aside from reducing the volume of waste released by a plant, is that effluents from the retorts are less likely to contain emulsified oils than when open steaming is used. Free oils are readily separated from the wastewater; and as a result of the reduction of the oily content, the oxygen demand and the solids content of the waste are reduced significantly relative to effluents from plants using conventional open steaming. Typical oil and COD values for wastewater from a single plant before and after the plant commenced modified-closed steaming are shown in Figures 25 and 26 (23), respectively. The COD of the wastewater was reduced by about two-thirds when this steaming method was initiated. Oil content was reduced by a factor of ten.

Water used in closed steaming operations increases in oxygen demand, solids content, and phenol concentration with each reuse. The high oxygen demand of this waste is attributable primarily to wood extracts, principally simple sugars, the concentration of which increases with the use of the water. Because practically all of the solids content of this waste are dissolved solids, only insignificant reductions in oxygen demand and

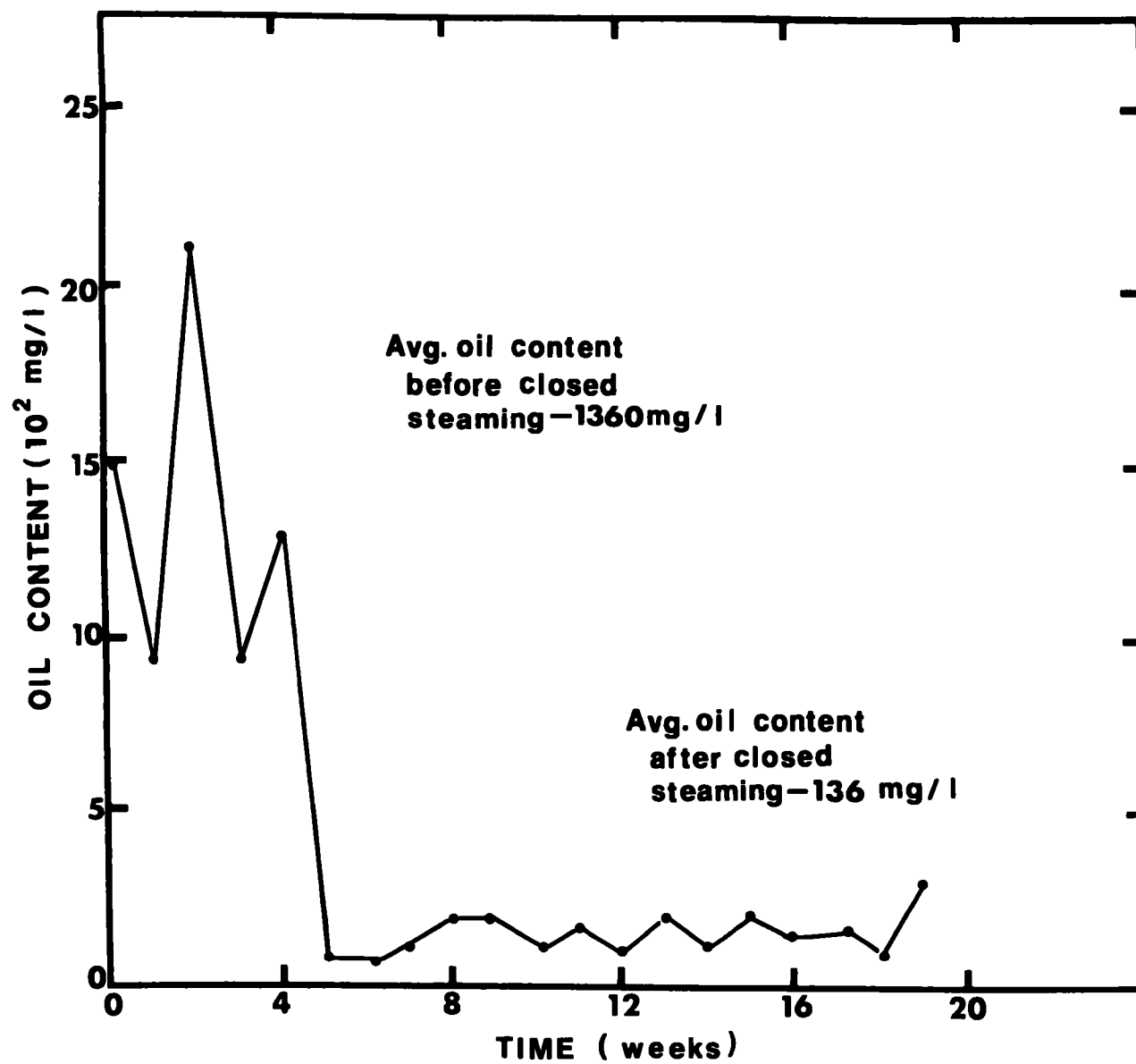


FIGURE 25 - VARIATION IN OIL CONTENT OF EFFLUENT WITH TIME BEFORE AND AFTER INITIATING CLOSED STEAMING (23)

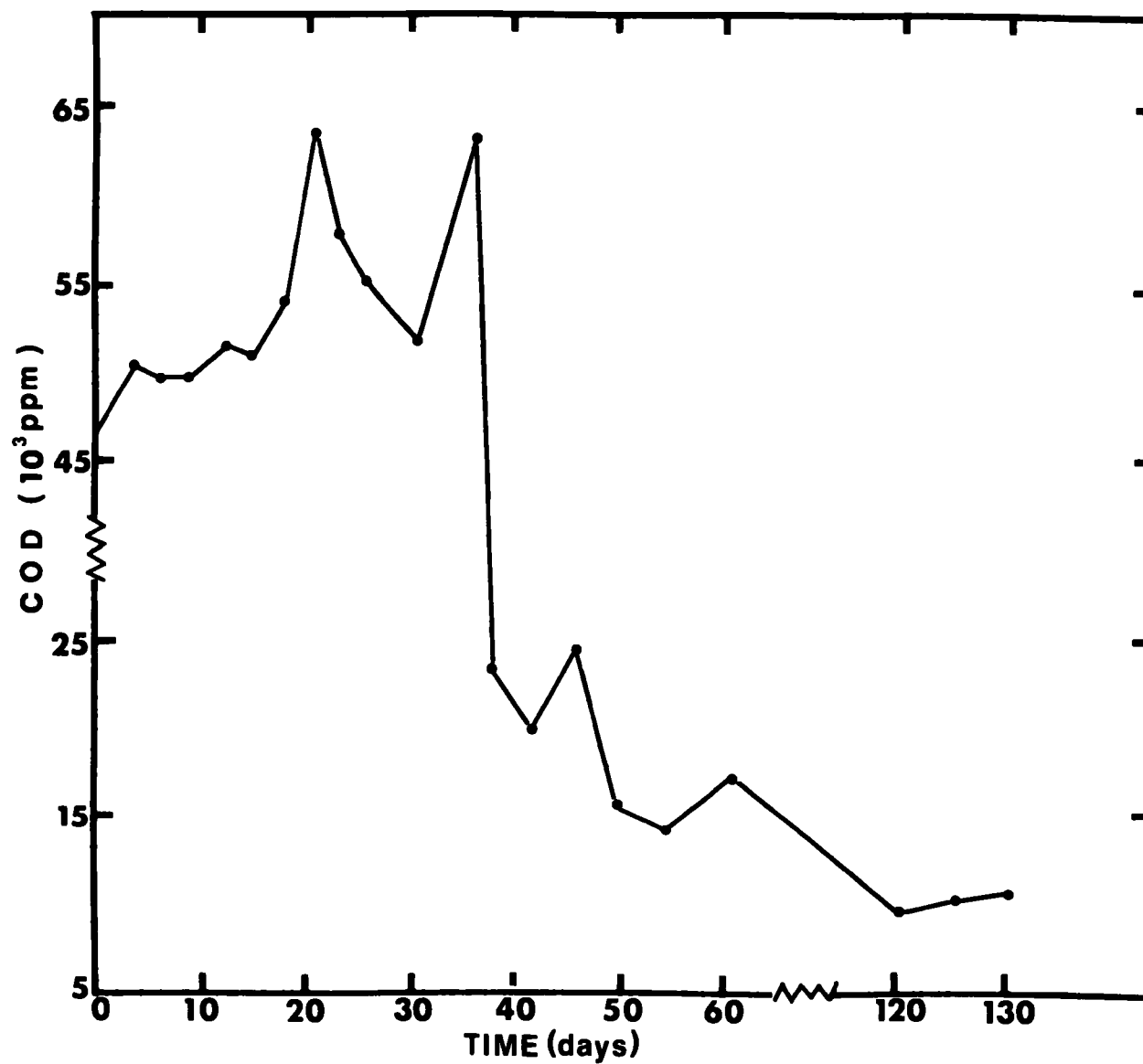


FIGURE 26 - VARIATION IN COD OF EFFLUENT WITH TIME BEFORE AND AFTER CLOSED STEAMING: DAYS 0-35 OPEN STEAMING; DAYS 35-130 CLOSED STEAMING (23)

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improvement in color result from primary treatments involving flocculation. The progressive changes in the parameters for water used in a closed steaming operation are shown in Table 29 (24). Although such wastes are perhaps more difficult to treat, this disadvantage is counterbalanced in part by the fact that substantial reductions in the volume of wastewater and total kilograms of pollutants released can be achieved by using closed steaming.

Table 29 Progressive Changes In Selected Characteristics Of Water Recycled In Closed Steaming Operations (24)

Charge No.	Phenol	COD	Total Solids	Dissolved Solids
1	46	15,516	10,156	8,176
2	169	22,208	17,956	15,176
3	200	22,412	22,204	20,676
4	215	49,552	37,668	31,832
5	231	54,824	66,284	37,048
7	254	75,856	66,968	40,424
8	315	99,992	67,604	41,608
12	208	129,914	99,276	91,848
13	230	121,367	104,960	101,676
14	223	110,541	92,092	91,028
20	323	123,429	114,924	88,796

NOTE: Values expressed as mg/liter.

Effect of Time

Because many plants use the same preservatives and follow essentially the same treating practices, the wastewaters they release are qualitatively similar with respect to a number of chemical and biochemical properties. Quantitatively, however, they differ widely from plant to plant -- and even from hour to hour at the same plant, depending upon the time during a treating cycle that samples for analysis are collected.

Data on the effect of time of sampling during a treating cycle on the flow rate and COD content of effluent from a plant operating a single retort are shown in Figure 27. Flow rate was measured and samples for analysis collected at 30-minute intervals, beginning during a steaming cycle and continuing through the treating cycle and part of the succeeding steaming cycle. The COD of the effluent varied inversely with flow rate and ranged from 400 mg/liter to 43,000 mg/liter during the 24-hour sampling period, a 100-fold variation. Flow rate varied from 7570 lpd to 151,400 lpd (2000 gpd to 40,000 gpd). The pattern of variation for phenol and solids content was similar to that for COD.

Variation in effluent characteristics among plants is illustrated by the data in Table 30, which show the phenol and COD values of raw waste for 13 plants. Also shown in the table are the COD values following a treatment consisting of flocculation and sedimentation. The phenol and COD values for the raw waste vary over a wide range, as does the efficiency of the treatment, as judged by the percent reduction in COD occasioned by flocculation (23).

Biological Characteristics

Wastewater from the wood preserving industry is usually relatively treatable. Limited experience with bench-scale and pilot plant activated sludge, trickling filter, and soil irrigation systems indicate that biological treating methods are generally effective in reducing the oxygen demand and phenolic compounds to acceptable levels. Because these waste waters have a very low nutrient content, the addition of nitrogen and phosphorus prior to biological treatment is necessary to maintain a viable bacterial population.

Because of its prolonged exposure to temperatures in the range of 110° to 121°C (230° to 250°F) and its relatively high content of phenolic compounds, process water is sterile upon its discharge from retorts. Its successful biological treatment requires the employment of strains of bacteria that have been acclimated to concentrations of phenolic compounds of 300 mg/liter or higher. On a laboratory scale, this requirement renders BOD determinations difficult to make and almost impossible to interpret, especially as regards comparisons of results obtained by different analysts. It is not possible to ascertain whether the differences obtained are due to the characteristics of the waste samples or to differences in the bacterial cultures employed and their degree of acclimation to the waste. Dust and Thompson (25) obtained differences in BOD values for creosote wastewater of 200 percent among several acclimated cultures of bacteria.

Fortunately, the correlation between BOD and COD for wood preserving wastewater is high. Using creosote wastewater with BOD values larger than 150 mg/liter, the above authors found that the equation $BOD = 0.497 \text{ COD} \times 60$, for which $r = 0.985$, accounted for practically all of the

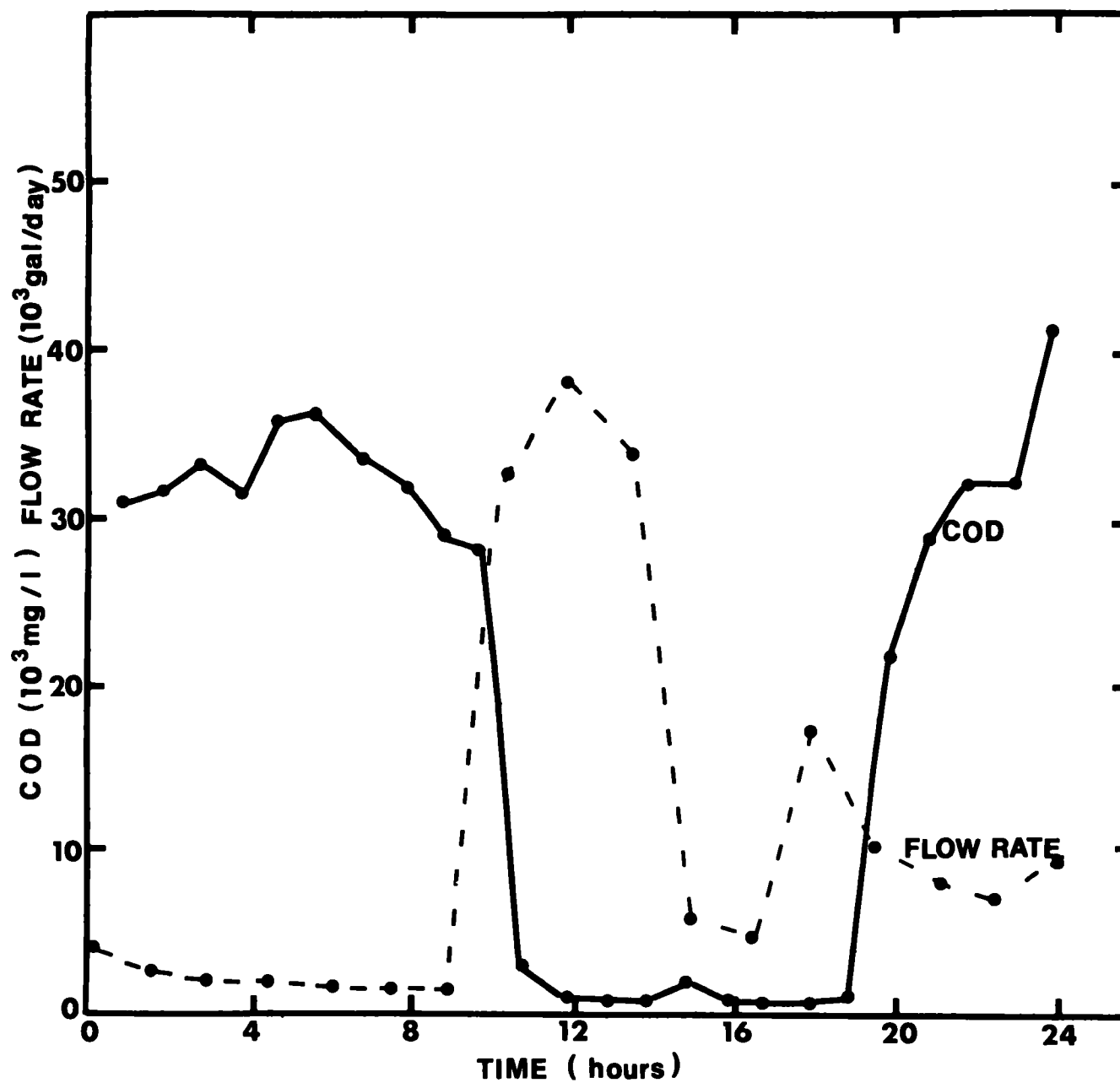


FIGURE 27 - VARIATION IN COD CONTENT AND WASTEWATER FLOW RATE WITH TIME (23)

TABLE 30 PHENOL AND COD VALUES FOR EFFLUENTS
FROM THIRTEEN WOOD PRESERVING PLANTS (23)

Plant Location	Phenol (mg/l)	COD (mg/l)		Percent Reduction
		Raw	After Flocculation	
Mississippi	162	6,290	3,700	41
Mississippi	109	11,490	5,025	56
Mississippi	--	48,000	2,040	96
Mississippi	168	42,000	31,500	25
Mississippi	83	12,300	4,500	63
Mississippi	50	1,000	--	--
Virginia	192	9,330	3,180	66
Virginia	508	32,300	8,575	73
Georgia	119	7,440	2,360	68
Georgia	331	3,370	1,880	44
Georgia	123	17,100	3,830	78
Tennessee	953	1,990	1,990	0
Louisiana	104	10,500	6,070	42

variation between the two parameters (Figure 28). The general applicability of this equation was indicated by spot checks of the COD:BOD ratio for similar wastes from several plants.

The COD:BOD ratio increases rapidly for BOD values smaller than 150 mg/liter (Table 31), and averages 6.2 for values in the range of 20 to 40 mg/liter. This ratio is in line with the value of 6.1 reported for the petroleum industry for effluents similar in composition to those of the wood preserving industry.

SALT-TYPE PRESERVATIVES AND FIRE RETARDANTS

Wastewaters resulting from treatments with inorganic salt formulations are low in organic content, but contain traces of heavy metals used in the preservatives and fire retardants employed. Average analytical data based on weekly sampling for a year of the effluent from a plant treating with both preservatives and a fire retardant are given in Table 32. The presence and concentration of a specific ion in wastewater from such treatments depend upon the particular formulation employed and the extent to which the waste is diluted by washwater and storm water.

RAW WASTE LOADING DATA

Average analytical data for five typical wood preserving plants treating with pentachlorophenol-petroleum solutions and/or creosote are given in Tables 33-37. Data for plants 1 through 4 (Tables 33-36) were obtained from 24 samples collected at hourly intervals at the outfall from each plant and analyzed separately to obtain information on short-term variation in effluent quality. These data were later supplemented by analysis of several grab samples collected over a period of several months. Data for Plant 5 are based on a series of grab samples collected during 1972. Information on volume of discharge of process water was obtained either from 24-hour measurements (Plants 1-4) or estimated based on number of retorts, processing operations used, and other considerations (Plant 5). Waste volume flow data do not include cooling water, which was recycled at all plants, coil condensate, or boiler blow-down water. Production figures for 1971 were estimated from the void volume of the retorts operated by the plants.

Raw waste loadings for each pollutant are expressed in terms of concentrations (mg/liter) and kilograms per 1000 m³ of product treated for each of the five plants. Maximum, minimum, and average raw waste loadings per day based on analytical data and volume of discharge are also given. A composite of these data, representing the average raw waste loadings given in Tables 33-37 is shown in Table 38. The effluent characteristics represented by these data are assumed to be representative of the raw waste streams of plants treating with creosote and pentachlorophenol-petroleum solutions. Since each of the five plants involved are typical of the industry, data for the hypothetical plant given in Table 38 will be the basis for an analysis of effluent treatment cost presented later in this report.

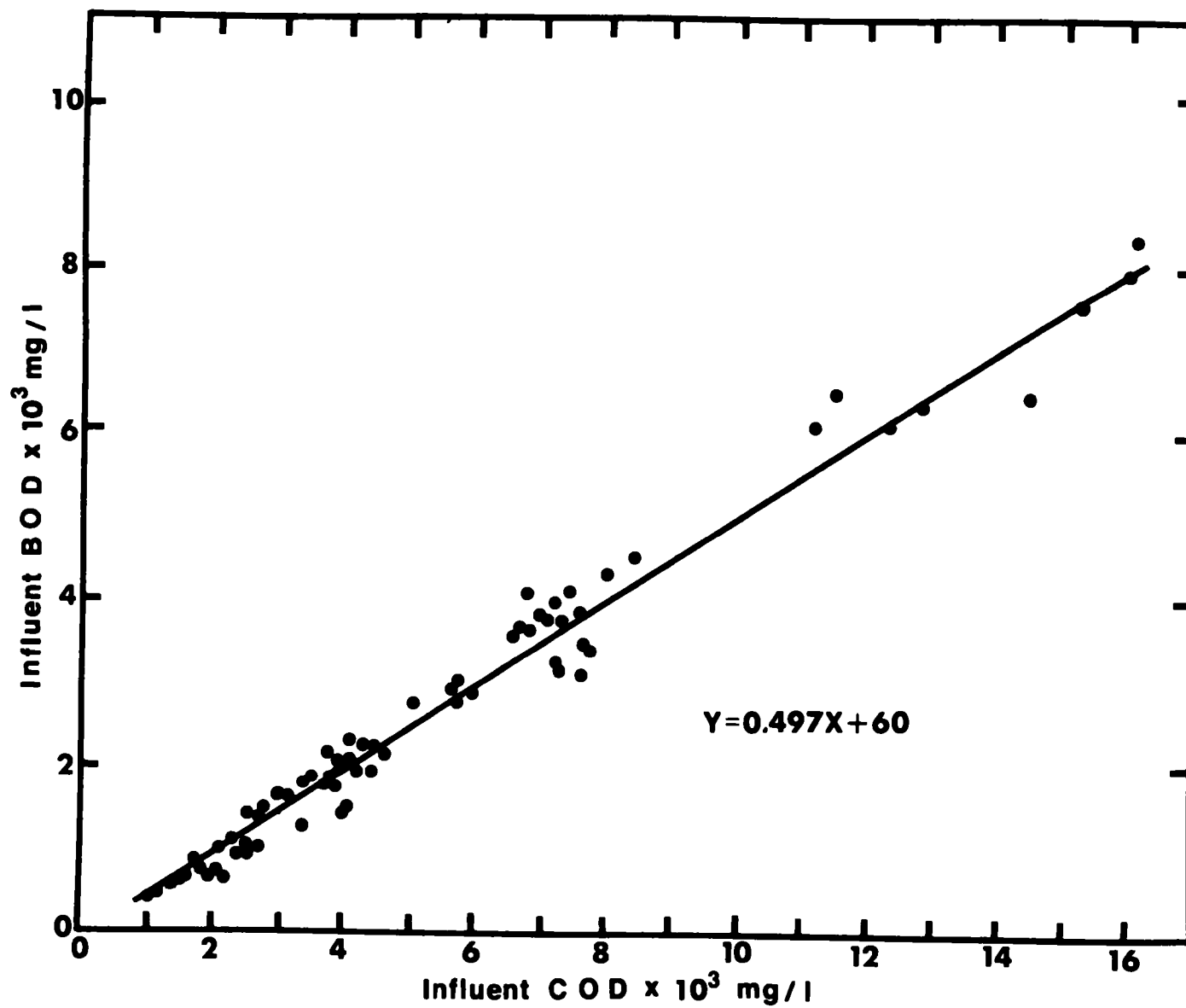


FIGURE 28 - RELATIONSHIP BETWEEN BOD AND COD FOR WASTEWATER FROM A CREOSOTE TREATING OPERATION (23)

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TABLE 31 RATIO BETWEEN COD AND BOD FOR VAPOR DRYING
AND CREOSOTE EFFLUENT WASTEWATERS*

(NOTE: Data provided by the Research Department, Koppers Company, Inc.)

(mg/liter)			
Range of BOD	COD	BOD	Ratio COD/BOD
40 - 75	150	45	3.3
	160	40	4.0
	300	45	6.7
	300	75	4.0
	320	45	7.1
	450	60	7.5
20 - 35	160	25	6.4
	210	35	6.0
	180	30	6.0
	120	20	6.0
10 - 15	100	10	10.0
	210	15	14.0*
	180	10	18.0*
	70	10	7.0
Average	--	--	6.2

*Analysis revealed these values to be statistical aberrants. They were not included in average.

TABLE 32 RANGE OF POLLUTANT CONCENTRATIONS IN WASTEWATER FROM
A PLANT TREATING WITH CCA- AND FCAP-TYPE
PRESERVATIVES AND A FIRE RETARDANT
(mg/liter)

Parameter	Range of Concentrations
COD	10 - 50
As	13 - 50
Phenols	0.05 - 0.16
Cu	0.05 - 1.1
Cr+6	0.23 - 1.5
Cr+3	0 - 0.8
F	4 - 20
PO ₄	15 - 150
NH ₃ -N	80 - 200
pH	5.0 - 6.8

TABLE 33 RAW WASTE LOADINGS FOR PLANT NO. 1

Parameter	Raw Waste Loadings*		Raw Waste Loadings/day (Kg)**		
	(mg/l)	(Kg/1000 m ³ Prod)	Max.	Min.	Avg.
COD	28,600	13,723.0 (854.8)	2,705.5 (5,952.0)	317.0 (697.5)	1,631.8 (3,590.0)
Phenols	134	48.2 (3.0)	6.7 (14.8)	0.1 (0.2)	5.6 (12.4)
Oil and Grease	530	188.3 (11.7)	84.5 (186.0)	4.2 (9.3)	22.4 (49.3)
Total Solids	11,963	4,251.6 (264.9)	836.6 (1,840.5)	5.0 (11.1)	505.7 (1,112.6)
Dissolved Solids	11,963	3,596.8 (224.1)	673.0 (1,480.6)	2.3 (5.1)	427.8 (941.1)
Suspended Solids	1,844	654.8 (40.8)	163.6 (359.9)	3.3 (7.2)	78.0 (171.5)
pH	4.6				

Average flow - 42,494 lpd (11,227 gpd)
 Void vol.of cylinders - 293 m³ (10,337 ft³)
 1971 production (est.) - 26,760 m³ (945,000 ft³)
 Average work days/year - 225
 Average daily production - 119 m³ (4,200 ft³)
 Preservatives - Creosote

*Parenthetical values in pounds/1000 ft³
 **Parenthetical values in pounds.

TABLE 34 RAW WASTE LOADINGS FOR PLANT NO. 2

Parameter	Raw Waste Loadings*		Raw Waste Loadings/day (Kg)**		
	(mg/l)	(Kg/1000 m ³ Prod)	Max.	Min.	Avg.
COD	22,685	7,712.0 (480.5)	5,988.9 (13,175.6)	794.0 (1,746.8)	1,546.7 (3,402.8)
Phenols	258	88.3 (5.5)	54.7 (120.3)	9.0 (19.9)	17.6 (38.7)
Oil and Grease	55	19.3 (1.2)	4.6 (10.2)	2.0 (4.4)	3.7 (8.2)
Total Solids	3,504	1,190.9 (74.2)	728.8 (1,603.4)	118.2 (206.0)	238.9 (525.6)
Dissolved Solids	3,044	1,035.2 (64.5)	645.3 (1,419.6)	106.5 (234.4)	207.5 (456.6)
Suspended Solids	460	155.7 (9.7)	95.7 (210.6)	16.1 (35.4)	31.4 (69.0)
pH	4.9				

Average flow - 68,471 lpd (18,090 gpd)
 Void vol. of cylinders - 427 m³ (15,068 ft³)
 1971 production (est.) - 60,163 m³ (2,124,588 ft³)
 Average work days/year - 300
 Average daily production - 201 m³ (7,082 ft³)
 Preservatives - Creosote, Pentachlorophenol

*Parenthetical values in pounds/1000 ft³

**Parenthetical values in pounds

TABLE 35 RAW WASTE LOADINGS FOR PLANT NO. 3

Parameter	Raw Waste Loadings*		Raw Waste Loadings/day (Kg)**		
	(mg/l)	(Kg/1000 m ³ Prod)	Max.	Min.	Avg.
COD	12,467	3,295.1 (205.3)	943.2 (2,075.0)	500.0 (1,100.0)	708.4 (1,558.4)
Phenols	82	25.7 (1.6)	5.9 (12.9)	3.5 (7.8)	5.6 (12.3)
Oil	150	40.1 (2.5)	25.0 (55.0)		8.5 (18.8)
Total Solids	1,724	455.8 (28.4)	130.3 (286.6)	69.5 (153.0)	98.0 (215.5)
Dissolved Solids	1,528	404.5 (25.2)	115.5 (254.0)	61.6 (135.6)	86.8 (191.0)
Suspended	196	51.4 (3.2)	14.8 (32.6)	7.9 (17.4)	11.1 (24.5)

pH 4.5

Average flow (est.) - 56,775 lpd (15,000 gpd)
 Void vol. of cylinders - 457m³ (16,152 ft³)
 1971 production (est.) - 64,491 m³ (2,277,432 ft³)
 Average work days/year - 300
 Average daily production - 215 m³ (7,591 ft³)
 Preservatives - Creosote, Pentachlorophenol

*Parenthetical values in pounds/1000 ft³

**Parenthetical values in pounds

TABLE 36 RAW WASTE LOADINGS FOR PLANT NO. 4

Parameter	Raw Waste Loadings*		Raw Waste Loadings/day (Kg)**		
	(mg/l)	(Kg/1000 m ³ Prod)	Max.	Min.	Avg.
COD	9,318	2,291.9 (142.8)	1,131.7 (2,489.8)	373.1 (822.6)	563.3 (1,239.3)
Phenols	312	77.0 (4.8)	21.2 (46.6)	14.6 (32.2)	18.9 (41.5)
Oil	580	142.8 (8.9)	45.8 (100.8)	24.5 (53.9)	35.0 (77.1)
Total Solids	3,432	844.2 (52.6)	530.3 (1,166.7)	99.9 (219.7)	207.5 (456.5)
Dissolved Solids	2,748	675.7 (42.1)	383.1 (842.4)	93.8 (206.4)	166.1 (365.5)
Suspended Solids	684	168.5 (10.5)	147.4 (324.2)	6.0 (13.3)	41.3 (90.9)

pH 5.8

Average flow (est.) - 60,560 lpd (16,000 gpd)
 Void vol. of cylinders - 523 m³ (18,470 ft³)
 1971 production (est.) - 73,746 m³ (2,604,270 ft³)
 Average work days/year - 300
 Average daily production - 246 m³ (8,681 ft³)
 Preservatives - Creosote, Pentachlorophenol

*Parenthetical values in pounds/1000 ft³

**Parenthetical values in pounds

TABLE 37 RAW WASTE LOADINGS FOR PLANT NO. 5

Parameter	Raw Waste Loadings*		Raw Waste Loadings/day (Kg)**		
	(mg/l)	(Kg/1000 m ³ Prod)	Max.	Min.	Avg.
COD	13,273	3,072.0 (191.4)	593.2 (1,305.0)	317.8 (699.1)	452.5 (995.5)
Phenol	126	28.9 (1.8)	5.1 (11.2)	3.4 (7.4)	4.3 (9.4)
Oil and Grease	172	40.1 (2.5)	9.9 (21.8)	1.0 (2.3)	5.9 (12.9)
Total Solids	5,780	1,338.6 (83.4)	259.5 (570.9)	168.3 (370.2)	197.0 (433.5)
Dissolved Solids	5,416	1,253.5 (78.1)	241.8 (532.0)	137.9 (303.4)	184.6 (406.2)
Suspended Solids	364	83.5 (5.2)	--	--	12.4 (27.3)
pH	4.5				

Average flow (est.) - 34,444 lpd (9,100 gpd)
 Void vol. of cylinders - 356 m³ (12,557 ft³)
 1971 production (est.) - 44,175 m³ (1,560,000 ft³)
 Average work days/year - 300
 Average daily production - 147 m³ (5,200 ft³)
 Preservatives - Creosote, Pentachlorophenol

*Parenthetical values in pounds/1000 ft³

**Parenthetical values in pounds

TABLE 38 AVERAGE RAW WASTE LOADINGS FOR
FIVE WOOD-PRESERVING PLANTS

Parameter	Raw Waste Loadings*		Raw Waste Loadings/day (Kg)**		
	(mg/l)	(kg/1000 m ³ Prod)	Max.	Min.	Avg.
COD	19,269	5,378.4 (335.1)	1,651.9 (3,634.2)	502.9 (1,106.3)	1,016.0 (2,235.2)
Phenols	182	51.4 (3.2)	12.8 (28.2)	6.3 (13.8)	9.6 (21.1)
Oil and Grease	297	83.5 (5.2)	37.5 (82.5)	7.5 (16.4)	15.6 (34.4)
Total Solids	5,280	1,463.8 (91.2)	470.7 (1,035.5)	109.5 (240.9)	278.4 (612.5)
Dissolved Solids	4,571	1,276.0 (79.5)	387.4 (852.2)	93.5 (205.8)	241.0 (530.2)
Suspended Solids	710	199.0 (12.4)	87.2 (191.9)	12.2 (26.8)	37.5 (82.4)
pH	4.9				

Average flow - 52,990 lpd (14,000 gpd)
 Void vol. of cylinders - 411 m³ (14,517 ft³)
 1971 production (est.) - 53,867 m³ (1,902, 258 ft³)
 Average work days/year - 285
 Average daily production - 189 m³ (6,674 ft³)
 Preservatives - Creosote, Pentachlorophenol

*Parenthetical values in pounds/1000 ft³

**Parenthetical values in pounds

SOURCES OF WASTEWATER

Wastewaters from wood preserving operations are of the following types and contain the contaminants indicated:

- a. Condensate from conditioning by steaming and Boultonizing - This is the most heavily contaminated wastewater, since it comes into direct contact with the preservative being used. Condensates from pentachlorophenol and creosote treatments contain entrained oils, phenolic compounds, and carbohydrates leached from the wood. Those from salt-type treatments contain traces of the chemicals present in the preservative formulation used. The oxygen demand of this waste is high because of dissolved wood extractives and, in the case of creosote and pentachlorophenol treatments, entrained oils.
- b. Cooling water - Cooling water is used to cool condensers, air compressors, and vacuum pumps and, in the case of plants that use it on a once-through basis, accounts for approximately 80 percent of the total discharge. Water used with surface condensers, air compressors, and dry-type vacuum pumps is unchanged in quality. That used with barometric condensers and wet-type vacuum pumps is contaminated with the preservative used, unless the preservative is of the water-borne type. In the latter case, the cooling water is unchanged in quality.
- c. Steam condensate from heating coils - Water from this source is uncontaminated, unless a coil develops a leak through which preservative can enter.
- d. Boiler blow-down water - is contaminated with chemicals, principally chromates and phosphates, used as boiler compounds.
- e. Vacuum water - Water extracted from the wood during the vacuum cycle following steam conditioning is contaminated with the preservative employed. In the Boulton process, the cylinder condensate is largely composed of water from this source.
- f. Wash water - Water used to clean equipment is contaminated with the preservative used, with oil and grease, and may also contain detergents.
- g. Water softener brine - Water used for this purpose is contaminated with various dissolved inorganic materials including salts of calcium and magnesium.

The source and volume of water used, including recycled water, and the amount of wastewater discharged by a hypothetical wood preserving plant (Table 38) that employs steam conditioning are shown in the flow diagram that is Figure 29. A more complete breakdown of these data is given in Table 39.

This plant has a daily intake of approximately 121,120 liters (32,000 gal.), gross water usage of 567,750 liters (150,000 gal.), and a discharge of 104,100 liters per day (27,500 gpd). An estimated 13,250 liters (3,500 gal.) of cooling water are lost by evaporation. Roughly 446,650 liters (118,000 gal.) are recycled as cooling water, including 6,400 liters (1,700 gal.) of water extracted during the conditioning process (vacuum water). The amount of vacuum water recovered averages about 1.9 kilograms per cubic meter (4.3 pounds per cubic foot) of green wood that is steam conditioned. Approximately two times this amount is removed from Boultonized stock.

The actual volume of water used at a plant of this size and type is not static, but rather varies depending upon the condition of the stock (either green or seasoned) being treated and the size of the individual items. For illustrative purposes only, the data in Table 39 were computed based on the assumption that the plant treated stock one-half of which was green and one-half of which was seasoned. If all green material were treated, the volume of boiler water and cooling water used would approximately double.

Both the gross water used in a plant and the volume discharged depends primarily upon whether a plant uses cooling water on a once-through basis or recycles it. To a lesser extent, the disposition of coil condensate -- either reused for boiler make-up water or discharged -- is also important in determining the volume of wastewater. Nationwide, approximately 75 percent of the plants recycle their cooling water; only 33 percent reuse their coil condensate.

Gross water usage is also influenced by cooling water requirements. Among plants of the same size and type of operation, the volume used varies by as much as fourfold. Such variation is attributable to the operating procedures used. Important variables in this regard are the length of the vacuum period, during which cooling water is required for both the condenser and the vacuum pump, and whether or not the rate of flow to the condenser is reduced after the initial period of operation when a high flow rate is needed.

Volume of cooling water used also varies with the conditioning process used--either steaming or Boultonizing. In the former process, the condenser is operated only about three hours following a conditioning cycle. In the Boultonizing process, the condenser is operated for the entire period, which often exceeds 30 hours. Gross cooling water usage at a larger plant employing the Boulton process may amount to 3.8 million liters (1 million gallons) per day.

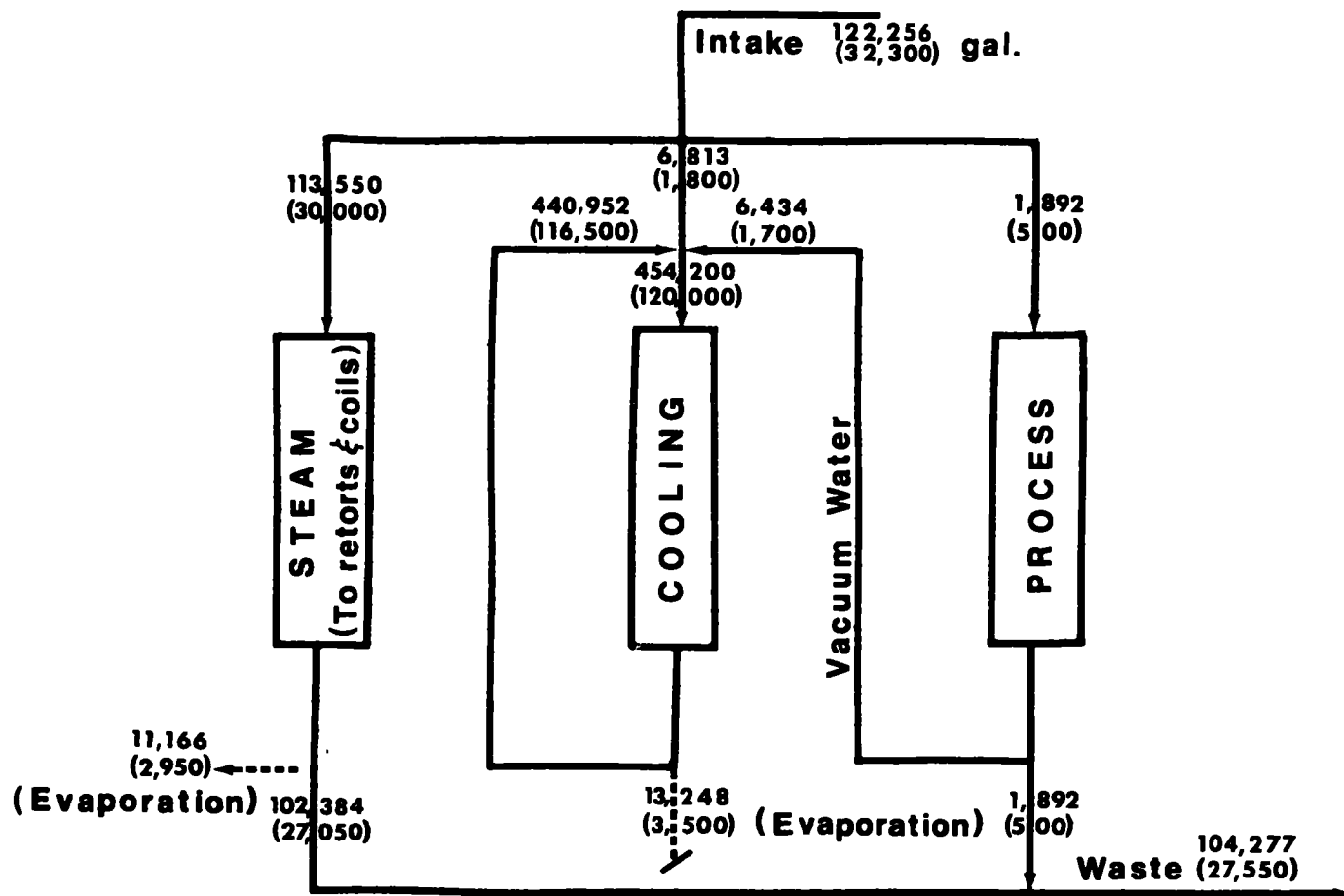


FIGURE 29 - SOURCE AND VOLUME OF DAILY WATER USE AND RECYCLING AND WASTEWATER SOURCE AT A TYPICAL WOOD-PRESERVING PLANT

TABLE 39 SOURCE AND VOLUME OF WATER DISCHARGED AND RECYCLED PER DAY BY A TYPICAL WOOD-PRESERVING PLANT

(Note: Based on hypothetical plant,
data for which are given in TABLE 38)

Source	Volume Used	Volume Discharged	Volume Recycled
Cylinder condensate	51,096 (13,500)	51,098 (13,500)	-
Coil condensate	55,640 (14,700)	44,474 ^b (11,750)	-
Boiler blowdown	6,813 (1,800)	6,813 (1,800)	-
Vacuum Water	-	-	6,434 ^a (1,700)
Cooling water	454,200 (120,000)	13,248 ^c (3,500) ^b	440,952 (116,500)
Other	1,892 (500)	1,892 (500)	-
TOTAL	567,500 (150,500)	104,277 (27,550)	447,387 (118,200)

Open values are in liters.

Parenthetical values are in gallons.

^aWater extracted from wood and recycled as cooling water.

^bApproximately 15 percent loss due to flash evaporation.

^cLoss of cooling water by drift and evaporation.

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Assuming recycling of cooling and coil condensate water, the most important source of wastewater in terms of volume and level of contamination is cylinder condensate. The amount of wastewater from this source varies with the volume of stock that is green and must be conditioned prior to preservative treatment. For plants operating on similar steaming or Boultonizing schedules the volume of waste does not vary widely among plants of comparable size and generally is less than 75,700 liters (20,000 gallons) per day.

SECTION VI
SELECTION OF POLLUTANT PARAMETERS

WASTEWATER PARAMETERS OF POLLUTIONAL SIGNIFICANCE

Veneer and Plywood Industry and Hardboard Industry

Major wastewater parameters of significance for the veneer and plywood industry and the hardboard industry include:

BOD
COD
Phenols
Oils and grease
pH
Temperature
Dissolved Solids
Suspended solids

In addition, parameters of lesser importance include:

Phosphorus
Nitrogen

The above parameters have been selected as representing those chemical constituents which might be present in wastewater from a veneer or plywood mill or a hardboard mill and which might have a detrimental effect on a receiving water.

Wood Preserving Industry

Chemical and biological constituents of wood preserving wastewaters that should be subject to effluent limitations because of potential deleterious effects on receiving waters are listed below. The selection of these parameters was based on data obtained from various sources, including industry sources, and on observations made at the exemplary plants inspected during the field phase of this study.

Phenols	Copper
BOD5	Chromium
COD	Arsenic
Dissolved solids	Zinc
Suspended solids	Fluorides
Oil and grease	Ammonia
pH	Phosphorus

All parameters are not present in the raw waste streams of all wood preserving plants, the inorganics listed in the second column occurring only in wastewater from plants treating with salt-type preservatives. The particular ions present in the discharges from these plants depend upon the preservative and/or fire retardant formulation used.

DISCUSSION OF POLLUTANT PARAMETERS

BOD5: Biochemical Oxygen Demand, 5 day at 20°C

This parameter is the widely used measure for determining degradable organic matter in a wastewater. It is a standard criterion utilized in pollution control regulations. BOD concentrations are an indication of soluble and suspended organics. These organics are composed of simple wood sugars as well as long chain and cyclic hydrocarbons, and, if discharged to a receiving body of water or into groundwater, pollution problems can result.

COD: Chemical Oxygen Demand

The COD of a wastewater is another measure for organic matter concentration. It is a chemical analysis used to augment the BOD analysis, and, in certain cases where a definite ratio between BOD and COD has been established, it can substitute for the BOD analysis. Furthermore, COD can often serve as an indicator of organics that are not readily biodegradable.

Phenols

Phenols are a natural constituent found in wood; therefore, water contacting wood can be expected to obtain some concentration of phenols. Resin, another potential source of phenols, might also be found in wastewater discharges. It is a cyclic hydrocarbon which can be degraded biochemically by the BOD test but not chemically by standard COD analysis.

Phenol concentrations in receiving waters offer the potential of taste and odor problems in drinking water supplies as well as the potential of toxicity to biota.

Oil and Grease

Oil and grease (hexane extractables) are standard lubricating chemicals in a variety of inplant machinery. These lubricating chemicals can find their way into cooling water, washwater, and other miscellaneous waste streams. Creosote is an oil, and various petroleum products are used as carriers for pentachlorophenol. These oils invariably are present in wastewater from

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treatments employing oily preservatives and they create a serious pollution problem. Values for raw wastewater range from less than 50 to over 1000 milligrams per liter.

pH

The pH of a liquid is by definition the negative log of the hydrogen ion concentration. It is an important parameter in that most reactions in water are a function of hydrogen ion concentrations from an equilibrium as well as from a kinetic standpoint.

Wastewaters from creosote and pentachlorophenol treatments are invariably acid in reaction, the pH ranging between 3.8 and 6.0. Those from salt-type treatments may be either acid or basic, depending upon the particular formulation used.

Temperature

Temperature is also an important parameter in reaction kinetics and equilibria. Large heat loads on a receiving stream can cause significant temperature increases which in turn can result in serious imbalance in micro-ecosystems.

Dissolved Solids

Total dissolved solids is a chemical analysis which, when added to the total suspended solids concentrations, gives the total solids in a waste stream. It is also a measure of the soluble organics that are leached from wood. In the case of salt-type treatments in wood preserving plants, inorganic preservatives contribute to the dissolved solids content of wastewaters. In any recycle system dissolved solids accumulate even though suspended solids are removed. Sufficient blowdown must be maintained to prevent deposition on heating and cooling surfaces.

Suspended Solids

Wastewaters can carry substantial suspended solids concentrations due to wood fibers, fiber fragments, and other residue. Suspended solids is an important factor in determining the quality of wastewater since it affects light penetration and the aesthetic properties of the receiving waters.

Phosphorus

The only source of phosphorus from the veneer and plywood industry is the wood itself. Phosphorus is an important nutrient and can have significant effect on the eutrophication of receiving waters. However, the wastewaters from this industry are nutrient deficient, and phosphorus is not considered a problem.

Nitrogen

The main forms of nitrogen in water are organic nitrogen, ammonia, nitrites, and nitrates. Nitrate is the lowest oxidation level of these. Biochemical reactions will oxidize ammonia to nitrite and finally to nitrate. This oxidation necessitates oxygen, thereby exerting an oxygen demand in water. Furthermore, nitrates have been found to be toxic at high levels to infants and to interfere with disinfection by halogens. Nitrogen is an important nutrient and can affect eutrophication in receiving waters. Urea formaldehyde glue and protein glues introduce organic nitrogen. Assuming no discharge from glue waste, the wastewaters from a veneer and plywood mill are nitrogen deficient and nitrogen concentrations are not a problem.

Inorganics

All of the inorganics listed for the wood preserving industry occur in one or more salt-type preservatives and fire retardants. As indicated previously, the particular ions present depend upon the salt formulation used. Concentrations in raw wastewater range from five to 100 milligrams per liter.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

PART A: CONTROL AND TREATMENT TECHNOLOGY IN THE VENEER AND PLYWOOD INDUSTRY

Introduction

Treatment and control technology in the veneer and plywood industry is not extensive. This is due in large part to the fact that the water pollution problems in the industry are relatively minor when compared to other industries. The major effort made by the industry to reduce wastewater discharge has been to reduce the amount of wastewater produced by reuse and conservation of water and to contain wastewaters that cannot be reused. Each source of potential wastewater and methods of treatment is discussed below.

Log Storage

As discussed in Section IV, Process Description and Industry Categorization, log storage may consist of log ponds, wet decking, or dry decking. Water quality and discharge volumes of log ponds cannot be characterized with available data; therefore, development of documentation for effluent limitations guidelines for this waste source will be accomplished in Phase II of the Timber Products study. Wet decking, on the other hand, allows for greater control of water usage to such an extent that zero discharge to navigable waters is feasible. There is no wastewater discharge from dry decking. Therefore, in this document, control and treatment technology for waste streams from log storage will be concerned with the wet decking method.

Several plywood mills presently recycle the water that has been used to sprinkle logs in wet decking. Such a recycle system generally consists of a settling pond or sump to catch the drainage from the log sprinkling area and of screening facilities prior to reuse. Sprinkling enhances evaporation of water, thereby balancing out runoff from rain in most areas of the country. Solids which tend to slowly fill the settling pond can be removed and disposed of as landfill. While there are operational problems associated with such a recycle system, in most instances the problems can be solved. It is felt that with few exceptions this technology is applicable to the industry in general.

Dry decking of logs is also practiced in a number of mills, although it is mostly applicable to mills producing low quality veneer and to mills that have a fairly constant supply of logs and do not require large log storage. If deterioration of logs becomes a problem, then wet-decking must be practiced.

Log Conditioning

Wastewater from log conditioning has become the largest and most difficult source to handle in a plywood mill since it has been demonstrated that glue washwater can be eliminated as a pollution source.

Although seldom used, biological treatment of the effluent from hot water vats and steam vats is practicable and effective. It has been reported that 85 to 90 percent reduction of BOD and COD is attainable by using lagoons or aerated lagoons (20). Other types of biological treatment have not been reported, but it is obvious that conventional biological processes such as the activated sludge process are also technically feasible.

Hot water vats when heated indirectly through coils will not have a continuous discharge caused by steam condensate. Any discharge results from spillage when logs are either placed into or taken out of the vat. Plants operating in this manner need only to settle the water in small settling tanks or ponds and reuse the water for any makeup that might be required. There are several plants designed to operate in this manner; however, the tendency has generally been to operate this system by injecting live steam into the vats to heat the water to the desired level and then to use the steam to maintain the temperature. The reason for the use of steam injection rather than heating coils is to raise the temperature as quickly as possible. Quicker heating may also be accomplished by adding more heating surface to the vats. Plants that use steam coils in their hot water vats and then settle and reuse the water have experienced a decreased pH in the vats with time. Addition of lime or sodium hydroxide may be necessary to reduce resulting corrosion problems. The resulting sludge may be trucked to landfill.

Wastewater discharge from steam vats is more difficult to eliminate. By design, condensate from the vats must be discharged because of the difficulty of reusing the contaminated condensate as boiler makeup water. Various modifications have been made to steam vats which allow them to be converted to totally closed systems. Several plants have

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converted steam vats to hot water spray tunnels which would have conditioning effects similar to hot water vats (20). Hot water does not heat the logs as rapidly or as violently as direct steam; however, it is a practical alternative for most plants. While many mills cannot use hot water vats due to the fact that some species of logs do not sink, hot water sprays can be used as an alternative. Hot water spray systems can be placed in existing steam vats with only minor modifications. These systems work on the principle of heating water through heat exchange coils and then spraying the hot water over the logs. The hot water can then be collected and reheated after settling and screening.

The other possible modification is a technology from the wood preserving industry called "modified steaming" (20). Modified steaming works on principles similar to hot water sprays with the exception that no sprays are used. Coils in the bottom of the vat are used to produce steam from the water. The steam conditions the log in much the same manner as in conventional steam vats. As the steam condenses, it falls to the bottom of the vat where it is revaporized.

Either the use of hot water sprays or the employment of modified steaming would allow mills that now use steam vats to operate similarly to mills that now use hot water vats without direct steam impingement. All of these methods are closed systems and, therefore, require some type of solids removal and "flush-outs" a few times each year. They may also require pH adjustment. The relatively small volumes of wastewater produced during the "flush-outs" could then be contained or used for irrigation.

Veneer Dryers

The practice of cleaning veneer dryers with water is one that will necessarily continue; however, the frequency of cleaning and the volume of washwater can be significantly reduced.

Plywood mills producing 9.3 million square meters (100 million square feet) on a 9.53 mm (three-eighths inch) basis per year presently use approximately 57,000 liters (15,000 gallons) of water per week to clean dryers. There are many modifications to cleaning procedures which can reduce this volume. A plywood mill in Oregon has already reduced its veneer dryer washwater to 8,000 liters (2,000 gallons) per week by manually scraping the dryer and blowing it out with air prior to the application of water. Close supervision of operators and the installation of water meters on water hoses also encourages water conservation. Most mills can reduce the

volume of water to about 12,000 liters (3,000 gallons) per week, and this small volume can be handled without discharge by containment, land irrigation; or evaporation.

Glue Lines

Current technology in the handling of glue washwater allows zero discharge to navigable waters to be achievable throughout the industry. Recycle systems which eliminate discharge from the glue lines are now in operation in about 60 percent of all mills visited and are practicable with all three major types of glue. In 1968, only one plywood mill had a glue washwater recycle system (10). Currently the system is accepted technology in the industry. Nevertheless, there are still a number of plywood mills that discharge wastewater from their glue operations.

A plywood mill using phenolic glue can reduce the wastewater flow from its glue operation to about 7,570 liters (about 2,000 gallons) per day, without altering the process, by conserving water (10). Urea formaldehyde glues do not require any more frequent washing than do phenolic glues and, therefore, can be similarly controlled. Protein glues, however, normally necessitate more frequent cleaning because of shorter glue pot life. In order to reduce the flows from a mill that uses protein glue, inplant modifications in addition to water conservation are necessary.

Phenolic glues usually require about 227 kilograms (500 pounds) of water per batch (4.5 cubic meters [1,200 gallons] per day). Further reduction of wastewater is then necessary for all of the wastewater to be used in the makeup of glue. Table 26, found in Section V, indicates that most southern plywood mills produce about twice as much wastewater from glue washing than can be used for glue mixing.

Various inplant operational and equipment modifications can be used to reduce glue washwater; for example:

- (1) Some plants wash glue spreaders several times a day, and some wash only once a week. The less frequent washings can reduce the amount of water to between 10 and 30 percent of the original volume.

- (2) The use of steam to clean the spreaders also reduces the water usage considerably. While steam cannot be used for some types of rubber coated roller spreaders commonly used with phenolic and urea glues, steam would be a practical modification for protein glue operations which use steel rollers. This is quite significant since the frequency of washing for protein glue lines cannot be reduced to the same extent as when synthetic resins are used.
- (3) The use of high pressure water lines and nozzles can reduce the amount of water used to 30 percent of the original volume.
- (4) The use of glue applicators which spray the glue rather than roll it onto the wood can reduce the volume of washwater, since these do not require washing as frequently as do the glue spreaders.
- (5) The use of washwater for glue preparation and the reuse of remaining washwater for washing the glue system is a simple method of reducing wastewater flows. Since a fraction of the washwater is used to prepare glue, a volume of fresh water can be added as final rinse in the washing of the glue spreaders.

Any number of these modifications in combination with each other can be used to completely recycle the washwater and eliminate discharge from the glue system. A typical recycle system is shown in Figure 30.

There has been no difference in the quality of glue made with fresh water and that made with washwater (19). An economic benefit has been established by using glue wastewater, due to the fact that it contains glue and other chemicals such as sodium hydroxide, as shown in Table 40. Substantial savings in raw materials can be realized.

Complete recycle systems are now in operation for phenolic, urea, and protein glues. Mills that use several types of glues must have separate recycle systems to segregate the different washwaters. Attempts at mixing washwater from different types of glues have been unsuccessful.

In addition to washwater recycle, there are plants that contain and evaporate glue washwater, spray the glue water on the bark that goes into the boiler, or use a combination of these techniques.

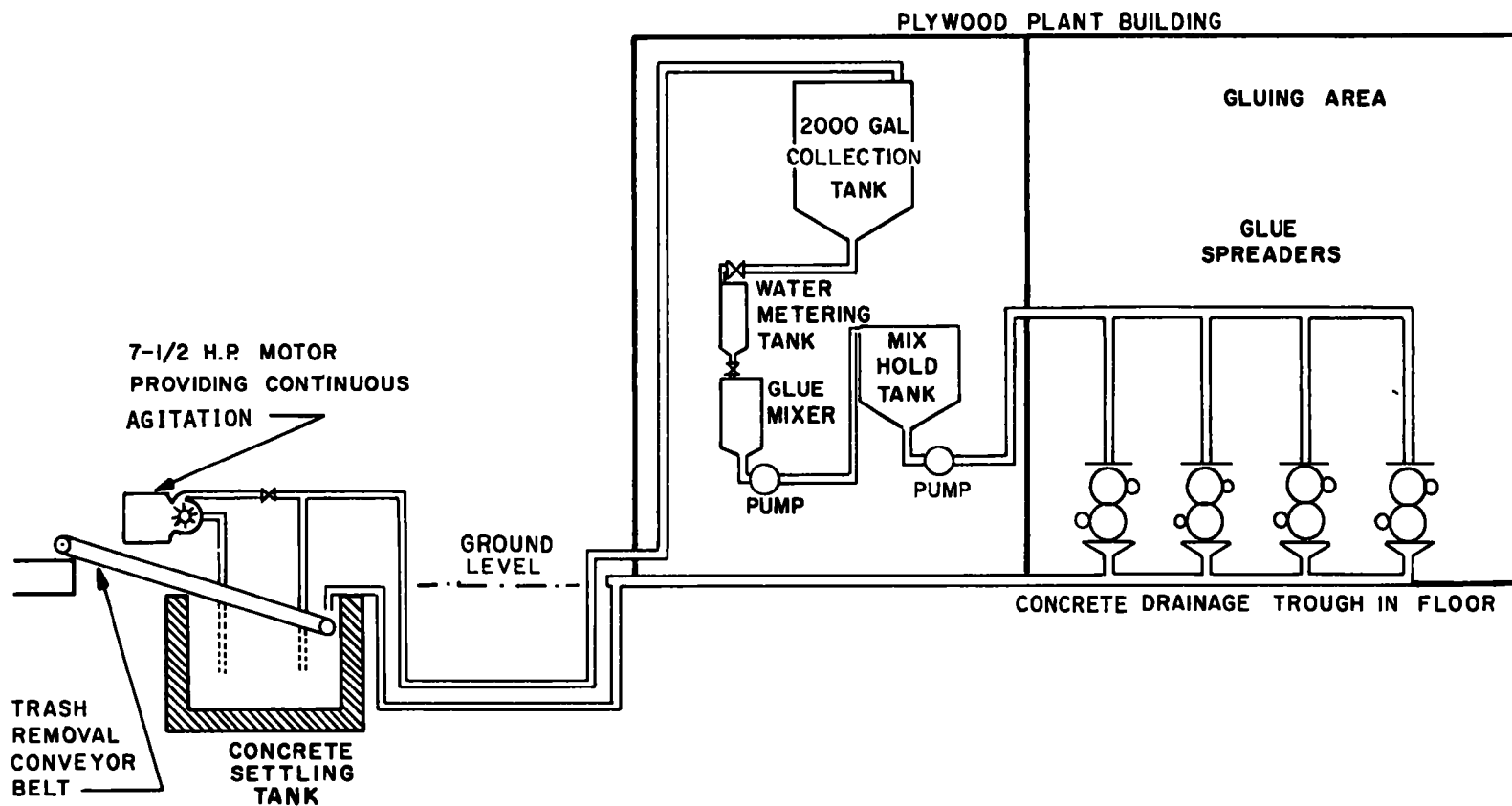


FIGURE 30 (19) - PLYWOOD PLANT WASH WATER REUSE SYSTEM

TABLE 40 (19)
THE ADHESIVE MIXES USED (CASCOPHEN 3566C)

Ingredients	Mix 1 ^a	Mix 2 ^b	Mix 3 ^c
Water	700	701	700
Phenofil	350	350	350
Wheat Flour	140	140	140
Mix 5 minutes			
W-156V Resin	220	220	220
Mix 2 minutes			
50% Caustic Soda	131	75	100
Mix 15 minutes			
W-156V Resin	2,178	2,156.5	2,163.5
Mix 5 minutes			
TOTAL	3,719	3,642.5	3,673.5
Resin Solids in Mix	25.7%	25.7%	25.7%

^aControl mix - clean water used for mix.

^b20:1 dilution of Mix 1 used for mix water - pH 11.5

^c30:1 dilution of Mix 1 used for mix water - pH 11.4

PART B: CONTROL AND TREATMENT TECHNOLOGY IN THE HARDBOARD INDUSTRY

DRY PROCESS HARDBOARD

Introduction

The small volumes of water discharged from dry process hardboard mills and the variation of waste sources from mill to mill have resulted in little new waste treatment technology being developed. In general, due to the small volumes of wastewater generated, the major treatment processes have been limited to oil-water separation, waste retention ponds, or perhaps spray irrigation.

The major wastewater source in one particular mill may be a zero discharge source in another mill. Inplant modifications to reduce, eliminate, or reuse wastewater flow can greatly affect total wastewater discharge from any mill. By inplant modifications and containment on site, zero discharge can be achieved in the dry process hardboard industry.

Inplant Control Measures and Technology

Log Wash: Only two mills out of 16 existing mills reported washing logs. One mill which washes logs has zero discharge of all its waste through impounding and land irrigation. The second mill uses approximately 82 cubic meters (21,600 gallons) per day for log washing which is discharged directly to a stream without treatment. Log washwater can be successfully reused by settling with only a small percentage of blowdown to remove accumulated solids. The blowdown from log washwater recycle systems can be disposed of by impounding or land spreading.

Chip Wash: At the present time, there are no dry process hardboard mills which report washing chips, however, several indicate plans to install chip washing in the future. Until such time as chip washers are installed and experience gained, no technology is available in the dry process hardboard industry for treatment of this waste stream. Predicted wastewater discharges from a chip wash system are 18.9 to 37.8 cubic meters (5,000 to 10,000 gallons) per day which could be disposed of by impounding or land spreading.

Six mills out of the total of 16 dry process hardboard mills report zero discharge from their resin systems. Several other mills report a waste discharge of less than 750 liters (200 gallons) per day. All hardboard mills use essentially the same types of resin (phenolic or urea formaldehyde). Taking into consideration that several mills already have zero discharge and that many plywood mills using the same resin have zero discharge, there is no reason all dry process hardboard mills cannot have zero discharge from their resin systems.

Caul Wash: Five mills report no caul washwater discharge for one of several reasons; the two most commonly given are: they do not use cauls or the water usage is so small that it is insignificant. Those mills reporting discharges of caul washwater average only some 750 liters (200 gallons/day). This low quantity of water can be neutralized as needed, then disposed of by impounding or land spreading.

Housekeeping: Housekeeping washwater is a miscellaneous wastewater flow which varies from mill to mill. Several mills report no housekeeping washwater as all cleaning inplant is done by sweeping and vacuum cleaning. At least two mills have waste flow from their press pit which usually contains oil. This wastewater can be eliminated by preventing condensate water from entering the press pit and by reducing hydraulic fluid leaks. Housekeeping wastewater can be either totally eliminated or, if water is used, held on site by impounding and spray irrigation.

Cooling Water: Cooling water is by far the major wastewater flow from dry process hardboard mills. Cooling water is used in such unit processes as refiner seal water cooling systems, air compressor cooling systems, and resonance frequency generator cooling systems. Use of cooling water varies widely but is consistently less than 380 cubic meters (100,000 gallons) per day. Cooling water can be recycled through cooling towers or cooling ponds. Blowdown from these areas could be used for log washing or chip washing.

Humidifier: Hardboard must be brought to a standard moisture content after dry pressing. This is done in a humidifier unit in which a high moisture and temperature is maintained. Nine mills report no water discharge from humidification units, while one mill reports a volume of less than 11 cubic meters (3,000 gallons) per day. It has been proven that humidifiers can be operated with zero discharge, therefore, all dry process hardboard mills should achieve zero discharge from this source.

Finishing: All dry process hardboard mills report zero discharge from finishing operations. Concern was indicated by industry with the potential of new technology causing wastewater flow from the finishing operation. For example, air pollution control regulations may make it necessary to switch from oil based paints to water based paints, in which case a potential wastewater source could exist. At the present time there is zero discharge from finishing operations. Until such time as technology changes create wastewater discharges from this source, there should be zero discharge.

Identification of Water Pollution Related Operation and Maintenance Problems At Dry Process Hardboard Mills

The water pollution resulting from dry process hardboard mills is directly related to wastewater flow and concentration, which, in turn, is influenced by operation and maintenance problems in each mill. The decision to wash logs or chips by a mill is a result of the effect of dirt and sand on inplant machinery. High maintenance cost resulting from abrasion of refiner plates, etc., make it desirable to wash logs and chips. Quantities of extraneous material on logs depend upon harvesting and storage operations, and therefore, directly affect wastewater flow composition.

The operation and maintenance of the resin system affects wastewater flow. Most hardboard mills and numerous plywood mills using similar resins are able to operate with zero discharge from their resin systems. Simple modification of inplant equipment or maintenance procedures should eliminate the resin system as a source of wastewater flow.

Caul washing, a minor wastewater source, is an inplant process that is affected by operation. Cauls are soaked in tanks containing sodium hydroxide and other cleaning agents. After soaking they are rinsed and put back into use. The method of operation of this cleaning system can greatly reduce the water usage and therefore the quantities of water to be discharged. The resulting low volumes of water (less than 750 liters [200 gallons] per day) can be easily discharged onsite.

Housekeeping practices vary widely from mill to mill with resulting effects on wastewater discharge. Several mills are able to perform clean up operations without having wastewater being discharged. Other mills use water for clean up operations because of the ease and efficiency of water cleaning. Modification of inplant housekeeping procedures can

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minimize water usage with resulting zero discharge from this source.

The press pit (a sump under the press) can collect oil, fiber, and condensate water. The method of clean up of the press pit can significantly reduce waste from this process. Modifications can be made to reduce or eliminate condensate water so that an oil/water emulsion will not be formed.

WET PROCESS HARDBOARD

Introduction

There is no single scheme currently being used to treat wastewater discharges from wet process hardboard mills. The major treatment and control methods presently being used include water recycle, filtration, sedimentation, coagulation, evaporation and biological oxidation processes such as lagoons, aerated lagoons, and activated sludge processes.

The treatment and control methods presently utilized in any one mill have been influenced by pressure from regulatory agencies, land availability, access to city sewer, and individual company approach to wastewater control.

Inplant Control Measures and Technology

Raw Materials Handling: There were no mills reporting washing logs; however, if logs were washed, a simple recirculation system could be installed to eliminate discharge from this source. This recirculation system would consist of a sedimentation basin or pond to catch the washwater and allow the removal of suspended solids. Pumps preceded by screens would recirculate the water for log washing. Accumulated deposits in the sedimentation basin or pond would be removed as needed and disposed of as landfill. Chip washing, if practiced, could be eliminated as a wastewater source in a similar manner.

Process Water: The major source of wastewater flow and concentration comes from discharging the process water. This includes fiber preparation, mat formation, and pressing. As has been previously discussed, the source of organic material in the process water is from the solution of wood chemicals. The quantity of organics released is directly dependent upon wood species, cooking time, and temperature.

It has been suggested that a decrease in BOD load can be made by reducing the cooking or preheating temperature at the expense of higher energy consumption in the refiners. Little research

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has been done in this area, but it should be stated that only a portion of the BOD can be eliminated in this manner.

Assuming that chips contain 50 percent fiber and must be diluted to 1.5 percent fiber prior to mat formation, for every ton of dry fiber processed, 60.5 cubic meters (16,000 gallons) of water is needed for dilution. The obvious procedure to obtain this quantity of water and prevent discharge of organic material is to recycle all of the process water.

There are several limiting factors preventing total recycle of process water, including temperature, soluble organics, and build up of fines. Temperature of process water can be controlled by the installation of a heat exchanger. At least two mills report the use of shell and tube heat exchangers to control process water temperature.

Soluble organics are the most difficult to control in the wet process. The explosion process utilized by two Masonite mills produce greater quantities of soluble organics than other processes because of the higher temperature and pressure. Due to the large quantities of organic material released from the wood, Masonite has installed evaporation systems to reduce the quantities of organics discharged in their wastewater. Figure 31 shows a schematic diagram of one of these systems. In this system counter-current washers are used to remove a major portion of the organics from the fiber prior to dilution and mat formation. This waste stream passes through a clarifier and is evaporated. The concentrated organic stream from the evaporator is sold as cattle feed or it can be incinerated, and the condensate is either reused as process makeup water or discharged as a wastewater stream. Process water from the felter and the press passes through a clarifier to remove settleable solids. All solids are reused to make board, while the overflow is used for fiber wash or dilution water. The total discharge from this mill without biological treatment is only 3.25 kilograms per metric ton (6.5 pounds per ton).

The more conventional cooking processes release less organics and it is questionable whether or not process water soluble concentrations can be increased to a high enough level to make evaporation economical without inplant modifications. However, at least one mill in Sweden is presently evaporating excess process water (26). One possibility to decrease the volume of wastewater without increasing the concentration of soluble substances in the process water system at the same time is to arrange some kind of pre-pressing of the pulp to remove the concentrated organics before they enter the main process water stream. An arrangement of this type is shown in Figure 32, where a pre-press has been inserted

FIGURE 31 - INPLANT TREATMENT AND CONTROL TECHNIQUES AT MILL NO. 7

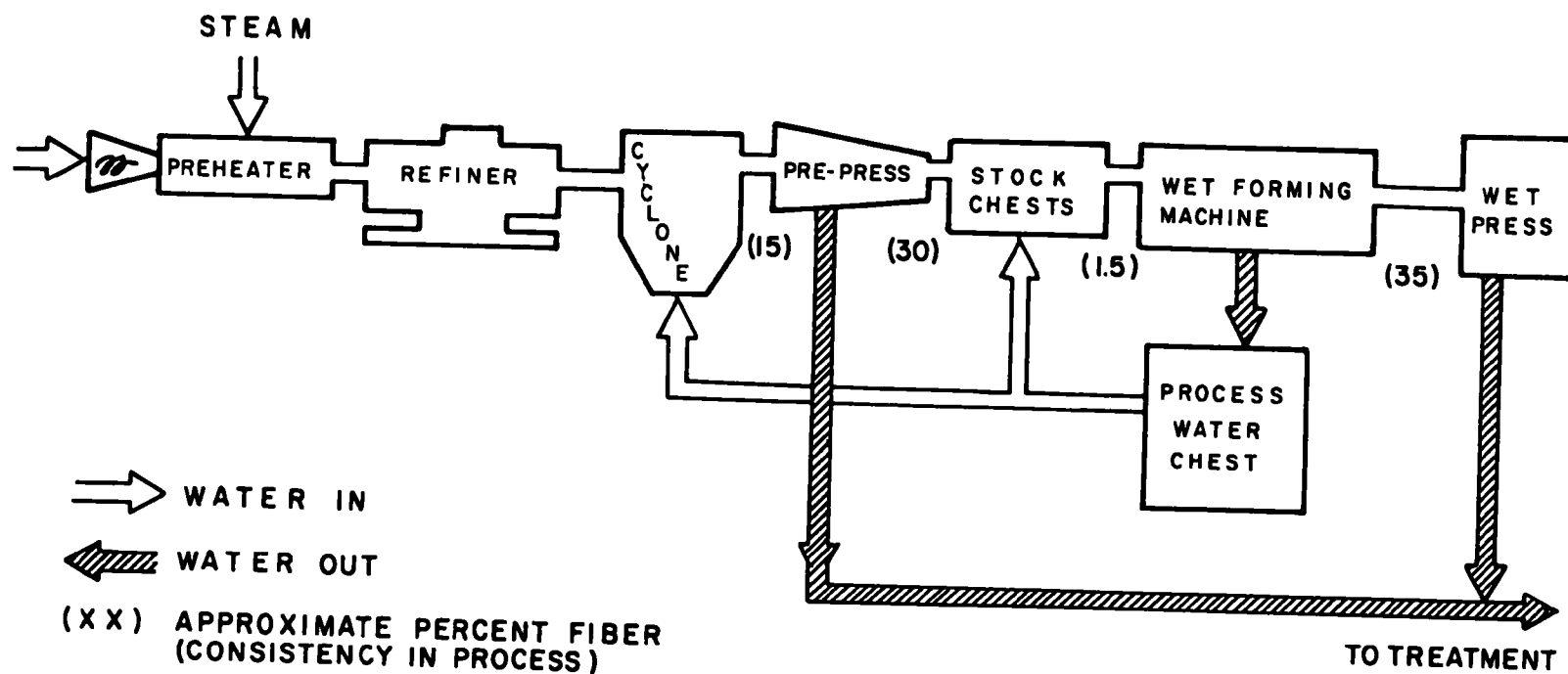


FIGURE 32 - TYPICAL WET-PROCESS HARDBOARD MILL WITH PRE-PRESS

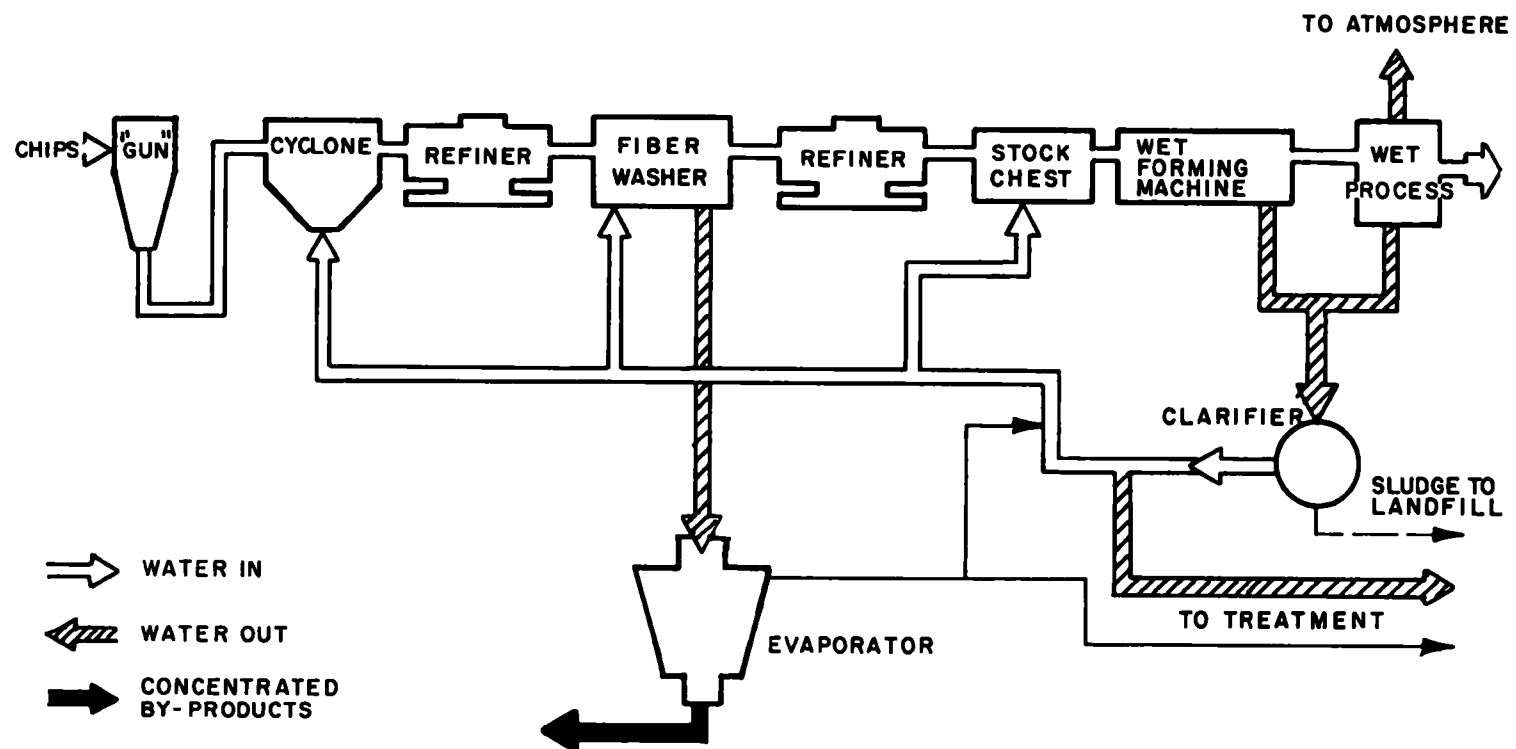


FIGURE 33 - INPLANT TREATMENT AND CONTROL TECHNIQUES AT MILL NO. 3

after the cyclone. If the process water system is completely closed, all soluble substances with the exception of those deposited in the hardboard would be contained in the wastewater leaving the pre-press. The concentration of soluble substances in this wastewater depends on the amount of substances dissolved during the pre-heating, on the volume of wastewater leaving the pre-press, and finally on the efficiency of the pre-press, i.e., the consistency of the pulp leaving the press. The efficiency of such a system can be increased by installing two or three presses in series. A system of this type can significantly reduce the concentration of soluble organics in the process water, allowing increased recirculation rates.

Suspended Solids: Suspended solids within the process stream should be controlled to limit the build up of fines which reduce water drainage during mat formation and to limit the suspended solids discharged in the raw wastewater. If inplant treatment methods such as evaporation are used, the suspended solids concentrations entering these processes must be controlled. Suspended solids removal systems consist primarily of gravity settling, screening, filtration, and flotation.

Only two mills utilize sedimentation tanks for removal of suspended solids in process water prior to recycle. Both of these mills utilize the explosion process. These systems are shown in Figures 31 and 33. Process water from both mat formation and final pressing is passed through a clarifier and reused in the process. Other mills utilize gravity separators in their final wastewater treatment scheme, but do not recycle back to process. In one of the two mills utilizing sedimentation to remove solids from the process water, the settled solids are returned to the process and become part of the board. The other mill has not been able to do this due to a different species of raw material.

Filters can accomplish the same liquid solid separation as gravity separation. The efficiency of such filters varies widely depending upon flow rates, suspended solids concentrations, and types and sizes of solids. Representative data for filter efficiency may be found in Table 41, below.

TABLE 41

REPRESENTATIVE PROCESS WATER FILTER EFFICIENCIES

Mill	Suspended Solids (mg/l)	
	Before Filter	After Filter
O	1000 - 3500	80 - 250
P	170 - 1000	30 - 150
Q	1000 - 1300	280 - 330
R	230 - 620	90 - 145

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One of the most interesting systems utilized for controlling suspended solids is a patented process developed in Finland at the Savo Oy Mill. This system is a chemical treatment system followed by sedimentation and/or flotation. The chemical treatment includes adjustment of the pH value, addition of chemicals for coagulation, followed by removal of suspended solids and some dissolved and colloidal solids.

There are two mills in the United States presently using this system to some degree. Typical data from the Savo system from one of these mills is shown below:

	<u>Influent</u> (mg/l)	<u>Effluent</u>	<u>Percent Reduction</u>
COD	7775	4745	39
SS	750	48	94
TDS	5525	4788	13
Soluble Organics	4285	3362	22
Volatile Suspended solids	740	46	94

An advantage reported from the use of the Savo system is that all sludge from the system can be reused in the board. One mill has been able to reduce its wastewater flow to 2.3 cubic meters (611 gallons) per ton and BOD discharge to 8.5 kilograms per metric ton (17 pounds per ton). This low discharge rate and concentration is the result of inplant modifications and does not include any end of line treatment. Figure 34 shows a schematic diagram of this process.

End Of Line Wastewater Treatment

The existing end of line waste treatment facilities consist primarily of screening followed by primary and biological treatment. All of the existing nine wet process hardboard mills utilize primary settling basins either within the process or as part of their final waste treatment facilities. In order to protect the primary settling units from sludge loading and to remove as much fiber as possible, screens are generally placed ahead of the primary units. Fiber removed by screening is disposed of by landfill or returned to process.

Three of the nine wet process mills were either sampled by Environmental Science and Engineering, Inc., or the mill reported treatment efficiencies across their primary clarifiers. This data is shown in Table 42. Although this data

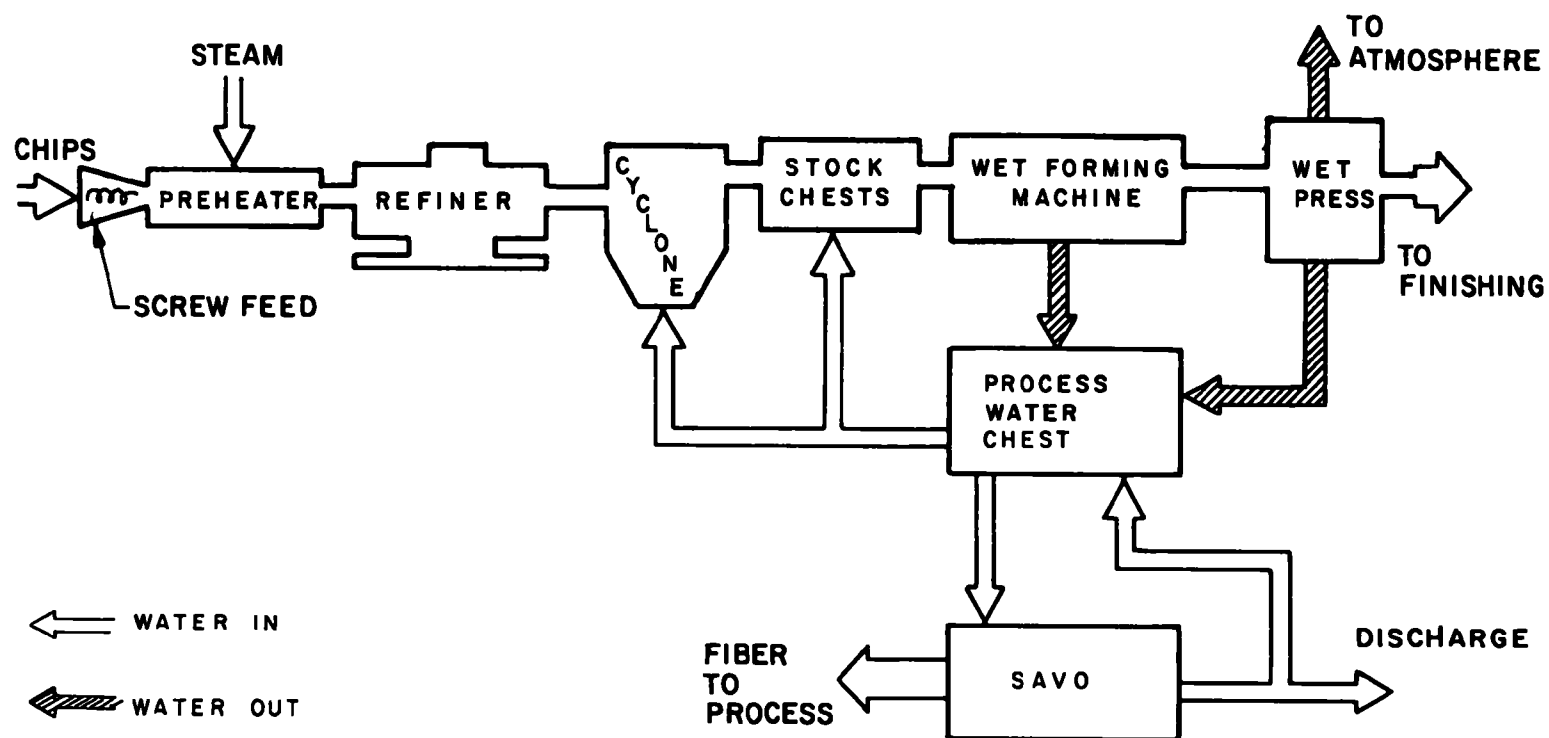


FIGURE 34 - TYPICAL WET-PROCESS HARDBOARD MILL WITH SAVO SYSTEM

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TABLE 42
PRIMARY SETTLING TANK EFFICIENCY

Mill	BOD In mg/l	k/kg	BOD Out mg/l	k/kg	Percent Removal	SS In mg/l	k/kg	SS Out mg/l	k/kg	Percent Removal
4	2400	28.5	2400	28.5	0	1650	19	178	2	89
5	3500	32	3300	30.5	5	430	4	154	1.4	69
6	6000	42.2	3900	28	35	1440	10	450	3.25	68

may be typical of the treatment efficiency that existing facilities are achieving, it is not representative of the efficiency that can be obtained through proper design and operation. The three mills listed in Table 42 utilized settling ponds as primary clarifiers. These ponds are allowed to fill with solids before being dredged for solids removal. Accumulated solids undergo anaerobic decomposition causing an increase in BOD and suspended solids (SS) in the effluent.

A properly designed clarifier with a mechanical sludge collector and continuous sludge removal can be expected to obtain approximately 75 to 90 percent SS removal and 10 to 30 percent BOD removal.

The pH of wet process wastewater varies from 4.0 to 5.0. The pH must be adjusted to near 7.0 to obtain satisfactory biological degradation. The pH may be adjusted by either the addition of lime or sodium hydroxide.

Wet process hardboard mill wastewater is deficient in nitrogen and phosphorus. These chemicals must be added in some form to obtain rapid biological degradation of the waste. The most commonly used source of nitrogen is anhydrous ammonia, and the most commonly used source of phosphorus is phosphoric acid.

Existing biological treatment systems consist of lagoons, aerated lagoons, activated sludge, or a combination of these. The type of system presently used at each mill is shown below:

<u>Mill No.</u>	<u>End Of Line Treatment System</u>
1	Primary settling pond - aerated lagoon - secondary settling pond.
2	Primary settling pond - aerated lagoon - secondary settling pond.
3	Primary clarifier - activated sludge - aerated lagoon.
4	Primary settling pond - activated sludge - aerated lagoon.
5	Primary settling pond - activated sludge - lagoon or spray irrigation.
6	Primary settling pond.
7	No treatment.
8	No treatment.
9	Aerated lagoon.

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Table 43 shows the treatment efficiency of the five mills which presently have biological treatment systems in operation. The values shown are average values and do not define the variations in effluent that can be expected from biological systems. It should be noted that the values shown for mills No. 1, 2, and 5 include the efficiency of the primary settling units while for mills No. 3 and 4 the efficiency is across the biological unit alone.

Mills No. 1 and 2 utilize aerated lagoons. Their treatment efficiencies for BOD removal have averaged 70 and 79 percent, respectively. Mills 3, 4, and 5 utilize some variation of the activated sludge process and their average efficiencies for BOD removal are 97, 77, and 95 percent, respectively. Mill No. 4, whose activated sludge system averages only 77 percent efficiency for BOD removal, is actually not operated as an activated sludge system as there is no sludge waste from the system. Therefore, the system is more representative of an aerated lagoon system.

The efficiency of solids removal across the biological system for all mills is essentially zero. There are several reasons for this. Biological solids produced in waste treatment systems treating hardboard wastewater are difficult to settle and dewater. There is presently no economical method that is satisfactory for handling waste activated sludge from these biological systems. One mill attempts to utilize a centrifuge for sludge thickening prior to incineration, however, the system is highly variable in its efficiency and frequently excess sludge has to be hauled by tank trucks to a land spreading area.

Several mills in the United States and Europe have put excess sludge back into the process water to become part of the board (21). The quantity of sludge which can be reclaimed in this manner is variable from mill to mill depending upon a variety of factors. It is known that the addition of sludge to the board increases the water absorption, reduces the drainage rates, and make it necessary to add additional chemicals to compensate for the sludge addition (27).

At least one mill (mill No. 5) is disposing of its waste sludge by spray irrigation. Waste sludge is pumped to an aerobic digester, then the digested sludge is pumped to a nearby spray irrigation field. Land irrigation or sludge lagooning has the advantage of making it unnecessary to dewater the sludge prior to disposal.

The difficulty in handling waste activated sludge from the activated sludge treatment of wet process hardboard wastewater leads to a build up of solids within the system with a resulting discharge of solids in the effluent. Weather conditions (temperature)

TABLE 43

TREATMENT EFFICIENCY OF BIOLOGICAL SYSTEMS

Mill No.	BOD, kg/kg			SS, kg/kg		
	Influent	Effluent	Percent Removal	Influent	Effluent	Percent Removal
*+1	33	7	79	10	9	10
*+2	50	15	70	--	--	--
*3	23	0.6	97	1.4	3.6	0
*4	28.5	6.45	77	0.7	4.2	0
*+5	32	1.55	95	1.4	3.6	0
<hr/>						
	BOD, mg/l			ss, mg/l		
**+1	720	151	79	220	198	10
**+2	1310	393	70	--	--	--
*3	1800	54	97	114	295	0
*4	2400	552	77	60	360	0
*5	3500	175	95	151	388	0

+ Includes efficiency of primary settling
 ** Aerated lagoons
 * Activated sludge

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are also reported to have an effect on the settling rate of biological solids in both aerated lagoon systems and the activated sludge system (28).

Figures 35, 36, and 37 show the variations in effluent BOD and suspended solids for mills No. 2, 3, and 4, respectively. Values shown are monthly averages and do not necessarily indicate a direct relationship between suspended solids and season (temperature). The main information presented by these graphs is that for either the aerated lagoon or activated sludge average, suspended solids in the effluent can be expected to be 250 milligrams per liter.

Table 44 shows an example of an aerated stabilization basin (ASB) or aerated lagoon performance related to temperature. This table is for a biological system treating paperboard waste; however, similar effects are experienced in the wet process hardboard industry. The main difference, however, is that the quantity of solids can be expected to be several times greater.

Summary of Waste Treatment Control Technology

Water Reuse: The existing nine wet process hardboard mills presently practice considerable recycle of wastewater. These systems include:

- (1) Process water recycle with blowdown to control suspended and dissolved organics. This blowdown may occur in a pre-press, from the wet or hot press, or from the process water chest.
- (2) Process water recycle through a primary clarifier with blowdown of some clarifier effluent and recycle of some or all sludge to the stock chest.
- (3) Process water recycle through a primary clarifier with blowdown being evaporated and some evaporator condensate being utilized for make-up. In the explosion process all fiber wash-water is discharged through a primary clarifier prior to evaporation.
- (4) Process water recycle with blowdown passing through a chemical coagulation system. Plant of coagulated waste recycled back to process and all sludge returned to stock chest.

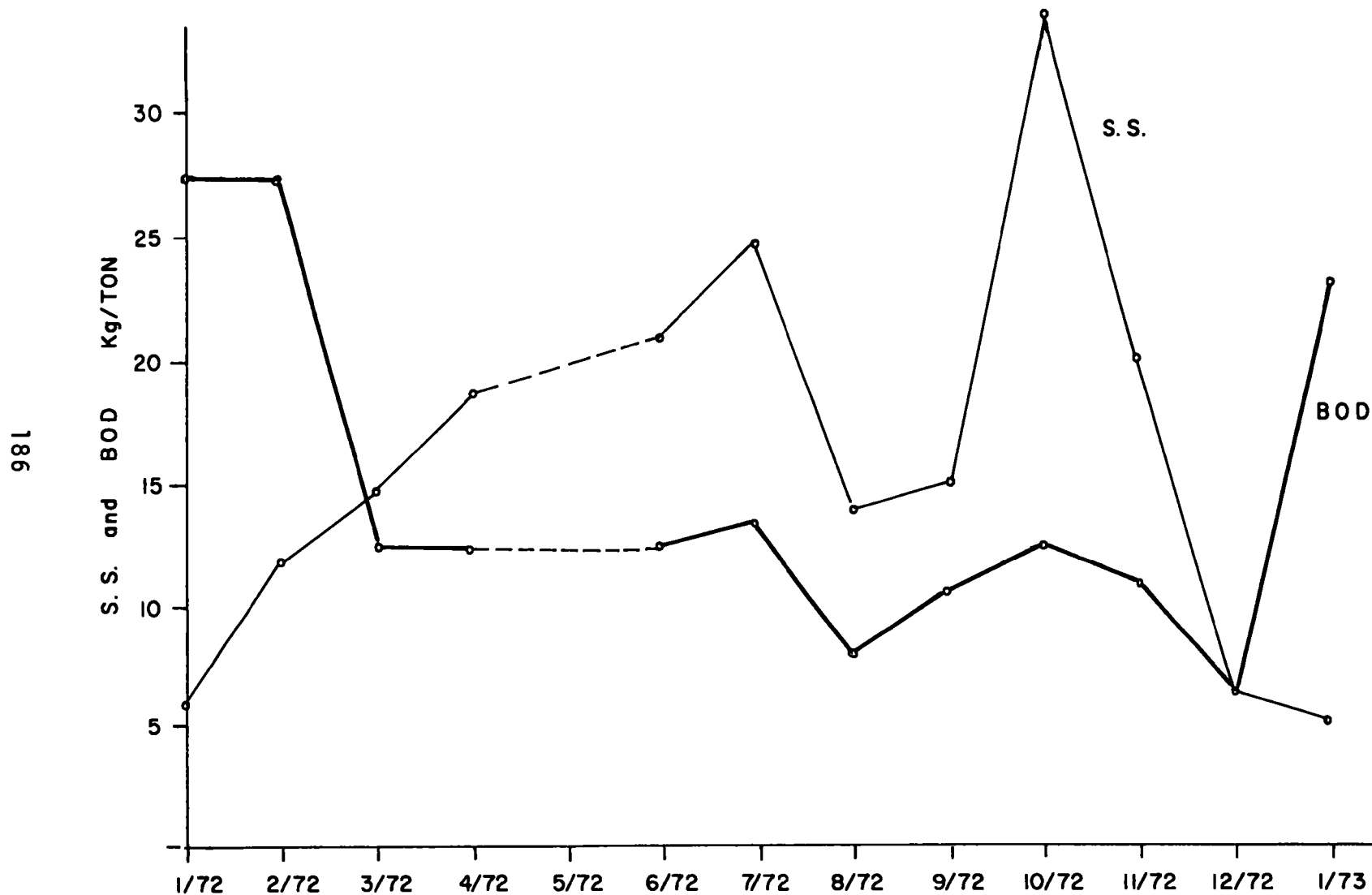


FIGURE 35 - VARIATION OF EFFLUENT BOD AND SUSPENDED SOLIDS
AS A FUNCTION OF TIME FOR MILL NO. 2

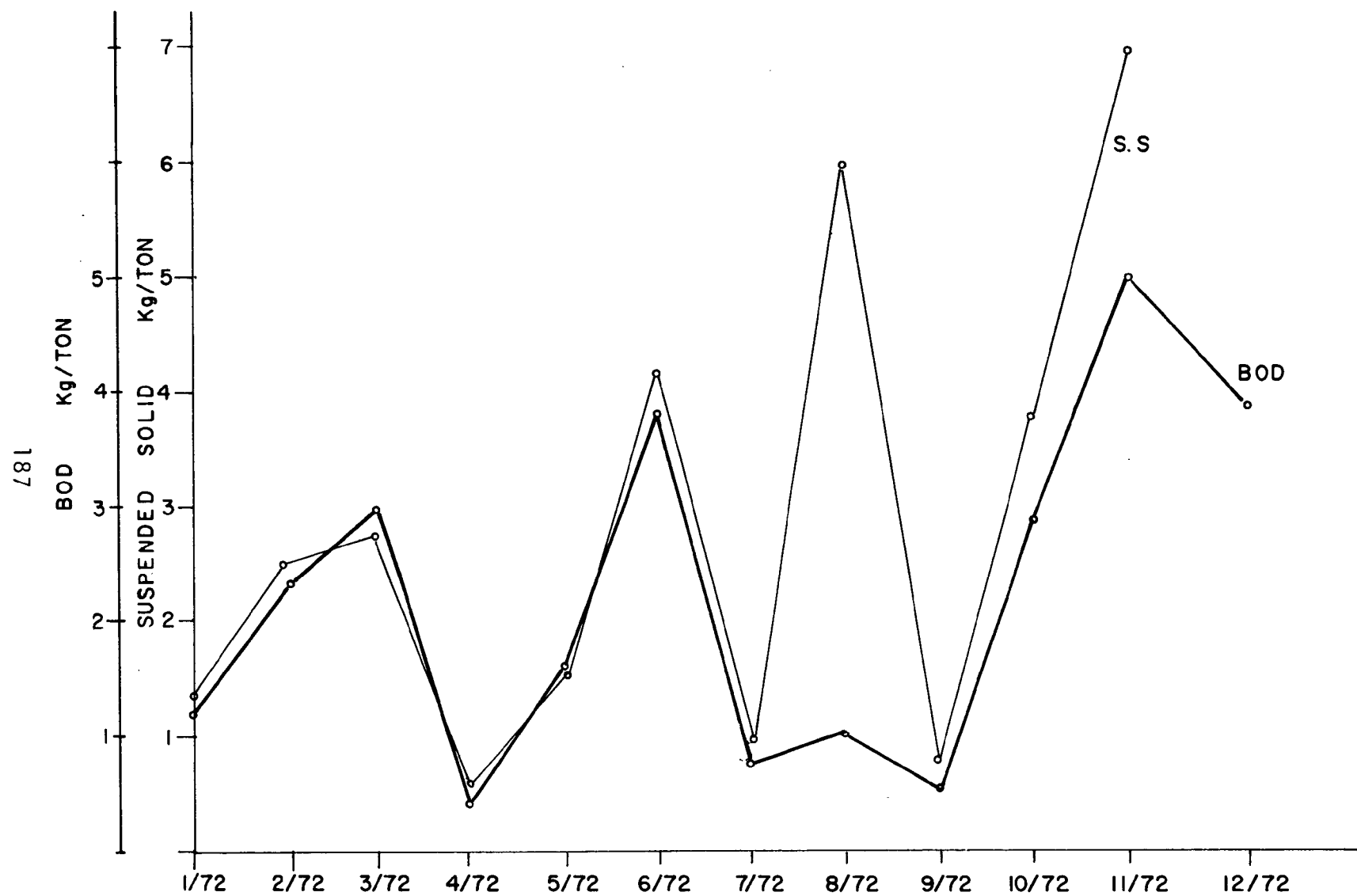


FIGURE 36 - VARIATION OF EFFLUENT BOD AND SUSPENDED SOLIDS AS A FUNCTION OF TIME FOR MILL NO. 3

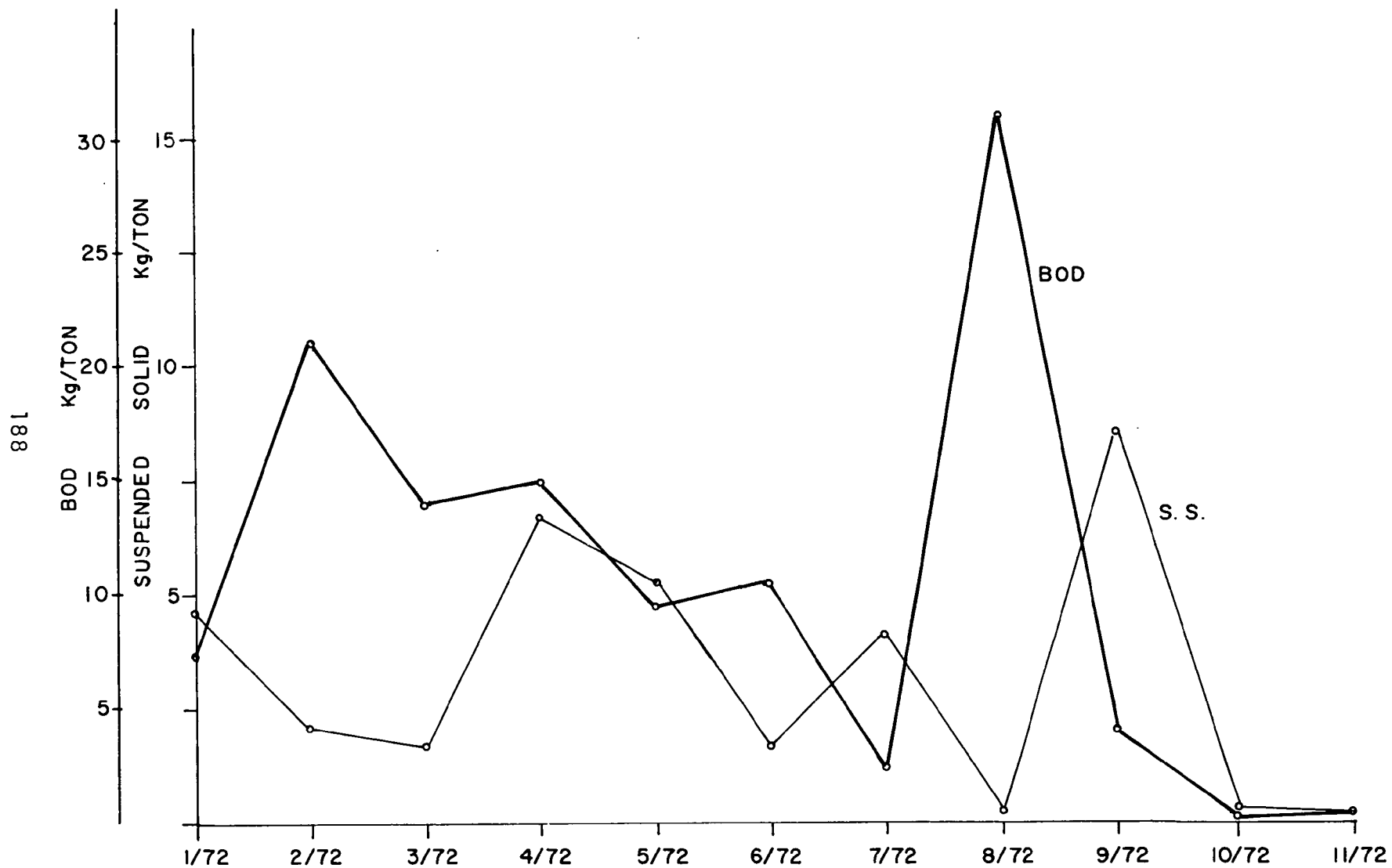


FIGURE 37 - VARIATION OF EFFLUENT BOD AND SUSPENDED SOLIDS
AS A FUNCTION OF TIME FOR MILL NO. 4

TABLE 44 (28)

EXAMPLE OF AN ASB SYSTEM PERFORMANCE RELATED TO TEMPERATURE

PAPERBOARD*		
Average Monthly Temperature (°C)	Effluent BOD5 (mg/l)	Conc. SS (mg/l)
21	11	22
21	17	21
19	22	23
17	17	17
17	11	16
11	20	29
7	40	56
5	29	61
5	38	31
3	42	42

* Includes long-term
settling

Wastewater Treatment: End of pipeline treatment technology presently consists of:

- (1) Screening
- (2) Primary clarification
 - a. settling ponds
 - b. mechanical clarifiers
- (3) pH control
- (4) Nutrient addition
- (5) Aerated lagoons
- (6) Activated sludge process
- (7) Oxidation lagoons

Sludge Handling: Systems utilized for disposal of waste sludge include:

- (1) Reuse in manufacture of hardboard
- (2) Landfill
- (3) Spray irrigation
- (4) Incineration

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PART C: CONTROL AND TREATMENT TECHNOLOGY IN THE WOOD PRESERVING INDUSTRY

STATUS OF TECHNOLOGY IN INDUSTRY

The technological base of the wood preserving industry is generally quite weak by comparison with most other industrial categories. Relatively few companies have employees with the engineering and other technical skills needed to utilize effectively current or potential developments in waste treatment and management, or to adopt processing methods that would minimize waste loads. Engineering services required by individual plants are most commonly performed by consulting firms. This situation is ameliorated somewhat by the American Wood-Preservers' Association through the activities of its technical committees and publication of its Proceedings, both of which serve to keep its members advised of current developments. Membership in the Association represents plants that account for an estimated 90 percent of the total production of the industry.

STATUS OF POLLUTION CONTROL IN INDUSTRY

The comments and data which follow summarize the status of pollution control activities in the wood preserving industry, as revealed by a recent survey of 377 plants (1). The data are based on results obtained from 207 plants.

Disposition Of Wastewater

The approach to the pollution problem taken by many treating plants is to store their wastewater on company property (Table 45). This is by far the most popular method of handling wastewater, accounting for 42 percent of the plants reporting. Seventeen percent are still releasing their wastewater with no treatment, while 14 percent of the plants are discharging to sanitary sewer systems. Of the latter group, 63 percent are discharging raw waste to sewers, while 37 percent are giving the waste a partial treatment before releasing it. Only 9 percent of the 207 plants responding to the survey presently are giving their waste the equivalent of a secondary treatment before releasing it. Eighteen percent either have no wastewater or are disposing of it by special methods such as evaporation or incineration.

There were no unusual trends when the data on methods of disposal of wastewater were broken down by region (Table 46). However, it is of interest to note that a high proportion of the plants in the West dispose of their waste by special methods, or have no waste stream.

Compliance With Standards

Sixty percent of the plants surveyed indicated that they currently meet state and federal water pollution standards (Table 47). Twenty-five percent stated that they do not meet these standards and 15 percent do not know whether they do or not. A higher portion of plants in the West

TABLE 45 METHOD OF DISPOSAL OF WASTEWATER BY WOOD
PRESERVING PLANTS IN THE UNITED STATES

Disposal Method	Number of Plants	Percent of Plants
Release - No Treatment	35	17
Store In Ponds	86	42
To Sewer - Untreated	19	9
To Sewer - Partial Treatment	11	5
Secondary Treatment	18	9
Other*	38	18
*No wastewater, incineration, etc.		

TABLE 46 METHOD OF DISPOSAL OF WOOD PRESERVING
WASTEWATER BY REGION

Region	Release Untreated	Store	Sewer	Treat	Other
Southeast	13	29	12	5	17
Southwest	5	20	6	4	5
Atlantic Coast	9	10	4	4	4
Lake and Northeast	2	17	6	5	2

and Southwest currently meet standards than in other regions of the country. However, the differences among regions are not great, ranging from 57 percent of the plants in the Atlantic Coast region to 73 percent in the West.

There was considerable evidence of confusion on the part of some respondents regarding the question of compliance or non-compliance. A number of plants that are currently releasing their wastewater with no treatment stated that they meet federal and state standards. Conversely, a number

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of plants that retain their waste on company property or release it into sanitary sewer systems stated that they do not meet standards, or do not know whether they do or not.

TABLE 47 COMPLIANCE WITH STATE AND FEDERAL WATER STANDARDS
AMONG WOOD PRESERVING PLANTS IN THE UNITED STATES

Compliance	Number of Plants	Percent of Plants
Yes	126	60
Don't Know	29*	15
No	52	25
*Includes Non-Responses		

Table 48 gives a breakdown of what the plants that do not now meet the standards plan to do with their wastewater. Nationally, roughly one-third of the plants have made no plans. Most of the remainder plan either to construct on-site treating facilities for their wastewater (31 percent) or discharge it to sewer systems (19 percent). Twelve of the 81 plants involved indicated that they would dispose of their waste by other means. Incineration and evaporation were two of the "other" methods mentioned.

TABLE 48 PLANS OF WOOD PRESERVING PLANTS NOT IN COMPLIANCE
WITH WATER STANDARDS -- UNITED STATES

Plan	Number of Plants
None	29
Discharge To Sewer - Raw	5
Discharge to Sewer - Oil Removal	6
Discharge To Sewer - Oil + Phenol Removal	4
Construct On-Site Treating System	25
Other	<u>12</u>
TOTAL	81

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Over a third of the plants not meeting standards are located in the Southeast. Most of these plants are planning to treat their waste on site or discharge it to a sewer system. Half of the plants in the West and Lake and Northeast states indicated that they have made no plans to meet applicable standards.

Of the plants that have installed or plan to install secondary treating facilities, 70 percent will use either oxidation ponds or soil percolation (Table 49). Only 14 plants (about 16 percent) have elected to use trickling filters or activated sludge. The choices of the various methods of treatment were generally uniform among regions, with no single region showing a strong preference of one method over another (Table 50).

TABLE 49 TYPE OF SECONDARY WASTEWATER TREATING FACILITIES
INSTALLED OR PLANNED BY WOOD PRESERVING PLANTS IN U.S.

	Number of Plants
Oxidation Pond	31
Trickling Filter	8
Activated Sludge	6
Soil Percolation	31
Chemical Oxidation	3
Other (incineration)	<u>10</u>
TOTAL	89

PLANT SANITATION

By plant sanitation is meant those aspects of plant housekeeping which reduce or eliminate the incidence of water contamination resulting from equipment and plumbing leaks, spillage of preservative, and other similar sources. Lack of attention to these sources of pollution is a serious problem at many plants that will require remedial action. Its origin lies in the lack of appreciation of the fact that even small losses of preservative can largely negate waste management practices directed toward collecting and treating process water.

TABLE 50 TYPE OF SECONDARY WASTEWATER TREATING FACILITIES INSTALLED OR PLANNED BY WOOD PRESERVING PLANTS BY REGION

Treatment	Region				
	SE	SW	AC	W	L&NE
Oxidation Pond	12	9	3	2	5
Trickling Filter	3	3	0	1	1
Activated Sludge	1	2	1	1	1
Soil Percolation	12	2	9	2	6
Chemical Oxidation	1	0	1	1	0
Other	0	4	0	6	0

Preservative Loss From Retorts

Areas under and in the immediate vicinity of retorts are the most important from the standpoint of plant sanitation. The camber in some retorts prevents the complete drainage of preservative from the retort upon completion of a charge. Consequently, when the retort door is opened to remove the charge, a quantity of preservative drains into pipe trenches or sumps under the retort where it becomes contaminated with dirt, storm water, and other types of preservatives. Most plants process the preservative through oil separators and thereby recover most of it. The better managed and equipped plants collect it in troughs as it drains from the retorts and transfer it to underground storage tanks.

Losses of preservative in the vicinity of the retort are of particular importance in salt-type treatments because they represent the major source of pollution. Many such plants are equipped to collect preservative spillage and wash water and reuse it as make-up water for fresh treating solutions.

Storm Water

Storm water becomes contaminated as it flows over areas saturated with preservative from spills and leaks. Areas of particular concern are those around and in the vicinity of treating cylinders, storage tanks, and separators. Because these areas are usually not large, it is practical to reduce the volume of storm water that must be treated by constructing dikes and drainage ditches around the areas to prevent uncontaminated water from flowing across them.

Preservative accumulation in the soil where treated stock is stored, although unavoidable, is another potential source of contaminated storm water. Storage yards frequently encompass large areas. Depending upon their topography, the problem of collecting all storm water from these yards for treatment may be a formidable one indeed, especially in regions of heavy rainfall. It is probable that no significant contamination of water occurs from this source. Thompson (29) analyzed storm water samples collected at various locations in storage yards of two commercial treating plants and found insignificant phenol and COD contents.

Equipment Leaks

Preservative losses from pipes and pumps contribute to the pollution problem at many plants. The early detection of leaks from these sources can best be accomplished by periodic and systematic checks of all pumps and plumbing employed in the transfer of preservatives.

TREATMENT AND CONTROL TECHNOLOGY

Wastewater treating facilities have been installed and are in operation at only about 9 percent of the estimated 390 plants in the United States (Table 45). Most of these facilities have been in operation for only a relatively short period of time. It follows that both experience in the treatment of wastewater from the wood preserving industry and the backlog of data on such operations is limited. This problem is lessened somewhat by studies and field experience in the treatment of petroleum wastes. Data from this industry are frequently directly applicable to the wood preserving industry because of the similarity of the effluents involved, particularly as regards phenol content, oil content and other parameters. Likewise, within the past three years laboratory and pilot-plant studies have supplied useful information on the treatment of effluents from wood preserving operations. Perusal of these sources, as well as information obtained from visits to and analyses of effluent samples from wood preserving plants that have effective waste treatment and management programs, provided the data on which this section is based.

Primary Treatments

Primary treatments for creosote and pentachlorophenol-petroleum wastewaters usually include flocculation and sedimentation. This process, as currently practiced at a number of plants, is normally carried out for one of two purposes: (1) to remove emulsified oils and other oxygen-demanding substances preparatory to secondary treatment, and (2) to render wastewaters acceptable to municipal authorities prior to releasing it into sanitary sewers. A few plants discharging their waste into city sewers apply primary treatments to reduce sewer charges levied by municipal authorities, rather than to meet specific influent limitations.

One of the principal benefits of primary treatments of oily wastewater is the reduction of the oil content of the wastewater to a level compatible with the secondary treating process that is employed. This is particularly important with those wastewaters containing emulsified oils, which normally cannot be removed by mechanical means. Flocculation treatments employing a suitable polyelectrolyte are quite effective in breaking emulsions and precipitating the oil. Reductions in oil content on the order of 95 percent are not unusual. Where the oil content of wastewater is not a serious problem, however, flocculation treatments preparatory to secondary treatment may not be necessary. The decision in this regard must be based on the relative cost of such treatments and that of providing sufficient secondary treating capacity to accommodate the additional COD loading that would normally be removed during primary treatment of the wastewater.

Primary treatments of wastewaters containing salt-type preservatives and fire retardants serve to precipitate heavy metals and thus make the waste amenable to biological treatment. The contractor is not aware of any plant that is currently applying a secondary treatment to this type of wastewater.

Wastewaters Containing Entrained Oils - It is the intermingling of the oils and water from the treating cycle and the condensate from conditioning operations that is responsible for most of the pollution problem in the industry. Oils account for most of the oxygen demand of the wastewater, serve as carriers for concentrations of pentachlorophenol far in excess of those attainable in oil-free water, and create emulsion problems. In a very real sense, control of oils is the key to pollution control in the wood preserving industry.

Recovery Of Free Oils - Most wood preserving plants have oil-recovery systems for reclaiming a high percentage of the oil that becomes entrained in water during treating operations. Apart from environmental considerations, this practice is and always has been done for economic reasons: it is less expensive to recover and reuse this oil than to buy new oil. With the passage of the Federal Water Pollution Control Act of 1965 and subsequent amendments, the contribution of non-recovered oils to the cost of treating wastewater has become an important consideration. Within the past five years many plants have added new oil-recovery systems or revamped existing ones.

Free oils are recovered from wastewater by gravity-type separators. Various designs are used. The most common ones are patterned after the API separator developed by the American Petroleum Institute (30). These are equipped to recover oils both lighter and heavier than water. Basically they consist of a horizontal tank divided into three or more compartments by strategically placed baffles which decrease turbulence. Heavy oils sink to the bottom where they are removed by a pump to a dehydrator, and

thence transferred to storage. Floating oils are removed by a skimmer. For pentachlorophenol-petroleum solutions, a simple tank or series of tanks with provisions for drawing off the oil that collects at the top and the water from the bottom is all that is required (31). Good practice dictates that separate effluent handling systems be installed for each preservative. However, many plants are not so equipped.

A few plants have installed air-flotation equipment to effect oil-water separation. In these units, all oil is brought to the surface of the water by bubbles created by saturating a portion of the wastewater with air under pressure and releasing it at the bottom of the flotation chamber. The oil is removed at the surface by a skimming device. Mechanical oil scavengers are also sometimes used to remove surface oils.

The percentage of entrained oils removed by oil-water separation equipment varies widely, depending in part upon whether or not the oil is in a free or emulsified form. Data on the percent efficiencies of several oil-separation processes, including the API separator, are given in Table 51. These data are based upon the treatment of petroleum refinery wastewater, but are probably applicable to other oily wastes. Separator efficiency is of course a function of detention time. The effect of this variable on oil removal is shown in Figure 38.

TABLE 51 EFFICIENCIES OF OIL SEPARATION PROCESSES (32)

	Source Of Influent	Percent Removal	
		Free Oils	Emulsified Oils
API Separator	Raw Waste	60 - 99	Not applicable
Air Flotation without Chemicals	API Effluent	70 - 95	10 - 40
Air Flotation with Chemicals	API Effluent	75 - 95	50 - 90
Chemical Coagulation and Sedimentation	API Effluent	60 - 95	50 - 90

Only free oils are removed in conventional oil-water separators. However, emulsions are broken by rotary vacuum filters and by centrifugation, both of which have been tested on wood preserving wastewater at a few plants in the South. Wastewaters containing emulsified oils frequently have oil contents in excess of 1000 mg/liter after passing through gravity-type separators (24). Oils in this form normally must be removed by primary treatments involving flocculation.

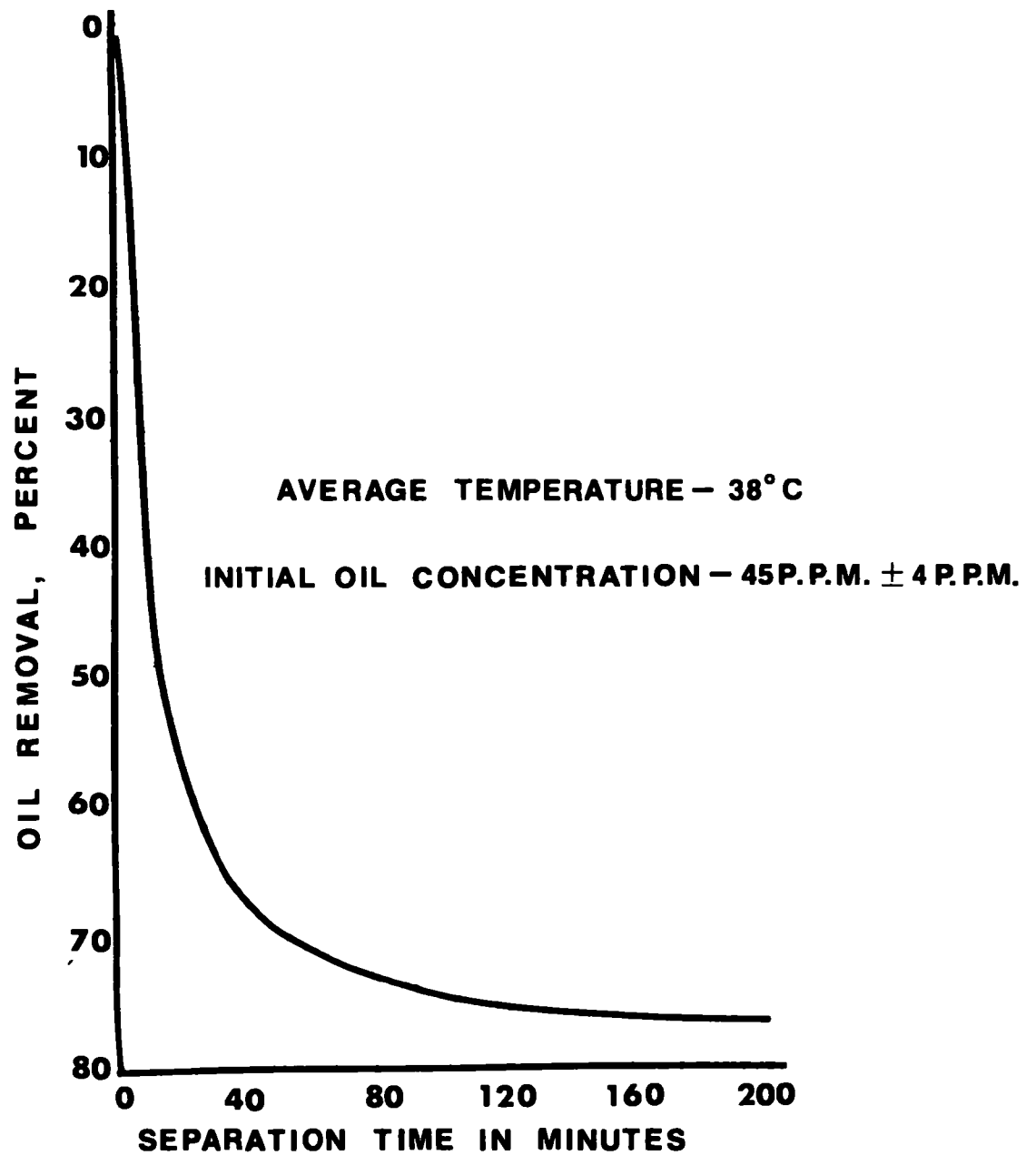


FIGURE 38 (33) - EFFECT OF DETENTION TIME ON OIL REMOVAL BY GRAVITY SEPARATION

The formation of oil-water emulsions is a particular problem where conventional steam conditioning is used and apparently results from agitation of retort condensate as it is expelled from the retort through a steam trap. Thompson (34) analyzed condensate samples collected alternately from a hole drilled near the bottom of a retort and from a pipe leading from the trap and found that only those samples that had passed through the trap contained emulsified oils. Some plants treating with pentachlorophenol-petroleum solutions have greatly reduced the problems of emulsion by replacing high-speed pumps involved in preservative transfer with low-speed, high-volume models.

Breaking Of Oil-Water Emulsions - Emulsions may be broken chemically, physically, or electrically. Chemical methods involving flocculation and sedimentation are the most widely used, generally are the least expensive, and are effective with effluents from wood preserving plants. For these reasons, the remarks which follow are confined to processes which are based on the use of chemicals.

Chemicals that have been used to break oil-water emulsions, either in the laboratory or field, include metallic hydroxides, principally lime, ferric chloride and other salts of iron, alum, bentonite clay, and various types of polyelectrolytes. The same material or combination of materials does not work equally well with wastewaters from all plants (Table 30, Section V). Jones and Frank (35) achieved COD and BOD reductions of 83 and 73 percent, respectively, in creosote wastewater by using a single cationic polymer at a rate of 40 mg/liter. Similar results were observed by Thompson at a Chicago-based plant treating with both creosote and pentachlorophenol that flocculated its waste prior to routing it to a sanitary sewer.

Oil reductions in refinery wastewater of more than 95 percent were obtained by Simonsen (36) who used both anionic and cationic polyelectrolytes in combination with bentonite clay. There was no difference between the two types of polymers in the results obtained. However, only cationic polyelectrolytes broke oil-water emulsions from wood preserving plants in work reported by Jones and Frank (35). Aluminum chloride, alum, activated-silica, clay and lime were employed by Weston and Merman (37) with refinery wastes. Reductions in BOD, COD, and oil content on the order of 50 percent were reported.

Ferric chloride was found by Thompson and Dust (23) to be an effective flocculating agent for both creosote and pentachlorophenol wastewaters. However, floc formation occurred only within very narrow pH limits. This feature would pose serious problems in field applications of this chemical.

Much of the research work on flocculating wood preserving wastewaters has involved the use of lime either singly or in combination with a polyelectrolyte. Thompson and Dust (23) reported that the optimum dosage of lime, as judged from COD reductions, varied from 0.75 to 2.0 g/liter, depending upon

wastewater characteristics. Percent reduction in this parameter increased with increasing dosage up to a maximum, and then was unaffected by further lime additions (Table 52). Phenol content, exclusive of pentachlorophenol, was not decreased by flocculation of the wastewater. However, pentachlorophenol was regularly reduced to a concentration of about 15 mg/liter in wastewaters containing this chemical. It was surmised from this result that pentachlorophenol, unlike other phenolic compounds, is primarily associated with the oil phase in oil-water emulsions and is precipitated with the oils when the emulsion is broken. The residual concentration of pentachlorophenol remaining in the filtrate was reported by Thompson and Dust (23) to correspond approximately to the solubility of this chemical in water. Typical data showing the reduction of pentachlorophenol resulting from lime additions to a wastewater are shown below:

<u>Lime Dosage (gm/liter)</u>	<u>Residual PCP Concentration (mg/liter)</u>
0	150
1.0	45
1.5	25
2.0	17

Middlebrook (38) also used lime, in dosages of 2 g/liter, to obtain reductions in COD of up to 70 percent in a creosote wastewater. Similar results were achieved with alum. Both chemicals were used successfully by Gaskin (39) to treat creosote and vapor-drying wastewater previously de-emulsified with sulfuric acid. Lime and caustic soda were reported by van Frank and Eck (40) to be effective in flocculating oily wastewater after polyelectrolytes alone failed to produce a floc.

Among numerous polyelectrolytes tested by Thompson and Dust (23) relatively few were found that were effective with wood preserving wastewater in the absence of lime. The primary contributions that many of the test materials made to the flocculation process were the agglomeration of minute floc particles, which promoted rapid settling, and reduction in sludge volume. Only a few of them were effective in initiating floc formation in samples of wastewater from 20 plants, and none increased COD removal beyond that obtained with lime alone. The few that were effective in initiating floc formation in the absence of lime are relatively new products currently marketed by a large chemical company. Reductions in COD for individual polyelectrolytes in this group ranged from 50 to 74 percent and averaged 62 percent (24). Several wood preserving plants currently use them in primary treatments of their wastewater. Lime in combination with polyelectrolytes is used by other plants.

TABLE 52 EFFECT OF LIME FLOCCULATION ON COD AND PHENOL CONTENT OF TREATING-PLANT EFFLUENT

Lime (gm/l)	pH	COD		Phenol (mg/l)
		Conc. (mg/l)	Percent Removal	
0.0	5.3	11,800	--	83
0.25	6.8	9,700	23	81
0.50	7.9	7,060	39	72
0.75	9.7	5,230	56	78
1.00	10.5	5,270	55	80
1.25	11.4	5,210	56	84
1.50	11.8	5,210	56	83

Vacuum and pressure filtration has also been used to break oil-water emulsions, permitting the recovery of the oil (41). Halff (42), in commenting on work with vacuum filtration through diatomaceous earth, reported that a precoated rotary vacuum filter efficiently broke oil-water emulsions from wood preserving operations. The same author tested sand filtration of composited wastewater from several wood preserving plants and concluded that the method was not practical, although a 99 percent reduction in turbidity was achieved by the process.

Methods of breaking oil-water emulsions in the petro-chemical industry have been reviewed by Halladay and Crosby (43). The theory of flocculation has been covered by Powell (121).

Sludge Dewatering - The availability of effective polyelectrolytes for flocculation treatments lessens considerably the problem of sludge handling and disposal. Using lime alone, a volume of sludge equal to 30 percent of the wastewater is produced by flocculation. This value is reduced to about 7 percent when lime is used in combination with a suitable polyelectrolyte, and is reduced still further when one of the newer polyelectrolytes is used alone.

Sludge drying beds similar to those employed with domestic sewage have been used successfully to dewater sludge resulting from primary treatments of wood preserving wastewater (39). Recent tests conducted by Dust (44) have shown that the dewatering characteristics of beds of this type are unaffected by adding a total of 41 centimeters (16 inches) of sludge from creosote wastewater to them in two applications during a 24-hour period. Upon drying, the sludge can be easily removed from the beds using a garden rake. Drying beds are currently in use at a number of plants in the southern states.

Sludge dewatering can also be accomplished mechanically with equipment currently available (45). Results of tests of the effectiveness of one machine in processing sludge from creosote wastewater were promising (44). The sludge was dewatered to a solids content of 25 percent.

Wastewaters Containing Heavy Metals - Because heavy metals contained in wastewater from plants that treat with salt-type preservatives and fire retardants are toxic to microorganisms in low concentrations (46), they must be removed before subjecting the wastewater to secondary treatments involving biological oxidation. Unlike primary treatments of oily wastewaters in which recovery of oil is primarily a physical problem, the removal of preservative salts from solution is a chemical problem and is related to the properties of the specific ions present. A listing of the principal water-soluble preservatives and fire retardants currently marketed in the United States, and the toxic constituents in each, is given in Table 53.

The procedure used to precipitate heavy metals from wood preserving effluents was adopted from the electroplating industry. Dodge and Reams (47) compiled a bibliography of over 700 references dealing with the processing and disposal of waste from this industry, and it has been estimated that 50 additional articles on the subject have been published annually since this bibliography first appeared (48). A detailed treatment of the subject has been prepared by Bliss (49). The basic procedure followed, while modified somewhat, depending upon the specific preservative salts involved, is described below.

With the exception of boron, hexavalent chromium is the only ion shown in Table 53 which will not precipitate from solution when the pH of the wastewater is raised to 7 or 8 with lime. Since trivalent chromium will precipitate from neutral or slightly alkaline solutions, the first step in treating wastewaters containing this metal is to reduce it from the hexavalent to the trivalent form. The use of sulfur dioxide for this purpose has been reported on in detail by Chamberlin and Day (28). Chromium reduction proceeds most rapidly in acid solution. Therefore, the wastewater is acidified with sulfuric acid to a pH of 4 or less before introducing the sulfur dioxide. The latter chemical will itself lower the pH to the desired level, but it is less expensive to use the acid.

TABLE 53 TOXIC CONSTITUENTS IN THE PRINCIPAL SALT-TYPE PRESERVATIVES AND FIRE RETARDANT CHEMICALS USED IN THE UNITED STATES

	Cu	Zn	Cr	B	As	F	Dinitro phenol
Fluor-Chrome Arsenate Phenol			X		X	X	X
Chromated Zinc Chloride		X	X				
Copperized Chromated Zinc Chloride	X	X	X				
Chromated Copper Arsenate	X		X		X		
Chromated Zinc Arsenate		X	X		X		
Acid Copper Chromate	X		X				
Ammoniacal Copper Arsenite	X				X		
Fire Retardant							
Type A		X	X				
Type B		X	X	X			
Type D		X	X	X			

When the chromium has been reduced, the pH of the wastewater is increased to 8.5 or 9.0 to precipitate not only the trivalent chromium, but also the copper and zinc. If lime is used for the pH adjustment, fluorides and most of the arsenic will also be precipitated. Care must be taken not to raise the pH beyond 9.5, since trivalent chromium is slightly soluble at higher values. Additional arsenic and most of any residual copper and chromium in solution can be precipitated by treating the waste with hydrogen sulfide gas, or by adding sodium sulfide. Ammonium and phosphate compounds are also reduced by this process.

This procedure is based on the well-known fact that most heavy metals are precipitated as relatively insoluble metal hydroxides at alkaline pH. The theoretical solubilities of some of the hydroxides are quite low, ranging down to less than 0.01 mg/liter. However, theoretical levels are seldom achieved because of unfavorable settling properties of the precipitates,

slow reaction rates, interference of other ions in solution, and other factors. Among the ions shown in Table 53, copper and zinc (51 and 52), and chromium (53 and 54) can be reduced to levels substantially lower than 1.0 mg/liter by the above procedure. Fluorides have a theoretical solubility at pH's of 8.5 to 9.0 of 8.5 mg/liter, but residual concentrations on the order of 10 to 20 mg/liter are more usual because of slow settling of calcium fluoride. The use of additional lime, alum coagulation (56) and filtration through bone char (57) are reported to reduce fluoride concentrations to 1.0 mg/liter or less.

The most difficult ion to reduce to acceptable concentration levels is arsenic. Treatment of water containing arsenic with lime generally removes only about 85 percent of the metal (58). Removal rates in the range of 94 to 98 percent have been reported for filtration through ferric sulfide beds (59), coagulation with ferric chloride (60), and precipitation with ferric hydroxide (61). However, none of these methods are entirely satisfactory, particularly for arsenic concentrations above 20 mg/liter.

Literature on treatment processes for removing boron from wastewaters is not available.

The sludge resulting from the precipitation process contains the heavy metals formerly in solution, along with the excess lime. It may also contain various organic materials of wood origin that are flocculated and precipitated with the lime. The sludge can be filtered to reduce its volume and disposed of in a suitable manner. The supernatant may be routed to a holding basin, as is currently being done by several plants, given a secondary treatment, or released, depending upon its oxygen demand and content of residual metals. Work is in progress to determine if the sludge can be acidified and reused in the treating solution (62).

Representative data on the laboratory treatment of wastewater containing CCA-type salt preservatives and a proprietary fire-retardant formulation composed mainly of ammonium and phosphate compounds are given in Table 54. Data for both concentrated solutions and diluted wastewater from a holding pond are given. Average results of treatments conducted daily over a period of a year on effluent from a plant are given in Table 55. The latter data were obtained by analyzing effluent from equipment designed by Russell (63) to process wastewater automatically.

Wastewaters from salt-type treatments frequently are heavily diluted and, consequently, may contain very low metal concentrations. The importance of subjecting the waste to a primary treatment to remove the metals, even when present in only trace quantities, was alluded to earlier. Numerous studies have shown that copper, chromium, zinc, and arsenic have a toxic effect on biological waste treatment systems (64, 65, 66). Results of these studies were recently reviewed by Jones (46).

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TABLE 54 CONCENTRATIONS OF POLLUTANTS BEFORE AND AFTER LABORATORY TREATMENT OF WASTEWATER FROM TWO SOURCES (62)

	Conc. Solution		Dilute Pond Waste	
	Influent	Effluent	Influent	Effluent
COD	1700	400.	112	20
As	300	15	20.8	1.0
Phenols	Nil	Nil	0.03	Nil
Cu	170	25	0.35	0.25
Cr ⁺⁶	375	0	0.52	0
Cr ⁺³	0	0	0	0
F	590	80	19	9.5
PO ₄	640	90	80	25
NH ₃ -N	1260	95	80	Nil

NOTE: Values expressed as mg/l.

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TABLE 55 CONCENTRATION OF POLLUTANTS IN PLANT WASTEWATER CONTAINING
SALT-TYPE PRESERVATIVES AND FIRE RETARDANTS
BEFORE AND AFTER FIELD TREATMENT (62)

	Influent Ranges	Effluent Averages
COD	10 - 50	25
As	13 - 50	8.9
Phenols	0.050 - 0.160	0.048
Cu	0.05 - 1.1	0.35
Cr ⁺⁶	0.23 - 1.5	0.1
Cr ⁺³	0.0 - 0.8	0.02
F	4 - 20	5.8
PO ₄	15 - 150	15
NH ₃ -N	80 - 200	75
Values expressed as mg/liter		

Ion exchange resins of the sulfonated-polystyrene and quaternaryamine types have been employed on a commercial scale for purification and recovery of metals used in the electroplating industry (67,68,69). The technology involved in ion exchange has application to the wood preserving industry, but the economics of the process in the purification of preservative wastewaters containing metal contaminants are unknown. It has been suggested that inert sulfate and sodium ions and organic materials in these wastewaters would lower the metal-removing capacity of the exchangers sufficiently to make the process impractical under most circumstances (70).

Plant experience in treating wastewater from salt-type treatments is limited. This situation arises from the fact that steam conditioning of stock prior to preservative injection is not widely practiced among plants that use preservative and fire-retardant salts. Consequently, only a small volume of wastewater is generated. The better managed plants use the wastewater that is available as make-up water in preparing fresh batches of treating solution.

Secondary Treatments

Biological treatments, chemical oxidation, activated-carbon adsorption and various combinations of these basic methods of wastewater treatment have been used commercially, proposed for such use, or tested in laboratory and pilot-plant investigations of wood preserving effluents. Each of these methods is discussed below in terms of: (a) characteristics relating to sensitivity to shock loadings, availability of equipment, and maintenance requirements; (b) efficiency with phenolic-type wastes, as revealed by the literature; and (c) effluent characteristics of wood preserving waste resulting from treatment. Because of the limited number of wood preserving plants that are currently providing secondary treatment for their waste, data for item (c) is, in some instances, based on grab samples collected in connection with this study, or on results of pilot-plant investigations.

Biological Treatments - Where a substantial volume of waste with a high organic load is involved, cost considerations usually dictate that biological oxidation be used as the major component in the waste treatment program. Polishing treatments involving chlorination, and possibly activated-carbon filtration, may or may not be required, depending upon the design of the biological system and the waste loads involved. Each of the several biological waste-treating systems that have present or potential application in the wood preserving industry is covered in this section.

Characteristics - According to Besseliere (84), trickling filters are not unduly susceptible to disruption by shock loads and recover quickly if disruption occurs. Their operation does not require constant attention, and, when equipped with plastic media, they are capable of handling

high loading rates. The latter feature minimizes the land area required. For package units sized for the relatively small volume of discharge at the average wood preserving plant, an area of 186 m² (2,000 ft²) should be adequate for the tower (approximately 6 meters (20 feet) in diameter) and associated equipment, including settling tank.

Processing Efficiency For Phenolic Wastes - The literature contains many references concerning wastewater treatment using trickling filters in the petroleum and by-product coal industries. Most of the references report on efforts to reduce phenol concentrations to acceptable levels. Sweets, Hamdy and Weiser (71) studied the bacteria responsible for phenol reductions in industrial waste and reported good phenol removal from synthesized waste containing concentrations of 400 mg/liter. Reductions of 23 to 28 percent were achieved in a single pass of the wastewater through a pilot trickling filter having a filter bed only 30 centimeters (12 in.) deep.

Waters containing phenol concentrations of up to 7500 mg/liter were successfully treated in laboratory tests conducted by Reid and Libby (72). Phenol removals of 80 to 90 percent were obtained for concentrations on the order of 400 mg/liter. Their work confirmed that of Ross and Shepard (73) who found that strains of bacteria isolated from a trickling filter could survive phenol concentrations of 1600 mg/liter and were able to oxidize phenols in concentrations of 450 mg/liter at better than 99 percent efficiency. Reid, Wortman, and Walker (74) found that many pure cultures of bacteria were able to live in phenol concentrations of up to 200 mg/liter, but few survived concentrations above 900 mg/liter, although some were grown in concentrations as high as 3700 mg/liter.

Harlow, Shannon, and Sercu (75) described the operation of a commercial-size trickling filter containing "Dowpac" filter medium that was used to process wastewater containing 25 mg/liter phenol and 450 to 1,900 mg/liter BOD. Reductions of 96 percent for phenols and 97 percent for BOD were obtained in this unit. Their results compare favorably with those reported by Montes, Allen, and Schowell (76), and Dickerson and Laffey (77). The former authors obtained BOD reductions of 90 percent in a trickling filter using a 1:2 recycle ratio. Dickerson and Laffey obtained phenol and BOD reductions of 99.9 and 96.5 percent, respectively, in a trickling filter used to process refinery wastewater.

A combination biological waste-treatment system employing a trickling filter and an oxidation pond was reported on by Davies, Biehl, and Smith (78). The filter, which was packed with a plastic medium, was used for a roughing treatment of 10.6 million liters (2.8 million gallons) of wastewater per day, with final treatment occurring in the oxidation pond. Removal rates of 95 percent for phenols and 60 percent for BOD were obtained in the filter, notwithstanding the fact that the pH of the influent averaged 9.5.

Biological treatment of refinery wastewaters was studied by Austin, Meehan, and Stockham (79) using a series of four trickling filters. Each filter was operated at a different recycle ratio. The waste contained 22 to 125 mg/liter of oil. BOD removal was adversely affected by the oil, the lowest removal rates corresponding to the periods when the oil content of the influent was highest. Phenol removal was unaffected by oil concentrations within the range studied.

Prather and Gaudy (80) found that significant reductions in COD, BOD, and phenol content of refinery wastewater were achieved by simple aeration treatments. They concluded that this phenomenon accounted for the high allowable loading rates for biological treatments such as trickling filtration.

Treatment of Wood Preserving Effluents - The practicality of using the trickling filters for secondary treatment of wastewaters from the wood preserving industry was explored by Dust and Thompson (25). A pilot unit containing a 6.4 meter (21 feet) filter bed of plastic media was used in their study. Creosote wastewater was applied at BOD loading rates of from 400 to 3050 kilograms/1000 m³ per day (25 to 190 pounds/1000 ft³ per day). The corresponding phenol loadings were 1.6 to 54.6 kilograms/1000 m³ per day (0.1 to 3.4 pounds/1000 ft³ per day). Raw feed-to-recycle ratios varied from 1:7 to 1:28. The pilot unit was operated and daily samples collected and analyzed over a period of seven months that included both winter and summer operating conditions.

Because of wastewater characteristics at the particular plant cooperating in the study, the following pretreatment steps were necessary: (a) equalization of wastes; (b) primary treatment by coagulation for partial solids removal; (c) dilution of the wastewater to obtain BOD loading rates commensurate with the range of raw flow levels provided by the equipment; and (d) addition to the raw feed of supplementary nitrogen and phosphorus. Dilution ratios of 0 to 14 were used.

The efficiency of the system was essentially stable for BOD loadings of less than 1200 kilograms/1000 m³ per day (75 pounds/1000 ft³ per day). The best removal rate was achieved when the hydraulic application rate was 2.85 lpm/m² (0.07 gpm/ft²) of raw waste and 40.7 lpm/m² (1.0 gpm/ft²) of recycled waste. The COD, BOD, and phenol removals obtained under these conditions are given in Table 56. Table 57 shows the relationship between BOD loading rate and removal efficiency. BOD removal efficiency at loading rates of 1060 kilograms/1000 m³ per day (66 pounds/1000 ft³ per day) was on the order of 92 percent, and was not improved at reduced loadings. Comparable values for phenols at loading rates of 19.3 kilograms/1000 m³ per day (1.2 pounds/1000 ft³ per day) were about 97 percent.

Phenol content was more readily reduced to levels compatible with existing standards than was BOD content. Consequently, the sizing of commercial units from data collected from the pilot unit was based on BOD removal

TABLE 56 BOD, COD, AND PHENOL LOADING AND REMOVAL RATES FOR PILOT TRICKLING FILTER PROCESSING A CREOSOTE WASTEWATER (81)

Measurement	Characteristic		
	BOD	COD	Phenol
Raw Flow Rate (gpm/ft ²)	0.07	0.07	0.07
Recycle Flow Rate (gpm/ft ²)	1.0	1.0	1.0
Influent Concentration (mg/l)	1698	3105	31
Loading Rate (lb/M ft ³ /day)	66.3	121.3	1.2
Effluent Concentration (mg/l)	137	709	<1.0
Removal (%)	91.9	77.0	99+

rates. Various combinations of filter-bed depths, tower diameters, and volumes of filter media that were calculated to provide a BOD removal rate of 90 percent for influent having a BOD of 1500 mg/liter are shown in Table 58 for a plant with a flow rate of 75,700 lpd (20,000 gpd).

Activated Sludge and Aerated Lagoon - Characteristics - Activated Sludge treatments which employ the complete-mix alternative to the conventional process are very resistant to disruptions caused by shock loads, offer low operation and maintenance costs, low initial cost, and have small land requirements. Package units designed to treat the wastewater from an average wood preserving plant could be located on an area of approximately 93 m² (1000 ft²). Additional space would be required for a pre-treatment equalization reservoir and, where required, flocculation tanks. A system designed by Environmental Engineering, Inc. of Gainesville, Florida for installation at Koppers Company's Carbondale, Illinois plant will occupy an area of approximately 140 m² (1500 ft²), including equipment for pre- and post-treatment chlorination.

An aerated lagoon is a special type of complete-mix, activated sludge system, without sludge recycle. It normally is operated in conjunction with a polishing pond into which waste from the lagoon is discharged. Both the lagoon and polishing pond are usually constructed with earthen embankments, a feature which reduced the cost of the system compared with the activated sludge process. This method of treatment has essentially the same advantages as the conventional complete-mix, activated sludge system, but does require more land area.

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TABLE 57 RELATIONSHIP BETWEEN BOD LOADING AND TREATABILITY
FOR PILOT TRICKLING FILTER PROCESSING A CREOSOTE WASTEWATER (81)

BOD Loading (lb/ft ³ /day)	Removal (%)	Treatability* Factor
23	91	0.0301
26	95	0.0383
37	92	0.0458
53	93	0.0347
66	92	0.0312
76	82	0.0339
85	80	0.0286
115	75	0.0182
156	62	0.0130

*Based on the equation:

$$\frac{L_e}{L_o} = e^{KD/Q^{0.5}} \quad (\text{Germain, 1966})$$

in which L_e = BOD concentration of settled effluent, L_o = BOD of feed, Q = hydraulic application rate of raw waste in gpm/ft², D = depth of media in feet, and K = treatability factor (rate coefficient).

TABLE 58 SIZING OF TRICKLING FILTER FOR A WOOD PRESERVING PLANT (81)

(NOTE: Data are based on a flow rate of 20,000 gallons per day, with filter influent BOD of 1500 and effluent BOD of 150.)

Depth of filter bed (ft)	Raw flow (gpm/ft ² filter surface)	Recycle flow (gpm/ft ² filter surface)	Filter Surface area (ft ²)	Tower dia. (ft)	Volume of media (ft ³)
10.7	0.019	0.73	708	30.0	7617
12.5	0.026	0.72	520	25.7	6529
14.3	0.034	0.71	398	22.5	5724
16.1	0.044	0.70	315	20.0	5079
17.9	0.054	0.69	255	18.0	4572
19.6	0.065	0.68	210	16.3	4156
21.4	0.078	0.67	177	15.0	3810

Processing Efficiency for Phenolic Wastes - Treatment of municipal and mixes of municipal and industrial wastes by the activated sludge process is common practice (82, 83, 84). In recent years the process has also been adapted to industrial wastes similar in composition to that of effluents from wood preserving plants. Pruessner and Mancini (85) obtained a 99 percent oxidation efficiency for BOD in petrochemical wastes. Similarly, Coe (86) reported reductions of both BOD and phenols of 95 percent from petroleum wastes in bench-scale tests of the activated sludge process. Optimum BOD loads of 2247 kilograms/1000 m³ per day (140 pounds/1000 ft³ per day) were obtained in his work. Coke plant effluents were successfully treated by Ludberg and Nicks (87), although they experienced some difficulty in start-up of the activated sludge system because of the high phenol content of the water.

The complete mixed, activated sludge process was employed to process a high-phenolic wastewater from a coal-tar distilling plant in Ontario. Initial phenol and COD concentrations of 500 and 6,000 mg/liter, respectively, were reduced in excess of 99 percent for phenols and 90 percent for COD (88).

Cooke and Graham (89) employed the complete-mixed, activated sludge system to treat waste containing phenols, organic acids, thiocyanates, and ammonia using detention times of 8 to 50 hours. At feed rates of 144 to 1605 kilograms/1000m³ per day (9 to 100 lb/1000 ft³ per day), phenol content was reduced from 281 mg/liter to 62 mg/liter, for a removal rate of 78 percent.

The employment of aerated reaction units on a continuous flow basis was used by Badger and Jackman (90) to treat coke gasification plant waste. They found that a two-day detention period was sufficient to remove 90 percent of the phenol from a waste stream containing up to 5,000 mg/liter of the chemical.

Nakashio (91) successfully treated coal gas washing liquor containing 1,200 mg/liter of phenols in a study that lasted more than a year. Phenol concentration was reduced by more than 99 percent. Similar phenol removal rates were obtained by Reid and Janson (92) in treating wastewater containing cresols by the activated sludge process.

In a report of pilot and full-scale studies performed by Bethlehem Steel Corporation (93), phenol removal efficiencies greater than 99.8 percent were obtained using the complete-mixed, activated sludge process. Loading rates of 0.86 kilograms phenol/kilogram (0.86 lb phenol/lb) MLSS/day were used successfully. Phenol influent concentrations of 3,500 mg/liter were reduced to 0.2 mg/liter in the effluent.

Treatment of Wood Preserving Effluents - Dust and Thompson (25) conducted bench-scale tests of complete-mixed, activated sludge treatments of creosote and pentachlorophenol wastewaters using 5-liter units and detention times of 5, 10, 15, and 20 days. The operational data collected at steady-state conditions of substrate removal for the creosote waste are shown in Table 59. A plot of these data showed that the treatability factor, $K = 0.30 \text{ days}^{-1}$ (Figure 39). The resulting design equation, with t expressed in days, is:

$$Le = \frac{Lo}{1 + 0.30t}$$

A plot of percent COD removal versus detention time in the aerator, based on the above equation, is shown in Figure 40. This figure shows that an oxidation efficiency of about 90 percent can be expected with a detention time of 20 days in units of this type.

Work done with pentachlorophenol waste was conducted to determine the degree of biodegradability of this chemical. Cultures of bacteria prepared from soil removed from a drainage ditch containing pentachlorophenol waste were used to inoculate the treatment units. Feed to the units contained 10 mg/liter of pentachlorophenol and 2,400 mg/liter COD. For the two 5-liter units (A and B) the feed was 500 and 1000 ml/day and detention times were, in order, 10 and 5 days.

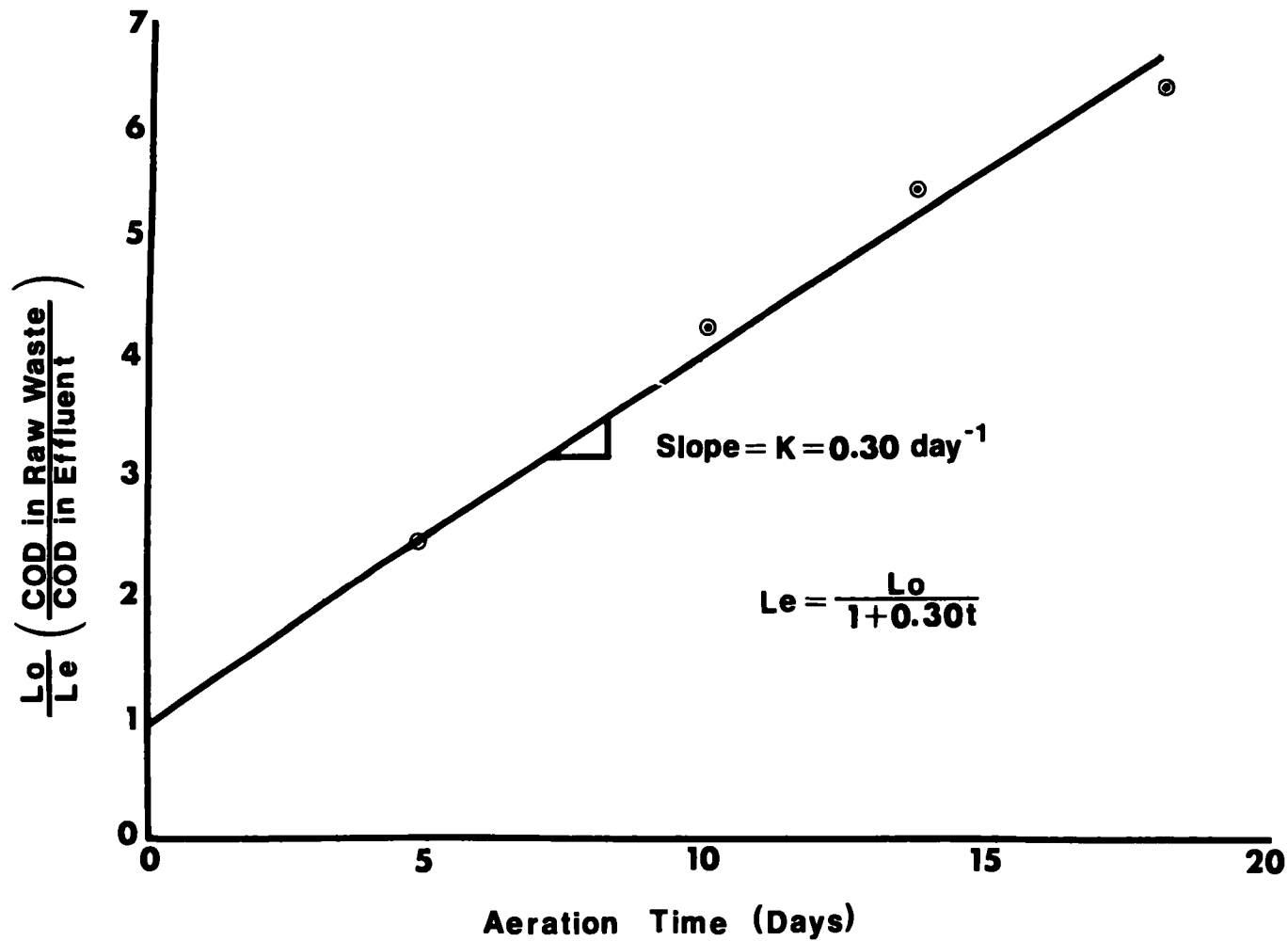


FIGURE 39 (25) - DETERMINATION OF REACTION RATE CONSTANT FOR A CREOSOTE WASTEWATER

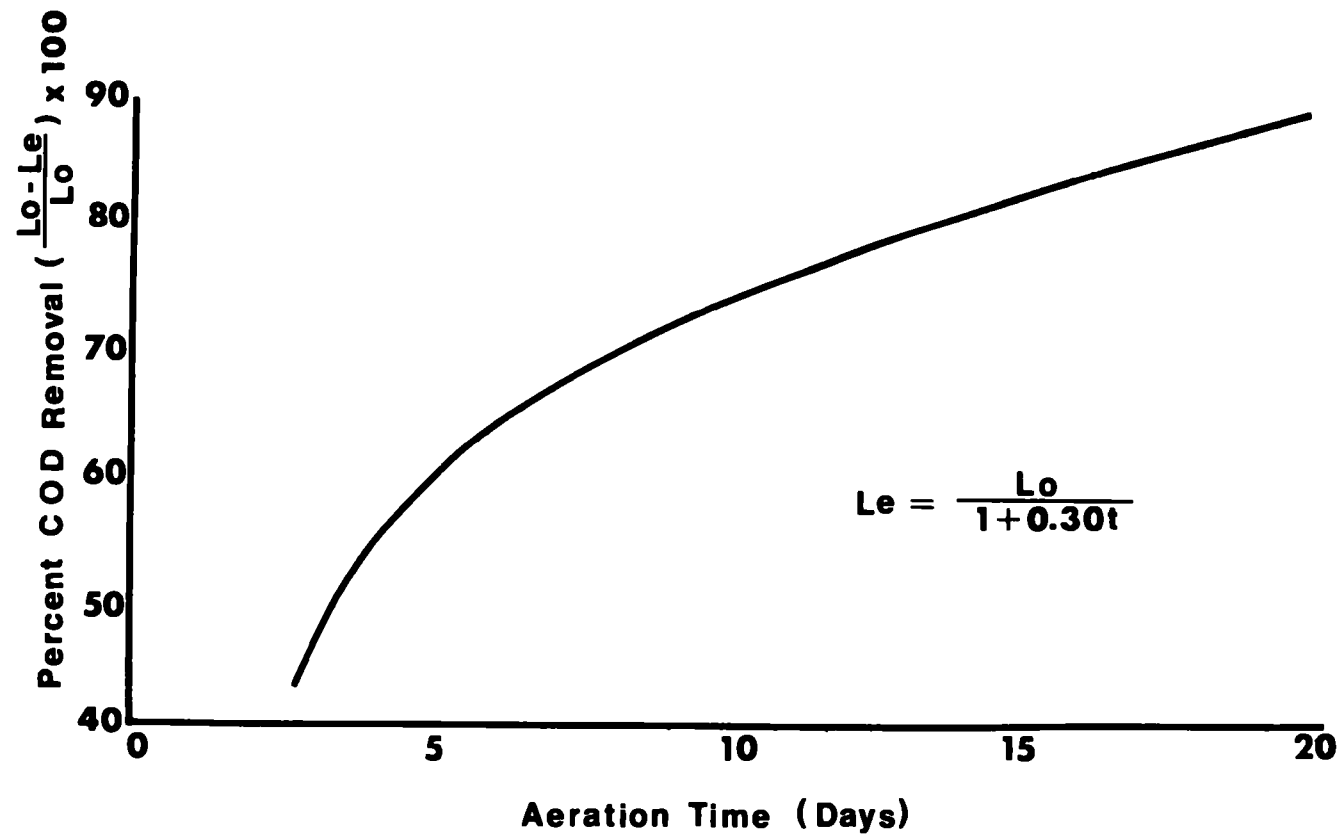


FIGURE 40 (25) - COD REMOVAL FROM A CREOSOTE WASTEWATER BY AERATED LAGOON WITHOUT SLUDGE RETURN

TABLE 59 SUBSTRATE REMOVAL AT STEADY-STATE CONDITIONS IN ACTIVATED SLUDGE UNITS CONTAINING CREOSOTE WASTEWATER

Aeration Time, Days	5.0	10.0	14.7	20.1
COD Raw, mg/l	447	447	442	444
COD Effluent, mg/l	178	103	79	67
% COD Removal	60.1	76.9	82.2	84.8
COD Raw/COD Effluent	2.5	4.3	5.6	6.6

Removal rates for pentachlorophenol and COD are given in Table 60. For the first 20 days Unit A removed only 35 percent of the pentachlorophenol added to the unit. However, removal increased dramatically after this period and averaged 94 percent during the remaining ten days of the study. Unit B consistently removed over 90 percent of the pentachlorophenol added. Beginning on the 46th day and continuing through the 51st day, pentachlorophenol loading was increased at two-day intervals to a maximum of about 40 mg/liter. Removal rates for the three two-day periods of increased loadings were 94, 97, and 99 percent.

COD removal for the two units averaged about 90 percent over the duration of the study.

Also working with the activated sludge process, Kirsh and Etzel (94) obtained removal rates for pentachlorophenol in excess of 97 percent using an 8-hour detention time and a feed concentration of 150 mg/liter. The pentachlorophenol was supplied to the system in a mixture that included 100 mg/liter phenol. Essentially complete decomposition of the phenol was obtained, along with a 92 percent reduction in COD.

Soil Irrigation - Characteristics - The principal feature of the soil irrigation method of wastewater treatment is its simplicity. Water that has been freed of surface oils and, depending upon the presence of emulsified oils, treated with flocculated chemicals and filtered through a sand bed is simply sprayed onto a prepared field. Soil microorganisms decompose the organic matter in the water in much the same fashion as occurs in more conventional waste treatment systems.

In addition to its simplicity, soil irrigation has the advantage of low capital investment, exclusive of land costs, low operating and maintenance costs, requires a minimum of mechanical equipment, and produces a high-quality effluent in terms of color, as well as oxygen demand and other

TABLE 60 REDUCTION IN PENTACHLOROPHENOL AND COD IN
WASTEWATER TREATED IN ACTIVATED SLUDGE UNITS

DAYS	RAW WASTE (mg/l)	EFFLUENT FROM UNIT (% Removal)	
		"A"	"B"
<hr/>			
	<u>COD</u>		
1-5	2350	78	78
6-10	2181	79	79
11-15	2735	76	75
16-20	2361	82	68
21-25	2288	90	86
26-30	2490	--	84
31-35	2407	83	80
<hr/>			
	<u>PENTACHLOROPHENOL</u>		
1-5	7.9	20	77
6-10	10.2	55	95
11-15	7.4	33	94
16-20	6.6	30	79
21-25	7.0	--	87
26-30	12.5	94	94
31-35	5.8	94	91
36-40	10.3		91
41-45	10.0		96
46-47	20.0		95
48-49	30.0		97
50-51	40.0		99

pertinent parameters. Its chief disadvantage is that its use requires a minimum area of approximately one hectare per 33,000 liters/day (3500 gal/acre/day) of discharge. This requirement makes the method impractical in locations where space is at a premium. However, it is not a major problem for the many plants in rural areas where land is relatively inexpensive.

Processing Efficiency For Phenolic Wastes - Effluents from a number of different types of industries have been successfully disposed of by soil irrigation. Besseliere (84) listed 20 types of industrial wastes that

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have been treated by this method. Among these were several wastes high in phenol content. Removal efficiencies as high as 99.5 percent for both BOD and phenols were reported.

Fisher (95) reported on the use of soil irrigation to treat wastewaters from a chemical plant that had the following characteristics:

pH	9 to 10
Color	5,000 to 42,000 units
COD	1,600 to 5,000 mg/liter
BOD	800 to 2,000 mg/liter

Operating data from a 0.81 hectare (2 acre) field, when irrigated at a rate of 7570 liters (2,000 gal) per acre/day for a year, showed color removal of 88 to 99 percent and COD removal of 85 to 99 percent.

The same author reported on the use of this method to treat effluent from two tar plants that contained 7,000 to 15,000 mg/liter phenol and 20,000 to 54,000 mg/liter COD. The waste was applied to the field at a rate of about 9460 liters (2500 gal) per acre/day. Water leaving the area had COD and phenol concentrations of 60 and 1 mg/liter, respectively. Based on the lower influent concentration for each parameter, these values represent oxidation efficiencies of well over 99 percent for both phenol and COD.

Bench-scale treatment of coke plant effluent by soil irrigation was also studied by Fisher (95). Wastes containing BOD and phenol concentrations of 5,000 and 1,550 mg/liter, respectively, were reduced by 95+ and 99+ percent when percolated through 0.9 meters (36 inches) of soil. Fisher pointed out that less efficient removal was achieved with coke-plant effluents using the activated sludge process, even when the waste was diluted with high-quality water prior to treatment. The effluent from the units had a color rating of 1,000 to 3,000 units, compared to 150 units for water that had been treated by soil irrigation.

Treatment of Wood Preserving Effluents - Both laboratory and pilot scale field tests of soil-irrigation treatments of wood preserving wastewater were conducted by Dust and Thompson (25). In the laboratory tests, 210-liter (55 gallon) drums containing a heavy clay soil 60-centimeters (24 inches) deep were loaded at rates of 32,800, 49,260, and 82,000 liters/hectare/day (3,500, 5,250, and 8,750 gallons/acre/day). Influent COD and phenol concentrations were 11,500 and 150 mg/liter, respectively. Sufficient nitrogen and phosphorus were added to the waste to provide a COD:N:P ratio of 100:5:1. Weekly effluent samples collected at the bottom of the drums were analyzed for COD and phenol.

Reductions of 99+ percent in COD content of the wastewater were attained from the first week in the case of the two highest loadings and from the fourth week for the lowest loading. A breakthrough occurred during the 22nd week for the lowest loading rate and during the fourth week for the

highest loading rate. The COD removal steadily decreased thereafter for the duration of the test. Phenol removal showed no such reduction, but instead remained high throughout the test. The average test results for the three loading rates are given in Table 61. Average phenol removal was 99+ percent. Removal of COD exceeded 99 percent prior to breakthrough and averaged over 85 percent during the last week of the test.

TABLE 61 RESULTS OF LABORATORY TESTS OF SOIL IRRIGATION
METHOD OF WASTEWATER TREATMENT*

Loading Rate (Liters/ha/day)	Length Of Test (Week)	Avg. % COD Removal to Breakthrough	COD REMOVAL Last Week of Test, %	Phenol Avg. % Removal (All Weeks)
32,800 (3,500)	31	99.1 (22 wks)	85.8	98.5
49,260 (5,250)	13	99.6	99.2	99.7
82,000 (8,750)	14	99.0 (4 wks)	84.3	99.7

Loading rates in parentheses in gallons/acre/day

*Creosote wastewater containing 11,500 mg/liter of COD and 150 mg/liter of phenol was used.

The field portion of Dust and Thompson's (25) study was carried out on an 0.28-hectare (0.8 acre) plot prepared by grading to an approximately uniform slope and seeded to native grasses. Wood preserving wastewater from an equalization pond was applied to the field at the rate of 32,800 liters/hectare/day (3,500 gallons/acre/day) for a period of nine months. Average monthly influent COD and phenol concentrations ranged from 2,000 to 3,800 mg/liter and 235 to 900 mg/liter, respectively. Supplementary nitrogen and phosphorus were not added. Samples for analyses were collected weekly at soil depths of 0 (surface), 30, 60, and 120 centimeters (1, 2, and 4 feet).

The major biological reduction in COD and phenol content occurred at the surface and in the upper 30 centimeters (1 foot) of soil. A COD reduction of 55.0 percent was attributed to overland flow. The comparable reduction for phenol content was 55.4 percent (Table 62). Average COD reductions at the three soil depths, based on raw waste to the field, were 94.9, 95.3, and 97.4 percent, respectively, for the 30-, 60-, and 120 centimeter (1-, 2-, and 4-foot) depths. For phenols, the reductions were, in order, 98.9, 99.2, and 99.6 percent.

TABLE 62 REDUCTION OF COD AND PHENOL CONTENT IN WASTEWATER
TREATED BY SOIL IRRIGATION (25)

Month	Raw Waste	Soil Depth (centimeters)			
		0	30	60	120
		<u>COD (mg/l)</u>			
July	2235	1400	--	--	66
August	2030	1150	--	--	64
September	2355	1410	--	--	90
October	1780	960	150	--	61
November	2060	1150	170	170	46
December	3810	670	72	91	58
January	2230	940	121	127	64
February	2420	580	144	92	64
March	2460	810	101	102	68
April	2980	2410	126	--	76
Average % Removal (weighted)		55.0	94.9	95.3	97.4
		<u>Phenol (mg/l)</u>			
July	235	186	--	--	1.8
August	512	268	--	--	0.0
September	923	433	--	--	0.0
October	310	150	4.6	--	2.8
November	234	86	7.7	3.8	0.0
December	327	6	1.8	9.0	3.8
January	236	70	1.9	3.8	0.0
February	246	111	4.9	2.3	1.8
March	277	77	2.3	1.9	1.3
April	236	172	1.9	0.0	0.8
Average % Removal (weighted)		55.4	98.9	99.2	99.6

Color of the wastewater before and after treatment was not measured. However, the influent to the field was dark brown and the effluent was clear. Samples taken from the 60- and 120-centimeter (2- and 4-foot) depths showed no discoloration.

The application of the wastewater to the study area did not interfere with the growth of vegetation. On the contrary, the area was mowed several times during the summer months to control the height of native grasses that became established.

The soil percolation method for treating the creosote wastewater from the wood preserving plant consistently showed a greater percentage removal of COD and phenol than either the activated sludge or the trickling filter methods.

Oxidation Ponds - Characteristics - Oxidation ponds are relatively simple to operate and, because of their large volume, difficult to disrupt. Operation and maintenance costs are usually lower than for other waste treating methods. Their disadvantages are numerous. Included among these are: (a) low permissible loading rate, which necessitates large land areas; (b) abrupt changes in efficiency due to weather conditions; (c) difficulty of restoring a pond to operating condition after it has been disrupted; (d) tendency to become anaerobic, thus creating odor problems, and (e) effluents contain algal cells, which are themselves a pollutant.

Processing Efficiency for Phenolic Wastes - Only a few cases of the use of oxidation ponds to treat phenolic wastes are recorded in recent literature. The American Petroleum Institute's "Manual on Disposal of Refinery Wastes" (96) refers to several industries that have successfully used this method.

Montes (97) reported on results of field studies involving the treatment of petrochemical wastes using oxidation ponds. He obtained BOD reductions of 90 to 95 percent in ponds loaded at the rate of 84 kilograms or BOD per hectare per day (75 pounds/acre/day).

Phenol concentrations of 990 mg/liter in coke oven effluents were reduced to about 7 mg/liter in field studies of oxidation ponds conducted by Biczysko and Suschka (98). Similar results have been reported by Skogen (99) for a refinery waste.

Treatment of Wood Preserving Effluents - Oxidation ponds rank high among the various methods that wood preserving companies plan to use to treat their wastewater (Table 49). However, the literature contains operating data on only one pond used for this purpose (100, 101, 102). This is the oxidation pond used as part of a waste treatment system by Weyerhaeuser Company at its DeQueen, Arkansas wood preserving plant.

As originally designed and operated in the early 1960's, the DeQueen waste treatment system consisted of holding tanks into which water from the oil-recovery system flowed. From the holding tanks the water was sprayed into a terraced hillside from which it flowed into a mixing chamber adjacent to the pond. Here it was diluted 1:1 with creek water, fortified with ammonia and phosphates, and discharged into the pond proper. Retention time in the pond was 45 days. The quality of the effluent was quite variable, with phenol content ranging up to 40 mg/liter.

In 1966 the system was modified by installing a raceway containing a surface aerator and a settling basin in a portion of the pond. The discharge from the mixing chamber now enters a raceway where it is treated with a flocculating agent. The floc formed collects in the settling basin. Detention time is 48 hours in the raceway and 18 hours in the settling basin. From the settling basin, the wastewater enters the pond proper.

These modifications in effect changed the treating system from an oxidation pond to a combination aerated lagoon and polishing pond. The effect on the quality of the effluent was dramatic. Figure 41 shows the phenol content at the outfall of the pond before and after installation of the aerator. As shown by these data, phenol content decreased abruptly from an average of about 40 mg/liter to 5 mg/liter.

Even with the modifications described, the efficiency of the system remains seasonally dependent. Table 63 gives phenol and BOD values for the pond effluent by month for 1968 and 1970. The smaller fluctuations in these parameters in 1970 as compared with 1968 indicate a gradual improvement in the system.

Chemical Oxidation - Phenolic compounds, in addition to contributing to the oxygen demand of wood preserving wastewaters, largely account for the toxic properties of effluents from creosote and pentachlorophenol treatments. These compounds can be destroyed by chemical oxidation. Oxidizing agents that have been successfully used for this purpose are chlorine and ozone.

Chlorine - Many references to the chlorination of phenol-bearing waters exist in the literature (103, 104, 105). Chlorine gas and calcium and sodium hypochlorite have been used most extensively for this purpose. Direct treatment with gaseous chlorine using a continuous-flow system is simpler and less expensive than hypochlorite where large volumes of wastewater must be treated. However, for batch-type treatments involving small wastewater volumes, hypochlorite is probably the more practical.

Chlorine dioxide may also be used to oxidize phenols. It has the advantage over other sources of chlorine of short reaction time, does not require close control of pH and temperature, does not produce chlorophenols,

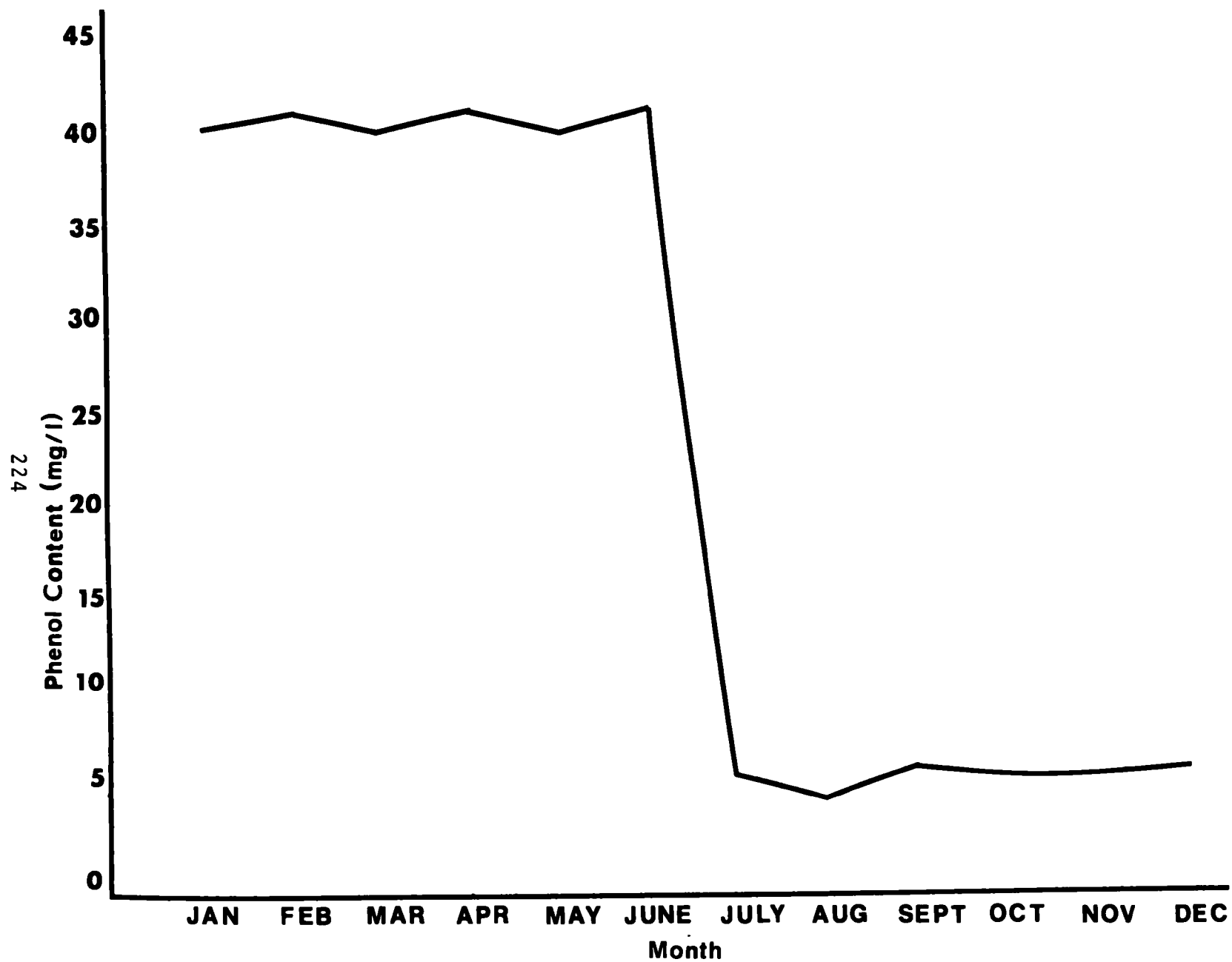


FIGURE 41 - PHENOL CONTENT IN WEYERHAEUSER'S OXIDATION POND EFFLUENT
BEFORE AND AFTER INSTALLATION IN JUNE, 1966 OF AERATOR

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TABLE 63 AVERAGE MONTHLY PHENOL AND BOD CONCENTRATIONS IN EFFLUENT
FROM OXIDATION POND AT WEYERHAEUSER'S DEQUEEN,
ARKANSAS OPERATIONS: 1968 and 1970 (100)

Month	(mg/liter)			
	1968		1970	
	Phenol	BOD	Phenol	BOD
January	26	290	7	95
February	27	235	9	140
March	25	190	6	155
April	11	150	3	95
May	6	100	1	80
June	5	70	1	60
July	7	90	1	35
August	7	70	1	45
September	7	110	1	25
October	16	150	--	--
November	7	155	--	--
December	11	205	--	--

and is effective at ratios of chlorine to phenol of 1:1 or 2:1. Its primary disadvantages are its lack of stability, which requires that it be produced as used, and its relatively high cost (30).

The theoretical ratio of chlorine to phenol required for complete oxidation is about 6:1. For m-cresol the ratio is 3.84:1 (106). However, because of the presence in wastewater of other chlorine-consuming compounds, much higher ratios are required. Thompson and Dust (107) found that the minimum concentration of calcium hypochlorite needed to destroy all phenols in creosote wastewater was equivalent to a chlorine:phenol ratio of 14:1 to 65:1. The exact ratio varied with the pH, COD content, and source of the wastewater. Comparable ratios for pentachlorophenol ranged as high as 300:1 when calcium hypochlorite was used to 700:1 for chlorine gas. Generally, approximately two times as much gaseous chlorine was required to oxidize a given weight of pentachlorophenol as chlorine from calcium hypochlorite.

In other work, Dust and Thompson analyzed wastewater samples for COD, phenol, and pentachlorophenol content following chlorination with quantities of calcium hypochlorite equivalent to 0 to 3.0 g/liter of chlorine. Typical results are shown in Table 64. Treatment of creosote wastewater achieved a reduction in phenol content of 95 to 100 percent, as determined by procedures recommended by APHA (108) (NOTE: This qualification is necessary, since the 4-amino antipyrine test for phenols does not detect all chlorinated phenols and cresols.). However, as illustrated in Table 64, a residual phenol content of 5 to 10 mg/liter that was resistant to oxidation remained in some samples. Substantial reductions in COD were also obtained by the treatments. However, practically all of the reduction in COD occurred at chlorine doses of 2 g/liter or less.

TABLE 64 EFFECT OF CHLORINATION ON THE COD AND PHENOLIC CONTENT OF PENTACHLOROPHENOL AND CREOSOTE WASTEWATERS

Ca(OCl) ₂ as Chlorine (g/liter)	PCP Wastewater (mg/liter)		Creosote Wastewater (mg/liter)	
	COD	PCP	COD	Phenol
0	--	40.7	5200	223.1
0.5	8150	17.3	4800	134.6
1.0	7970	13.1	4420	65.3
1.5	8150	12.0	4380	15.4
2.0	7730	10.4	4240	10.0
3.0	7430	0	3760	5.4

In the same study, both chlorine gas and calcium hypochlorite were used to treat pentachlorophenol wastewater adjusted to pH levels of 4.5, 7.0, and 9.5. The results, which are summarized in Tables 65 and 66, showed that the efficiency of the treatments, in terms of the ratio of weight of chlorine used to weight of pentachlorophenol removed, varied with the pH of the wastewater, the source of chlorine, and whether or not the waste was flocculated prior to chlorination.

A large proportion of the chlorine added to the wastewater in the above studies was consumed in oxidizing organic materials other than phenolic compounds. This is indicated by the major reductions in COD that occurred coincident to the chlorination treatments. For unflocculated waste, the COD averaged 24,000 mg/liter before and 10,300 mg/liter after treatment with calcium hypochlorite, a reduction of 58 percent (Table 67). The comparable reduction for samples treated with chlorine gas was 55 percent. These reductions were obtained at the maximum dose of chlorine employed; that is, 5 g/liter for calcium hypochlorite and 10 g/liter for chlorine gas. However, practically all of the reduction in COD occurred at chlorine doses of 1 g/liter or less, in the case of samples treated with the hypochlorite, and 2 g/liter or less for those treated with chlorine gas. For example, a typical sample of raw waste treated with chlorine gas had an initial COD of 20,400 mg/liter. This value was reduced to 10,250 mg/liter by a chlorine dose of 2 g/liter. The addition of 10 g/liter of chlorine further reduced the COD only to 10,200 mg/liter. These data indicate that a portion of the organic content of the wastewater was resistant to chemical oxidation.

The reduction in COD caused by chlorination of raw wastewater was practically the same as that achieved by flocculation with lime and a polyelectrolyte.

Chlorination of phenol-bearing waters has long been associated with odor and taste problems in municipal water supplies. Phenol itself apparently does not impart taste to water in concentrations below about 60 mg/liter. Its significance as a taste and odor problem arises from its reaction with chlorine to produce chlorophenols. Some of the latter group of chemicals are reported to impart taste in concentrations as low as 0.00001 mg/liter (109).

Ingols and Ridenour (110) postulated that a quinone-like substance was responsible for the taste and odor problem of chlorinated water, and that this substance was an intermediate product in a succession of chlorinated products produced by chlorine treatments of phenol. A ratio of 5 to 6 grams of chlorine per gram of phenol was found to eliminate the taste problem. They hypothesized from this result that high levels of chlorination rupture the benzene ring to form maleic acid.

TABLE 65 EFFECT OF CHLORINATION WITH CALCIUM HYPOCHLORITE
ON THE PENTACHLOROPHENOL CONTENT OF WASTEWATER

Ca(OCl) ₂ as Chlorine (g/liter)	Pentachlorophenol (mg/liter)					
	Unflocculated			Flocculated		
	4.5	pH 7.0	9.5	4.5	pH 7.0	9.5
0	21.5	19.0	20.5	12.0	12.0	14.0
0.5	10.0	14.0	10.0	6.0	9.0	11.0
1.0	8.0	10.0	8.0	4.0	8.0	9.0
1.5	6.0	8.0	8.0	2.0	5.0	6.0
2.0	6.0	7.5	8.0	0	3.6	7.0
3.0	3.5	6.0	5.0	0	0	4.0
4.0	2.0	6.0	4.0	0	0	0
5.0	2.0	5.8	4.0	0	0	0

TABLE 66 EFFECT OF CHLORINATION WITH CHLORINE GAS ON
THE PENTACHLOROPHENOL CONTENT OF WASTEWATER

Chlorine (g/liter)	Pentachlorophenol (mg/liter)					
	Unflocculated			Flocculated		
	4.5	pH 7.0	9.5	4.5	pH 7.0	9.5
0	22.0	20.0	18.0	18.0	17.0	19.5
0.5	13.0	14.0	16.0	16.0	14.0	16.5
1.0	10.0	12.5	15.0	14.0	13.0	11.0
1.5	9.0	9.0	11.5	10.0	14.0	11.0
2.0	8.0	8.0	11.5	8.0	10.0	8.0
3.0	8.0	8.0	8.0	7.5	8.0	8.0
4.0	10.0	8.0	11.0	2.0	6.0	6.0
5.0	14.0	11.5	12.0	0	2.0	4.0
10.0	14.0	11.5	14.0	0	2.0	2.0

TABLE 67 EFFECT OF CHLORINATION OF PENTACHLOROPHENOL WASTE ON COD

Test Conditions	Available Chlorine (g/liter)	COD (mg/liter)
Calcium Hypochlorite pH = 4.5	0.0	24,200
	0.5	
	1.0	10,650
	1.5	
	2.0	10,600
	3.0	
	4.0	10,300
	5.0	
Calcium Hypochlorite pH = 7.0	0.0	23,800
	0.5	
	1.0	10,300
	1.5	
	2.0	10,200
	3.0	
	4.0	
	5.0	10,050
Chlorine Gas pH = 4.5	0.0	20,400
	0.5	
	1.0	
	1.5	
	2.0	10,250
	3.0	
	4.0	10,600
	5.0	
	10.0	10,200
Chlorine Gas pH = 7.0	0.0	23,600
	0.5	
	1.0	
	1.5	
	2.0	9,760
	3.0	
	4.0	10,700
	5.0	
	10.0	11,250

Later studies by Ettinger and Ruchoft (111) largely substantiated earlier work which showed that taste intensity increases with chlorine dosage and then decreases with further chlorination, until no taste remains. Results of work by these authors on the chlorination of various phenolic compounds and the quantities of chlorine required to eliminate taste are given in Table 68. These data indicate that a chlorine-to-phenol ratio of 5:1 would be adequate to form chlorination end products. Work reported by others (106) show that for m-cresol this ratio is 3.84:1. A ratio of 5:1 resulted in a free chlorine residual after a reaction time of 2 hours.

More recent work by the Manufacturing Chemists Association (105) shows that the reaction between chlorine and phenolic compounds proceeds at a rapid rate for the first 15 minutes and is essentially complete after 2 hours contact time. For concentrations of m-cresol of 10 and 20 mg/liter, the application of 50 and 100 mg/liter of chlorine produced a free chlorine residual after 2 hours. A residual chlorine content after 2 hours contact time was obtained for phenol only when chlorine was applied at ten times the level of phenol. The relationship among m-cresol concentration, chlorine dosage, contact time, and chlorine residual is shown in Table 69.

In related studies, phenol in concentrations of 25 mg/liter was treated with levels of chlorine calculated to provide an excess of phenol. Gas chromatographic analyses of samples withdrawn after a contact time of 0.5 hour revealed the presence of O-chlorophenol, p-chlorophenol, 2,6-dichlorophenol, 2,4-dichlorophenol, and 2,4,6-trichlorophenol. Similar tests with m-cresol showed the formation of a number of reaction products, which were assumed to be a mixture of chloro-m-cresols. Positive identification was not made because chlorine-substituted cresols for use as standards are not available commercially.

The authors proposed that the reaction proceeds in part sequentially by the stepwise substitution of the 2,4, and 6 ring positions, and in part simultaneously, resulting in the formation of a complex mixture of chlorophenols and their oxidations products. Ring oxidation was assumed to follow the formation of 2,4,6-trichlorophenol. Other authors have postulated that the reaction proceeds only by a stepwise substitution (111, 112).

Burttschell's work (112) indicated that the progression of chlorinated products occurs as follows:

- Phenol
- 2-Chlorophenol
- 4-Chlorophenol
- 2,4-Dichlorophenol
- 2,6-Dichlorophenol
- 2,4,6-Trichlorophenol
- 4,4-Dichloroquinone
- Organic Acids

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TABLE 68 CHLORINE REQUIRED TO ELIMINATE TASTE IN AQUEOUS
SOLUTIONS OF VARIOUS PHENOLIC COMPOUNDS (111)

	Chlorine Required To Eliminate Taste (mg/l)	Chlorine Added To Produce Free Residual (mg/l)
Phenol	4	7
O-Cresol	5	5
M-Cresol	5	5
P-Cresol	3	4
1-Napthol	4	5
2-Chlorophenol	3	5
4-Chlorophenol	3	6
2-, 4-Dichlorophenol	2	6
2-, 4-, 6-Trichloro- phenol	Could not be tasted	3
2-, 4-, 5-Trichloro- phenol	Could not be tasted	2
2-, 3-, 4-, 6-Tetra- chlorophenol	Could not be tasted	1.5
Pentachlorophenol	Could not be tasted	1.0

TABLE 69 CHLORINE DEMAND OF M-CRESOL AFTER VARIOUS CONTACT TIMES (106)

m-Cresol Concentration (mg/l)	Chlorine (mg/l)	Contact Time (hr)	Chlorine Residual (mg/l)	Net Chlorine Demand	
				mg/l	m mol cl ₂
					m mol m-Cresol
10	20	0.25	3.3	16.7	2.5
		0.5	1.5	18.5	2.8
		1.0	0.5	19.5	3.0
		2.0	0.2	19.8	3.0
10	50	0.25	30.8	19.2	2.9
		0.5	30.8	19.2	2.9
		1.0	28.3	21.7	3.3
		2.0	17.0	33.0	5.0
10	100	0.25	81.4	18.6	2.8
		0.5	77.0	23.0	3.5
		1.0	61.6	38.4	5.9
		2.0	61.6	38.4	5.9
20	50	0.25	16.3	33.7	2.6
		0.5	11.1	38.9	3.0
		1.0	8.0	42.0	3.2
		2.0	8.0	42.0	3.2
20	100	0.25	61.6	38.4	2.9
		0.5	58.2	41.8	3.2
		1.0	56.6	43.4	3.3
		2.0	46.0	54.0	4.1

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Destruction of the benzene ring was found to occur at a chlorine-to-phenol ratio of 10:1. Burttschell attributed the taste problem associated with chlorophenols to 2,6-dichlorophenol. The development of taste was reported not to occur at pH values of less than 7.0.

Results of a study by Eisenhauer (113) supported earlier work of other investigators that non-aromatic products are formed when phenols are treated with high levels of chlorine.

Oxidation products resulting from the chlorination of pentachlorophenol have not been studied intensively. However, Thompson and Dust (107) reported the presence of chloranil in samples of chlorinated wastewater analyzed using a gas chromatograph.

With the exception of the last reference cited, the studies described in the foregoing paragraphs have dealt with phenolic compounds in solutions not contaminated with other substances. Because of other chlorine-consuming materials in wood preserving wastewater, a question arises concerning the levels of chlorine required to fully oxidize phenols in such wastes. Unpublished results of a recent study (1970) at the Mississippi Forest Products Laboratory provides a partial answer.

Creosote wastewater with phenol and COD contents of 508 and 13,500 mg/liter, respectively, were flocculated and samples of the filtrate adjusted to pH values of 4.5, 7.0, and 9.5. The samples were treated with quantities of calcium hypochlorite calculated to yield a gradient series of chlorine concentrations. The pH readings of the samples were adjusted to the original values after a contact period of 30 minutes. After 8 hours, the samples were filtered, analyzed for phenols by the 4-aminoantipyrine method, and then analyzed for di- and tri-chlorophenols using an electron capture detector. Chloro-cresols and other chlorophenols were not included because reagent-grade materials for use as standards could not be found. The results are given in Table 70.

Trichlorophenol was present in all samples, but the concentration decreased rapidly with increasing levels of chlorine. However, traces remained in samples treated with the highest levels of chlorine. The rate of oxidation was highest at pH 4.5 and decreased with increasing alkalinity, although the difference between pH 7.0 and 9.5 was not great. The relationship between results of the APHA test for phenols and levels of chlorophenols determined using an electron capture detector was generally poor at low chlorine levels. However, low values for the APHA test always corresponded with low concentrations of chlorophenols.

Ozone Treatments - Ozone is a powerful oxidizing agent, but its employment in waste treatment is a relatively recent development. Its principal disadvantages are its lack of stability, which requires that it be produced as used, and its high cost both in terms of capital investment

TABLE 70 CHLOROPHENOL CONCENTRATION IN CREOSOTE WASTEWATER
TREATED WITH CHLORINE

pH	Ca(OCl) ₂ As Chlorine (g/l)	Residual Phenols (mg/l) by APHA Method	ECD Analysis (mg/l)	
			2-, 4-dichloro- phenol	2-, 4-, 6-tri- chlorophenol
	0	438.5	--	--

4.5	0.5	256.1	161.0	910.0
	1.0	30.8	0.0	6.7
	1.5	0.0	0.0	1.5
	2.0	0.0	0.0	1.0
	3.0	0.0	0.0	0.3
	5.0	0.0	0.0	0.3
7.0	0.5	300.0	122.0	316.0
	1.0	101.5	0.0	35.0
	1.5	7.7	0.0	6.4
	2.0	0.0	0.0	2.8
	3.0	0.0	0.0	1.5
	5.0	0.0	0.0	1.3
9.5	0.5	315.4	198.0	264.0
	1.0	101.5	0.0	27.0
	1.5	11.5	0.0	25.0
	2.0	0.0	0.0	3.7
	3.0	0.0	0.0	3.8
	5.0	0.0	0.0	1.9

in equipment and operating costs. The major cost of producing ozone is electricity. It requires 19.8 kwh of electricity to produce one kilogram of ozone with air feed to the generating equipment and 9.9 kwh with oxygen feed (96). The high initial cost of ozonation is offset in part by the fact that the equipment has a useful life expectancy of 25 years (114).

Treatment of wastewater with ozone may be either by batch or continuous flow methods. Ozone reacts rapidly with phenols at all pH levels, but the optimum pH observed by Niegowski (114, 115) was 12.0. Ozone demand at pH 12 was less than one-half that at pH 7 in treating petroleum wastewaters. However, the difference in demand was manifested only in oxidizing the last 30 percent of the phenol in the waste. During two-thirds of the oxidation, the reaction was so rapid that pH had very little effect.

A ratio of ozone:phenol of about 2:1 normally is required to destroy the phenols in a solution. However, ratios as low as 1:1 and as high as 10:1 were reported by Niegowski (114) for wastewaters from different sources. According to Gloyna and Malina (116), only about one-tenth as much ozone is required as chlorine to oxidize the same amount of phenol.

Because of its high energy requirements and the resulting high operating costs, ozonation does not lend itself to the treatment of wood preserving wastewaters, and hence will not be considered further in this report.

Activated Carbon Filtration - Activated carbon is used commercially to treat petroleum (117) and other types (118) of industrial wastewaters. It can also be used effectively to remove phenolic compounds from wood preserving waste streams. Although carbon has a strong affinity for non-polar compounds such as phenols, adsorption is not limited to these materials. Other organic materials in wastewater are also adsorbed, resulting in a decrease in the total oxygen demand of the waste. Because the concentration of the latter substances exceeds that of phenols in effluents from wood preserving plants, the useful life of activated carbon is determined by the concentration of these materials and the rate at which they are adsorbed.

Results of carbon-adsorption studies conducted by Dust and Thompson (25) on a creosote wastewater are shown in Figure 42. Granular carbon was used and the contact time was 24 hours. The wastewater was flocculated with ferric chloride and its pH adjusted to 4.0 prior to exposure to the carbon. As shown in the figure, 96 percent of the phenols and 80 percent of the COD were removed from the wastewater at a carbon dosage of 8 g/liter. The loading rate dropped off sharply at that point, and no further increases in phenol removal and only small increases in COD removal occurred by increasing carbon dosage to 50 g/liter. Similar results were obtained in tests using pentachlorophenol wastewater.

Results of adsorption isotherms that were run on pentachlorophenol wastewater, and other samples of creosote wastewater followed a pattern similar

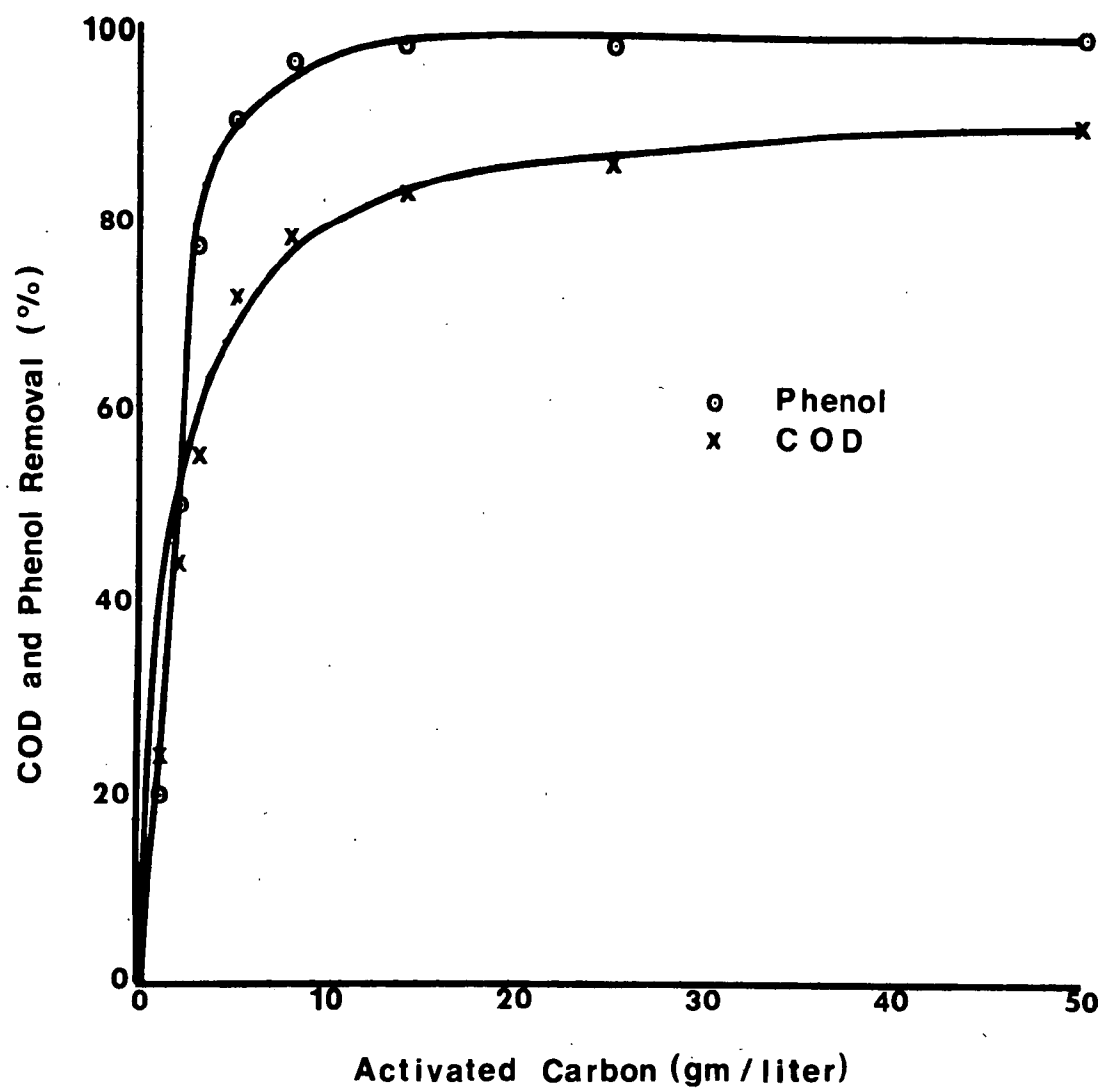


FIGURE 42 (25) - RELATIONSHIP BETWEEN WEIGHT OF ACTIVATED CARBON ADDED AND REMOVAL OF COD AND PHENOLS FROM A CREOSOTE WASTEWATER

to that shown in Figure 42. In some instances a residual content of phenolic compounds remained in wastewater after a contact period of 24 hours with the highest dosage of activated carbon employed, while in other instances all of the phenols were removed. Loading rates of 0.16 kilograms of phenol and 1.2 kilograms of COD per kilogram of carbon were typical, but much lower rates were obtained with some wastewaters.

Other Waste Handling Methods

Containment and Spray Evaporation - Forty-two percent of the plants responding to the survey referred to in Section V indicated that they currently are storing their wastewater on company property, and therefore have no discharge (Table 45). The popularity of this method of waste handling undoubtedly is attributable to its low cost, in the case of plants with ample land area, and its simplicity. The practicality of the method is questionable in areas of high rainfall and low evaporation rate, unless the rate of evaporation is increased by the application of heat or by spraying. The latter alternative is being employed by a number of plants in the Gulf South.

The use of spray ponds to dispose of wastewater by evaporation requires that a diked pond of sufficient capacity to balance annual rainfall and evaporation be constructed. The pond is normally equipped with a pump and the number of spray nozzles necessary to deliver to the air the volume of water calculated to provide the desired amount of evaporation, assuming a given evaporation efficiency.

The feasibility of spray evaporation depends upon the availability of a land area of such size that a pond large enough to permit a balance between inflow and evaporation can be constructed. Pond size and number of spray heads are determined by waste volume and the ratio of rainfall to surface evaporation. Where rainfall and evaporation in a region are approximately equal, the effect of both can be neglected, if sufficient storage capacity is provided. For areas with higher annual rainfall or lower evaporation rate, the design of a spray evaporation system must account for a net annual increase in water volume in the pond due to rainfall.

Pan Evaporation - A few plants with small volumes of wastewater are evaporating it directly by application of heat. Basically, the procedure involved is to channel the effluent from the oil-separation system into an open vat equipped with steam coils. The water is then vaporized by boiling, or, as in one instance, heated to approximately 71°C (160°F) and the rate of evaporation increased by circulation of air across the surface of the water. The method is expensive, fuel cost alone amounting to an estimated \$8 00 per 3,785 liters (1000 gallons). This estimate is based on using natural gas as fuel and assumes an overall efficiency of 65 percent for the process.

Evaporation In Cooling Towers - In this process, effluent from the oil-separation system is discharged to the basin of a cooling tower and re-used as cooling water. Normal evaporation associated with the operation of the tower accounts for an average loss of approximately 7,570 lpd (2000 gpd) for a typical tower. Evaporation of excess water is expedited by the intermittent operation of a heat exchanger or other heating system in conjunction with a fan. The efficiency of the condensers, both tube-type and barometric, are reported to be unaffected by water temperatures of up to 38°C (100°F) and by light oils that accumulate in the water. The owner of one plant stated that oil concentrations as high as 10 percent could be tolerated in the cooling water. However, problems with condenser efficiency were reported at another plant in which the oil content of the process water used for cooling was less than 100 mg/liter.

Incineration - Two plants in the U.S. are known to operate incinerators for wastewater disposal. The one plant for which data are available currently operates a unit capable of "burning" 5,676 liters (1500 gal) of wastewater per hour. Fuel cost alone for this unit, which is fired with Bunker C oil, is \$15.00 per 3,785 liters (1000 gal) of waste.

Data reported by the American Wood Preservers' Association (48) indicate that incineration of wastewater is economical only when the oil content of the waste is 10 percent or higher. Such high oil contents are not common for wastewater from the wood preserving industry.

General Information

Required Implementation Time - Because of the relatively small volume of wastewater at most wood preserving plants, "off-the-shelf" equipment should ordinarily meet the requirements of the individual plants with regard to the application of treatment technology required to be achieved by July 1, 1977 and July 1, 1983, respectively. It is not anticipated, therefore, that either equipment availability, or (because of the simplicity of the equipment) availability of construction manpower will seriously affect implementation time. For the same reason, it is not anticipated that the time required to construct new treating facilities or modify existing ones will affect implementation time for any of the treatment and control technologies that are likely to be employed in the industry.

Land availability will influence the choice of treatment and control technology at many wood preserving plants located in urban areas. For example, the employment of oxidation ponds, soil irrigation, and possible aerated lagoons will not be feasible in areas where all company land is in use and additional acreage cannot be purchased at a reasonable price. Plants thus located will have to select extended aeration or other treating methods, the land requirements of which conform to the space that is available.

Effect Of Treatment Technology On Other Pollution Problems - None of the treatment and control technologies that are currently feasible for use in the wood preserving industry will have an effect on other pollution problems.

Solid Waste - Solid wastes resulting from treatment and control technologies that have potential use in the wood preserving industry are of two types: sludge from coagulation of wastewater and bacterial sludges originating from biological treatments. The former material contains oil and dissolved phenolic compounds originally in the preservative, along with the flocculating compound used. In the case of water-soluble preservatives, the sludge will contain traces of the metals used in the particular preservative or fire retardant formulation involved. Bacterial sludges contain the biomass from biological treatments, but are of importance from the standpoint of disposal only in the case of treatments that employ activated sludge and trickling filter units.

The volume of sludge involved with both types is small. Plants currently are disposing of these materials in sanitary landfills. Incineration of organic waste and burial of inorganic salts are possible disposal methods that could be used.

Plant Visits

A number of wood preserving plants judged to be exemplary in terms of their waste management programs were visited in conjunction with this study. Selection of plants for visits was based on the type of wastewater treating and/or disposal system employed and, insofar as possible, geographic location. Plants that dispose of their raw waste by discharging it to a sewer, as well as those that simply store their waste on site, were not represented among the plants visited. Exclusion of these plants limited the number considered for a visit to the approximately 30 plants in the U.S. that either give their waste the equivalent of a secondary treatment before discharging it, or which have no discharge. Only four of this number were found both to treat their waste on site and discharge it directly to a stream. The remainder either channel their treated water to an irrigation field or to a sewer, or have no discharge due to reuse of wastewater, evaporation, or both.

Plant visits were used to obtain samples, the analyses of which permitted an evaluation of the efficiency of the wastewater treating system employed. Performance data provided by the plants themselves were used in this evaluation when available. Information was also obtained on flow rate, annual production, and other parameters needed for the development of effluent guidelines. Cost data on wastewater treating systems were requested of all plants and provided by some.

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A summary of the data obtained for each plant visited is presented in Table 71. Flow diagrams illustrating waste treatment systems employing extended aeration, soil percolation, and combination aerated lagoon and oxidation pond are shown in Figures 43, 44, and 45, respectively.

Detailed data on each plant are given in Supplement B.

TABLE 71 SUMMARY OF WASTEWATER CHARACTERISTICS FOR 17 EXEMPLARY WOOD PRESERVING PLANTS

Plant No.	Phenol (mg/l)	COD (mg/l)	Oil And Grease (mg/l)	Suspended Solids (mg/l)	Volume of Effluent (lpd)	Volume of Discharge (lpd)	Daily Production (m ³)	Cost (\$)	Final Disposition of Waste
1	6.00	845	7	100	73,800	0	283	42,000	Sewer
2*	0	10	7	253	49,200	0	283	90,000	Field
3	0.50	10	0	60	49,200	0	266	30,000	Field
4*	35.96	1695	83	724	34,100	0	436	17,000	Field
5	--	--	--	--	3,800	0	210	40,000	Field
6	--	--	--	--	34,100	0	403	25,000	Field
7	3.30	523	55	103	567,800	492,100	708	85,000	Stream
8	0.40	435	158	270	98,400	87,100	425	46,000	Stream
9	--	--	--	--	15,100	0	178	38,000	Pond
10	--	--	--	--	22,700	0	204	85,000	Evaporated
11	--	--	--	--	49,200	49,200	93	--	Ditch
12	--	--	--	--	18,900	0	210	120,000	Evaporated
13	--	--	--	--	4,700	0	62	5,500	Evaporated
14	--	--	--	--	9,500	0	125	6,000	Evaporated
15	--	--	--	--	7,600	0	34	50,000	Evaporated
16	--	--	--	--	19,700	0	190	39,000	Sewer
17	2.50	240	12	82	63,200	63,200	223	--	Stream
Average	2.50	240	46	123	34,600	--	255	47,900	

*Data not included in average.

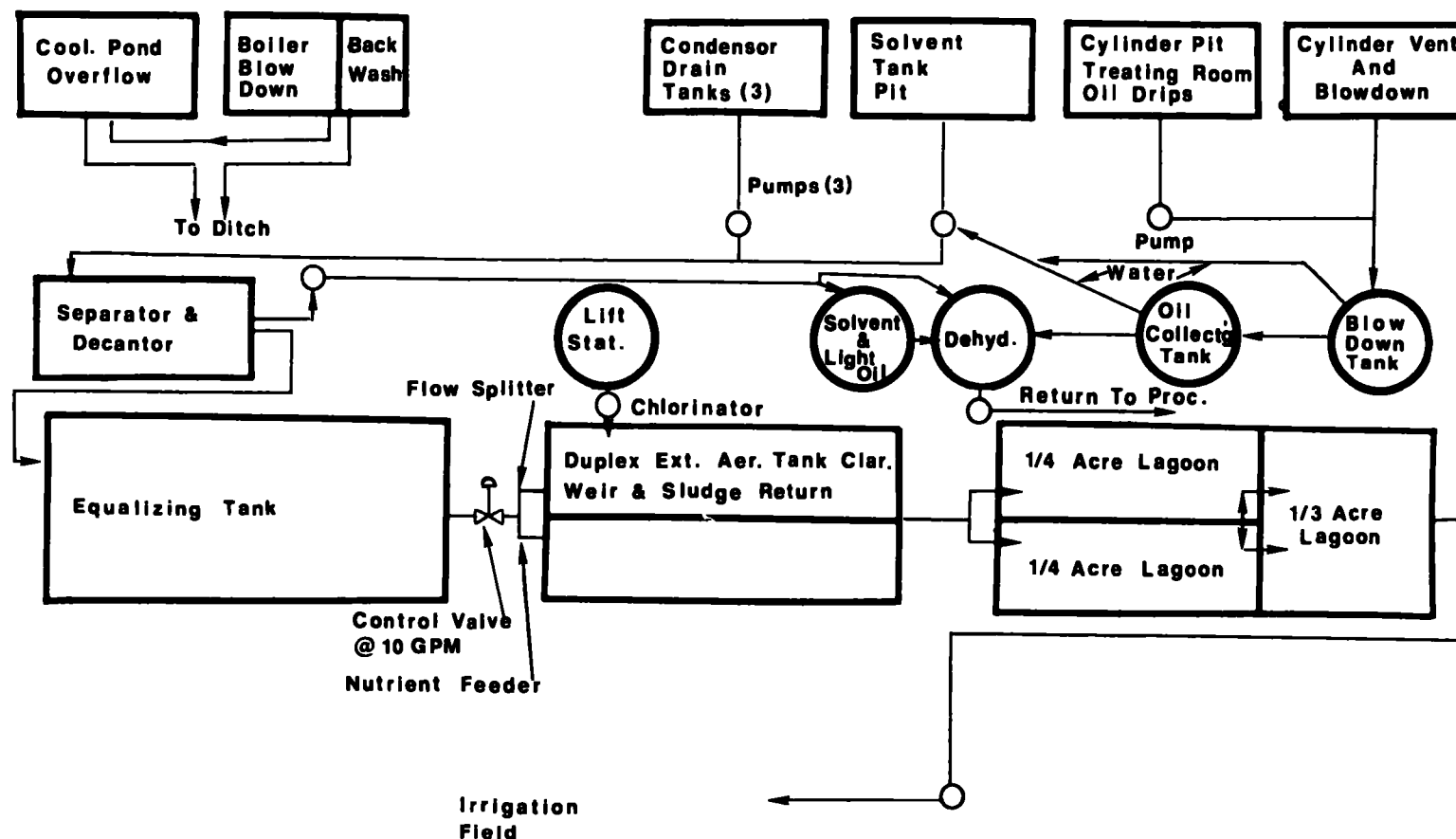


FIGURE 43 - WASTEWATER FLOW DIAGRAM FOR WOOD-PRESERVING PLANT EMPLOYING AN EXTENDED AERATION WASTE TREATMENT SYSTEM IN CONJUNCTION WITH HOLDING LAGOONS AND SOIL IRRIGATION

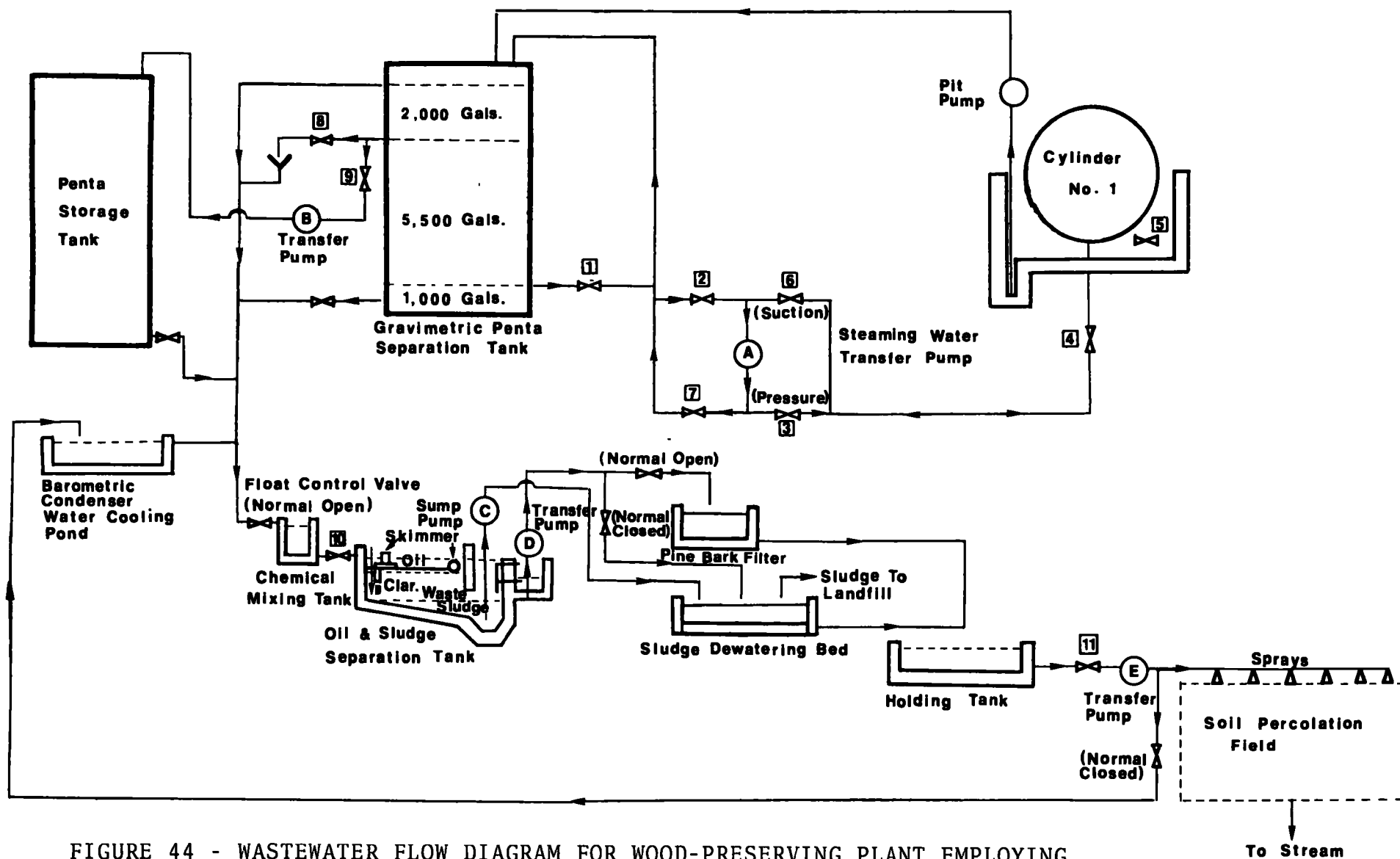


FIGURE 44 - WASTEWATER FLOW DIAGRAM FOR WOOD-PRESERVING PLANT EMPLOYING CHEMICAL FLOCCULATION, SAND FILTRATION, AND SOIL IRRIGATION

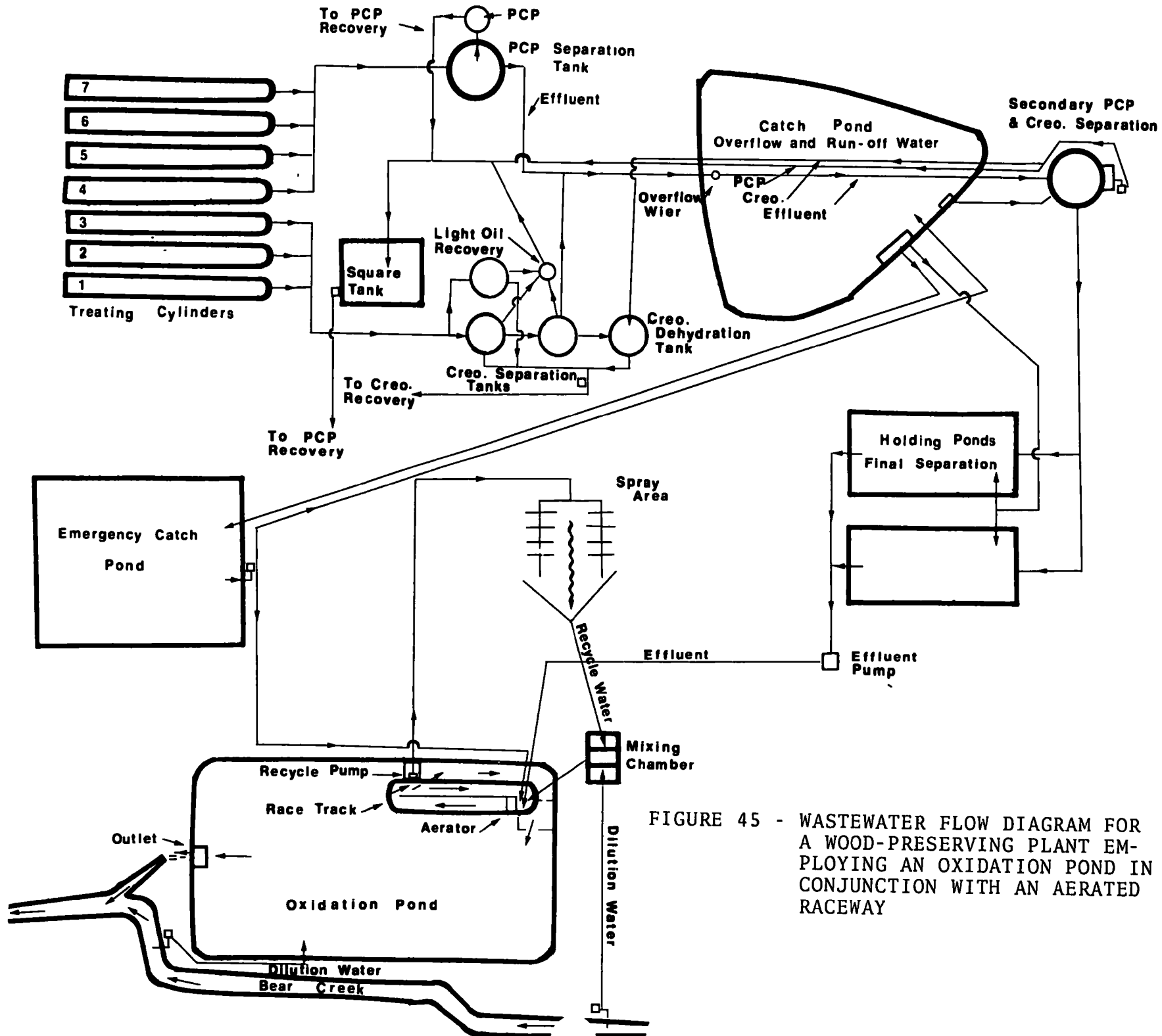


FIGURE 45 - WASTEWATER FLOW DIAGRAM FOR A WOOD-PRESERVING PLANT EMPLOYING AN OXIDATION POND IN CONJUNCTION WITH AN AERATED RACEWAY

SECTION VIII

COST, ENERGY, AND NON-WATER QUALITY ASPECTS

PART A: VENEER AND PLYWOOD

Cost And Reduction Benefits of Alternative Treatment And Control Technologies For Selected Typical Plant

A detailed analysis of the costs and pollution reduction benefits of alternative treatment and control technologies applicable to the veneer and plywood industry is given in Supplement A of this document. The typical veneer and plywood mill chosen as a basis for cost estimates is a mill producing 9.3 million square meters on a 9.53 millimeter basis (100 million square feet on a three-eighths inch basis) per year. It is assumed to have the following:

- (1) Wet decking of logs without recycle;
- (2) Log conditioning by means of hot water vats with discharge due to direct steam impingement;
- (3) No containment of dryer washwater;
- (4) A phenolic glue line without recycle or reuse of washwater.

Table 72 summarizes waste loads from each treatment and control alternative.

TABLE 72

SUMMARY OF WASTE LOADS FROM TREATMENT ALTERNATIVES

Effluent Constituent Parameters	Units	Raw Waste Loads	Resulting Effluent Levels				
			A	B	C	D	E
BOD	kg/day	558	558	481	411	2.7	0
COD	kg/day	1174	1174	1000	1000	19	0
SS	kg/day	363	363	378	378	11	0
TS	kg/day	1109	1109	1000	1000	19	0
Phenols	kg/day	0.25	0.25	0.09	0.09	0.004	0
Kjld-N	kg/day	4.14	4.14	3.8	3.8	0.5	0

Alternative A: No Waste Treatment Or Control

Effluent waste load is estimated at 560 kilograms (1230 pounds) per day for the selected typical plant.

Costs: None
Reduction Benefits: None

Alternative B: Complete Retention of Glue Washwater

This alternative includes complete retention of glue wastes by recycle and reuse in glue preparation. This practice has now become standard in the industry although four years ago only one mill practiced complete recycle. Effluent waste load is estimated at 481 kilograms (1060 pounds) per day for the selected typical plant at this control level. In addition, 73 percent of the phenol load is removed.

Costs: Incremental costs are approximately \$17,500 over Alternative A, thus total costs are \$17,500.
Reduction Benefits: An incremental reduction in plant BOD is approximately 77 kilograms (170 pounds) per day. Total plant reduction in BOD would be 13.8 percent.

Alternative C: Complete Retention of Wet Decking Wastewater

This alternative includes complete retention of wet decking wastewater by collection and recycle, but no control for other wastes. This practice is a relatively new technology, but it is currently used in several mills. Effluent waste load is estimated at 409 kilograms (900 pounds) of BOD per day for the selected typical plant at this control level.

Costs: Incremental costs are approximately \$39,000 over Alternative B, thus total costs are \$56,500.
Reduction Benefits: An incremental reduction in plant BOD of 73 kilograms (160 pounds) is evidenced when compared to Alternative B. The total plant reduction in BOD is 26.5 percent.

Alternative D: Complete Retention of Wastewater From Log Conditioning

Alternative D would result in complete recycle of water from hot water vats with containment of excess wastewaters. Modification of hot water vats to provide heat by means of coils

rather than direct steam impingement is assumed. Effluent waste load is estimated as three kilograms (six pounds) of BOD per day for the selected typical plant at this control level.

Costs: Incremental costs of approximately \$12,000 over Alternative C would be incurred, thus producing total costs of \$68,500.

Reduction Benefits: An incremental reduction in plant BOD of 406 kilograms (894 pounds) per day is evidenced when compared to Alternative C. Total plant reduction in BOD is 99.5 percent.

Alternative E: Complete Retention of Dryer Washwater

Alternative E would result in the complete retention of dryer washwater. Modification of washing operations to reduce the volume of water used is assumed. Effluent waste load is estimated at zero kilograms (zero pounds) of BOD per day for the selected typical plant at this control level. Complete control of wastes without discharge to receiving waters is effected.

Costs: Investment costs of \$5,000 to \$10,000 over Alternative D would be incurred, thus producing total costs of about \$76,000 (\$74,000 to \$79,000).

Reduction Benefits: An incremental reduction in plant BOD of three kilograms (six pounds) per day is evidenced when compared to Alternative D. Total plant reduction in BOD of 100 percent.

Mills With Existing Steam Vats

In Sections I, II, and IX of this report; it is mentioned that special consideration is recommended for mills with existing steam vats. Since there are a number of mills with steam vats, it is felt that these should not be treated as rare cases to be dealt with as the occasion arises. In Section VII, Treatment And Control Technology, it is noted that existing technology for treatment and control of wastewaters from steam vats consists of biological treatment which is capable of 85 to 90 percent removal of BOD. Two modifications of steam vats (modified steaming and hot water sprays) which make zero discharge feasible are also discussed in Section VII. It is evidenced, however, that these modifications do not represent currently available technology as defined by the "Act."

As discussed in Section VII, Control and Treatment Technology, biological treatment is applicable to wastewaters from steam vats. A summary of costs and effluent levels for biological treatment of wastewaters from mills with existing steam vats is presented below.

A system consisting of a vacuum separator followed by an aerated lagoon would cost approximately \$81,000 for the selected typical mill utilizing a steam vat and would reduce the load to around 41 kilograms (90 pounds) of BOD per day.

An activated sludge plant may result in slightly higher BOD removals for a cost of about \$138,000 and a resulting BOD load of about 20 kilograms (45 pounds) of BOD per day for the selected typical mill.

Related Energy Requirements of Alternative Treatment and Control Technology

It is estimated that 180 kilowatt-hours of electricity are required to produce 93 square meters (1000 square feet) of plywood (119). This electrical energy demand is affected by the following factors: (1) type of wood, (2) whether or not logs are conditioned, (3) type of dryer, (4) amount of lighting, and (5) pollution control devices.

For a typical mill producing 9.3 million square meters (100 million square feet) of plywood per year on a 9.53 millimeter (three-eighths inch) basis, total energy demand is estimated at 4500 kilowatts (119). At a cost of one cent per kilowatt-hour, the plant would have a yearly energy cost of \$180,000. Associated with the control alternatives are annual energy costs. These are estimated to be:

For Alternative A:	\$0
For Alternative B:	\$800
For Alternative C:	\$2,100
For Alternative D:	\$2,200
For Alternative E:	\$2,300

Non-Water Quality Aspects Of Alternative Treatment And Control Technology

Air Pollution: While there are no appreciable air pollution problems associated with any of the treatment and control alternatives, in the veneer and plywood industry there are air pollution problems presently in existence that may cause water

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pollution problems. The two main sources of air pollution are from veneer dryers and from the hog boiler (bark boiler).

Associated with each are different polluttional problems of significance. Stack gases from the dryers contain volatile organics and those from the boiler contain suspended particulate matter.

Veneer Dryers: Since there are currently no emission control systems installed on any plywood veneer dryers, it is not possible to cite typical applications or technology. There are, of course, methods operating on similar processes which would be suitable and applicable for controlling emissions from veneer dryers.

If particulate emissions were excessive, they could be adequately controlled utilizing inertial collectors of the cyclone or mechanical type. Volatile and condensable hydrocarbon emissions could be effectively controlled by one of the several following methods:

- (1) Condensation, utilizing tube condensers with air or water for cooling.
- (2) Absorption (scrubbing), utilizing water or a selective solvent.
- (3) Incineration or thermal oxidation.
- (4) Adsorption
- (5) A combination of the above.

The water pollution potential of these control methods is not great. Only condensation and scrubbing use water. Water used in condensation is only cooling water and is, therefore, not contaminated, while the most efficient scrubber appears to be that using a selective solvent rather than water for absorption.

Boiler: The emissions from hogged fuel boilers consist of flyash particulates. Both the sulfur oxide and nitrogen oxide gaseous concentrations are negligible. While most hogged fuel boilers are equipped with the multiple cyclone type of centrifugal collectors, in most areas this solution is no longer adequate because of increasingly stringent emissions limitations. The solution to the flyash emission problem appears to depend on the use of wet scrubbers.

Such a control method creates a water pollution problem. A boiler generating 68,000 kilograms (150,000 pounds) per hour of steam generates a flyash slurry wastewater of 190 liters (50 gallons) per minute with a solids concentration of about 6,000 milligrams per liter (120).

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Odors: Odors presently associated with veneer and plywood are not considered a problem. Since the control and treatment technology of this industry is greatly dependent on containment ponds, there is always the danger of ponds becoming anaerobic. Frequently anaerobic ponds will promote growth of organisms which biochemically reduce compounds to sulfur dioxide and other odor causing gases.

Solid Waste: The bulk of the solid waste from veneer and plywood mills is comprised of wood residues and bark. These wastes are commonly used as fuel in the boiler.

In addition to wood wastes are the settleable solids that accumulate in ponds and those that are separated in screening devices. Disposal of this material may be at the plant site or the waste material may be collected by the local municipality with disposal by landfill. While the amount of solids generated is not expected to be great, consideration must be given to a suitable site for landfill and, in turn, to protection of groundwater supplies from contamination by leachates.

SECTION VIII

PART B: HARDBOARD

COST AND REDUCTION BENEFITS OF ALTERNATIVE TREATMENT AND CONTROL TECHNOLOGIES FOR DRY PROCESS HARDBOARD

A detailed analysis of the costs and pollution reduction benefits of alternative treatment and control technologies applicable to the dry process hardboard industry is given in Supplement A of this document. The typical mill selected to represent the dry process hardboard industry has a production of 227 metric tons (250 tons) per day. The wastewater discharges result only from caul washing and cooling water. The basic results are summarized below:

Alternative A: No Waste Treatment Or Control

Effluent consists of only 950 liters (250 gallons) per day of caul washwater and 28,500 liters (75,000 gallons) of cooling water. There is no log or chip wash, no resin washwater, humidifier water or housekeeping water discharges.

Costs: None
Reduction Benefits: None

Alternative B: Retention of Caul Washwater and Discharge of Cooling Water

This alternative includes the collecting of caul washwater in a holding tank and trucking to land disposal after pH neutralization. Cooling water would be discharged into a receiving stream.

Costs: Incremental costs are approximately
\$21,500 over Alternative A, thus total
costs are \$21,500.
Reduction Benefits: Elimination of caul wash-
water as a discharge stream.

Factors Involved In The Installation Of Treatment Systems

The only treatment system involved in the representative dry process mill is the disposal of caul washwater by hauling to land disposal. There are no problems concerning the reliability of the system as caul washwater will be put into a storage tank, neutralized, then hauled by truck to a disposal area. This system is not sensitive to shock loads, and start-up and shutdown procedures do not cause a problem. This

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system can be designed and installed within one year and requires little or no time to upgrade operational and maintenance practices. There are no air pollution, noise, or radiation effects from the installation of this treatment system. The quantities of solid waste generated from this system are insignificant as are the additional energy requirements.

COST AND REDUCTION BENEFITS OF ALTERNATIVE TREATMENT AND CONTROL TECHNOLOGIES FOR WET PROCESS HARDBOARD

A detailed analysis of the costs and pollution reduction benefits of alternative treatment and control technologies applicable to the wet process hardboard industry is given in Supplement A of this document. The typical mill selected to represent the wet process industry has a production of 127 metric tons (140 tons) per day, a wastewater flow of 1,432 cubic meters (0.378 million gallons) per day, a BOD of 33.75 kilograms per metric ton (67.5 pounds per ton), and a suspended solids concentration of nine kilograms per metric ton (18 pounds per ton). The basic results of the cost estimates are shown below. All cost estimates are based on August, 1971, prices.

Alternative A: Screening and Primary Clarification

Raw wastewater characteristics for the typical mill having a BOD of 33.75 kilograms per metric ton (67.5 pounds per ton) represents a mill with recirculation but no inplant treatment facilities.

Costs: \$109,000

Reduction Benefits: A BOD reduction of ten percent and a suspended solids reduction of 75 percent would be incurred.

Alternative B: Addition of Activated Sludge Process

This alternative includes the addition of an activated sludge process including pH adjustment and nutrient addition to Alternative A. The effluent from this system would average 3.4 kilograms per metric ton (6.8 pounds per ton) BOD and 2.25 kilograms per metric ton (4.5 pounds per ton) suspended solids, respectively.

Costs: Incremental costs are approximately \$435,000 over Alternative A, thus the total costs are \$544,000.

Reduction Benefits: An incremental reduction in BOD₅ of from 2700 milligrams per liter to 300 milligrams per liter for a reduction of 88.9 percent would be achieved. Suspended solids would increase from 200 milligrams per liter to 250 milligrams per liter for a 0.0 percent reduction. Total plant reduction in BOD₅ would be 90 percent; and suspended solids reduction would be 69 percent.

Alternative C: Addition of An Aerated Lagoon Treatment System to Alternative B

This alternative includes the addition of a five day detention time aerated lagoon to the preceding treatment system in Alternative B. The effluent from this system would average 1.6 kilograms per metric ton (3.2 pounds per ton) BOD and 2.8 kilograms per metric ton (5.6 pounds per ton) of suspended solids, respectively.

Costs: Incremental costs of \$299,000 over Alternative B would be incurred, thus producing a total cost of \$843,000.

Reduction Benefits: The BOD₅ in the effluent of this system would average 150 milligrams per liter for an incremental reduction of 50 percent and an overall reduction of 69 percent.

Alternative D: Evaporation Of Process Water - Activated Sludge Treatment of Condensate

This alternative is a new process separate from those discussed previously. Alternative D consists of the addition of a pre-press inplant which results in wastewater discharges totaling 442 liters per minute (117 gallons per minute) being discharged from the pre-press and the hot press. The total waste flow would be passed through a screen, primary clarifier, and evaporator. Condensate from the evaporator would then be treated in an activated sludge system prior to discharge.

Costs: Total cost of this system would be \$722,000.

Reduction Benefits: The BOD₅ of this system would average 0.2 kilograms per metric ton (0.4 pounds per ton) and the suspended solids 1.25 kilograms per metric ton (2.5 pounds per ton) for an overall reduction of 99.4 percent and 86 percent, respectively.

Factors Involved In The Installation of Alternative A

All existing wet process hardboard mills presently have screening and settling or the equivalent of primary settling as part of their treatment systems. Several mills utilize a single lagoon or pond for both settling and sludge storage. The use of a settling and storage pond in one unit is not desirable because of anaerobic decomposition which resuspends solids and releases dissolved organics into the effluent. The primary clarifier recommended in Alternative A consists of a mechanical clarifier with continuous sludge wasting to a sludge lagoon.

Mechanical clarifiers are one of the simplest and most dependable waste treatment systems available. They are not sensitive to shock loads and shut-down and start-up of manufacturing processes have little or no effect. Primary clarifiers and screening devices are readily available on the market and an estimated time of one year would be required for the design and construction of such a facility. It is estimated that an area less than one and one-half acres would be required for this system. The additional energy required to operate this system is estimated to be 22 kilowatt-hours.

There are no noise or radiation effects related to this process; however, the disposal of 285 kilograms (630 pounds) per day of solids into a sludge lagoon may be a source of potential odor problems.

Factors Involved In the Installation of Alternative B

Alternative B consists of an activated sludge system following the facilities previously discussed in Alternative A. Activated sludge treatment of wet process hardboard mill waste can be quite effective. However, the system has all of the problems associated with activated sludge treatment of domestic plus several more. These include the necessity for pH control and nutrient addition. Another major problem is that the activated sludge produced does not readily settle. This can frequently cause high suspended solids in the effluent. Temperature apparently has a major effect not only by reducing the biological reaction rates during cold weather, but also affecting the settling rates of the mixed liquor suspended solids (MLSS).

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Activated sludge systems require constant supervision and maintenance. They are quite sensitive to shock loads and to shut-down and start-up operations of the manufacturing process. The equipment needed for activated sludge systems is available on the market; however, up to two years may be required from initiation of design until beginning of plant operation. The energy requirements as high as approximately 320 kilowatt-hours are needed to operate the process. There is essentially no noise or radiation effects associated with the process; however, the disposal of approximately 3.3 metric tons (three tons) of waste solids each day can cause potential odor problems.

Factors Involved In The Installation Of Alternative C

Alternative C consists of an aerated lagoon following the process described in Alternative B. Similar problems associated with the operation of an activated sludge process hold true with this system. Since the system will be preceded by an activated sludge process, slug loads are not a problem. Temperature does affect the system as it does any biological system. The only additional equipment necessary for this system is aeration equipment of which an additional 225 kilowatt-hours of energy is required. The estimated time of construction of this facility is one year from initiation of design. No noise or radiation problems are associated with this process, nor are there any odor problems.

Factors Involved In The Installation Of Alternative D

Alternative D is a completely different system from those described in Alternatives A through C. This system consists of the installation of a pre-press inside the wet process mill to dewater the stock between the cyclone and the stock chest. This allows a projected decrease in wastewater flow from 1,432 cubic meters (0.378 million gallons) per day to 629 cubic meters (0.166 million gallons) per day. Wastewater from the pre-press and the wet press will first be treated through a screening and clarification system as described in Alternative A. Next, instead of using a biological system to remove organics, an evaporation system is used. This system produces a saleable by-product similar to that presently being produced by the Masonite Corporation at two mills. A portion of the condensate is recycled back inplant and the remaining 545 cubic meters (0.144 million gallons) per day is treated in an activated sludge system similar to the system described in Alternative B.

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Evaporation systems must be fed at a relatively constant rate as they are sensitive to shock loads. Maintenance requirements are high due to the nature of the material being evaporated. The evaporator must be cleaned out weekly, if not more frequently. Evaporation equipment can be obtained on the market; however, a two year period from initiation of design until start-up is not unreasonable. Noise and radiation effects are nil, but energy requirements for steam and electricity are significant. For example, approximately 150 kilowatt-hours are required to operate the system in addition to steam requirements. Air pollution factors are related to the energy requirement as fuel must be burned to produce both steam and electricity.

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PART C: WOOD PRESERVING

ALTERNATE TREATMENT AND CONTROL TECHNOLOGIES

Detailed information on the costs and benefits of various alternative treatment and control technologies applicable to the wood-preserving industry is given in Supplement A of this document. As previously indicated, Subcategory 1 and 2 plants are the only ones for which substantial costs may be involved in achieving the recommended effluent limitations. Thus only these alternatives are summarized in this section. Further data and the basis for cost calculations are presented in Supplement A.

ENGINEERING ESTIMATES FOR A HYPOTHETICAL SUBCATEGORY 1 PLANT

Cost figures which have been obtained for wood-preserving plants in Subcategory 1 as shown in Supplement A vary widely for a number of reasons. In order to attempt to provide a reasonable common basis for comparison, a hypothetical waste treatment facility was devised to meet the suggested standards and costs estimated based on May 1973 construction data.

The treatments to be provided are those which already have been recommended: A - Oil separation; B - Coagulation and filtration; C₁ - Biological treatment in aerated lagoons; C₂ - Biological treatment by activated sludge; D - Chlorination as a polishing treatment; and E - Effluent measurement. The two biological treatments are alternates, either one or the other is intended to be used. For estimating purposes, a daily wastewater flow of 53,000 liters (14,000 gallons) was used. The waste loading and quality of effluent which is expected from each stage of treatment suggested is as follows:

_____mg/ liter_____					
Parameter	Raw Waste	A	Treatments B	C	D
COD	40,000	7,260	3,630	410	300
BOD	20,000	3,670	1,865	260	50
Phenols	190	190	190	2.5	0.5
Oil & Grease	1,500	225	80	45	25
Suspended Solids	700	700	350	125	100

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A-Oil Separation - Standard oil separation equipment, equipped for both surface and bottom removal, can be used for this purpose.

Capital cost estimate	\$ 29,760
Annualized cost including operation and maintenance	\$ 0.31/ 1000 liters

B-Coagulation and Filtration - This would consist essentially of a multi-compartmented tank equipped for rapid mix of coagulant, slow mix, and sedimentation. Filtration would be by slow sand filters.

Capital cost estimate	\$ 43,320
Annualized cost including o and m	\$ 0.58/ 1000 liters

C₁-Biological Treatment, Aerated Lagoons - A lined lagoon of about 3 meters in depth and having a surface of about 353 square meters was selected. Two aerators of 7.5 hp each were selected to provide the necessary aeration.

Capital cost estimate	\$ 21,120
Annualized cost including o and m	\$ 0.70/ 1000 liters

C₂-Biological Treatment, Activated Sludge - An activated sludge package plant having a capacity of 378,000 liters per day was selected.

Capital cost estimate	\$120,000
Annualized cost including o and m	\$ 1.75/ 1000 liters

D-Polishing Treatment, Chlorination - Provision is made for dosages of chlorine up to 500 mg/liter and a detention time of 3 to 6 hours. Chlorine will be handled in 200-pound cylinders..

Capital cost estimate	\$ 8,400
Annualized cost including o and m	\$ 0.65/ 1000 liters

E-Effluent Measurement - A recording flow measurement device was selected.

Capital cost estimate	\$ 3,600
Annualized cost including o and m	\$ 0.16/ 1000 liters

Total capital costs for complete treatment with lagoons	\$106,200
Annualized costs for same system	\$2.40/ 1000 liters

Total capital cost for complete treatment with activated sludge	\$205,080
Annualized costs for same system	\$3.45/ 1000 liters

ENGINEERING ESTIMATES FOR A HYPOTHETICAL SUBCATEGORY 2 PLANT

Among Subcategory 2 plants, the most common method of achieving the

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recommended effluent limitations is oil separation followed by evaporation of the residual water. The cost estimate summary for oil separation (Treatment A) has already been presented. Energy, of course, is the most expensive item in disposing of wastewater by evaporation. Based on evaporation of 7,600 liters/day (2,000 GPD) the fuel costs using natural gas are estimated at more than \$4,000 per year. The total annual cost for this scheme (Treatment A plus evaporation) would be about \$ 5.98/ 1000 liters (\$22.67 per 1000 gal.) of excess water evaporated.

NON-WATER QUALITY ASPECTS

None of the wastewater treatment and control technologies discussed above has a significant effect on non-water environmental quality. The limited volume of sludge generated by coagulation and biological treatments of wastewater is currently being disposed of in approved landfills by most plants. Because the organic components of these sludges are biodegradable, this practice should present no threat to the environment.

SECTION IX

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE EFFLUENT LIMITATIONS GUIDELINES

INTRODUCTION

The effluent limitations which must be achieved by July 1, 1977, are to specify the degree of effluent reduction attainable through the application of the Best Practicable Control Technology Currently Available. Best Practicable Control Technology Currently Available is generally based upon the average of the best existing performance by plants of various sizes, ages, and unit processes within the industrial category and/or subcategory. This average is not based upon a broad range of plants within the timber products industry, but based upon performance levels achieved by exemplary plants.

Consideration must also be given to:

- (a) The total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application;
- (b) The size and age of equipment and facilities involved;
- (c) The processes employed;
- (d) The engineering aspects of the application of various types of control techniques;
- (e) Process changes;
- (f) Non-water quality environmental impact (including energy requirements).

Also, Best Practicable Control Technology Currently Available emphasizes treatment facilities at the end of a manufacturing process but includes the control technologies within the process itself when the latter are considered to be normal practice within an industry.

A further consideration is the degree of economic and engineering reliability which must be established for the technology to be "currently available." As a result of demonstration projects, pilot plants, and general use, there must exist a high degree of confidence in the engineering and economic practicability of the technology at the time of commencement of construction or installation of the control facilities.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF
BEST POLLUTION CONTROL TECHNOLOGY CURRENTLY AVAILABLE FOR
THE VENEER AND PLYWOOD INDUSTRY

Based upon the information contained in Sections III through VIII of this report, a determination has been made that the degree of effluent reduction attainable through the application of the Best Pollution Control Technology Currently Available is no discharge of wastewater (not including cooling water) into navigable waters, with special consideration for mills that now use steam vats and for mills that have hydraulic barkers.

Identification of Best Pollution Control Technologies Currently Available

Best Pollution Control Technology Currently Available for the veneer and plywood industry is recycle and reuse of certain process waters within the operation with land disposal of excess water. To implement this requires:

- (a) Recycle of sprinkling water from wet decking. This includes screening and suspended solids removal.
- (b) Recycle of water from hot water vats. This includes: (1) use of steam coils rather than direct steam, (2) suspended solids removal, and (3) pH control for minimization of corrosive effects.
- (c) Containment of dryer washwater. This includes; (1) reduction of water usage and (2) retention of entire flow.
- (d) Recycle of glue washwater. This includes: (1) reduction in the amount of fresh water used, (2) use of washwater to prepare glue, and (3) monitoring of glue and glue washwater to maintain proper solids concentration.
- (e) Retention of all general wastes: e.g., floor and equipment washes.

Mills with existing steam vats are to be treated as special cases for the following reasons: .

- (1) The development of technology for complete retention of wastewater from steam vats is not sufficiently advanced to be definitely achievable by July 1, 1977.

- (2) Biological treatment of steam vat wastewaters is technically feasible and it has been reported that 85 to 90 percent removal can be obtained; however, only one mill is known to do this, and no verification of the degree of treatment exists. The cost of biological treatment is much greater than the apparent cost to modify steam vats to allow zero discharge.

Approximate costs and effluent loads that can be achieved with the application of biological treatment are described in Section VIII, Cost, Energy and Non-Water Quality Aspects.

In addition to mills with steam vats, it has also been recommended that mills that have hydraulic barkers also be given special consideration concerning the July 1, 1977 deadline. There are only a few mills with hydraulic barkers and it is felt that by 1983, there will be none. The application of hydraulic barkers is in the debarking of very large logs, and the harvesting of large logs is decreasing rapidly.

Control and treatment technology for the effluent of hydraulic barkers is non-existent. Waste characteristics are given in Section V. From these it can be seen that suspended solids concentrations are quite high. It is suggested that settling be considered in dealing with effluents from hydraulic barkers.

Engineering Aspects of Control Technique Applications

The technology defined for this level is practicable since it is practiced throughout the industry. In addition, there are mills which are now achieving the effluent reductions set forth herein. The concepts are proven, available for implementation, and may be readily adopted through adaptation or modification of existing production units.

Costs of Application

The cost of achieving zero discharge for a mill with the maximum water pollution problems is summarized in Section VIII, Cost, Energy and Non-Water Quality Aspects. The investment costs associated with this level of technology represent about one percent of the total capital investment needed to build a veneer and plywood mill and the operating costs may be a similar contribution. It appears that the application of this level of technology can be achieved without placing a heavy burden on the industry.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF
BEST POLLUTION CONTROL TECHNOLOGY CURRENTLY AVAILABLE FOR
THE DRY PROCESS HARDBOARD INDUSTRY

Based upon the information contained in Sections III through VIII of this report, a determination has been made that the degree of effluent reduction attainable through the application of the best pollution control technology currently available is no discharge of wastewater to navigable waters.

The best pollution control technology currently available for discharge of non-contact cooling waters is described in the Steam-electric Generation Effluent Guideline document.

Identification of Best Pollution Control
Technology Currently Available

Best pollution control technology currently available for the dry process hardboard industry is recycle and reuse of certain process waters within the dry process hardboard mill with land disposal of excess water. To implement this requires:

- (a) The recycle of log wash or chip wash water when used;
- (b) The recycle of resin wash water;
- (c) Neutralization of caul wash water followed by land disposal;
- (d) Elimination of housekeeping water by dry cleaning;
- (e) Elimination of discharge from humidification by inplant control.

Rationale for the Selection of Best Pollution Control
Technology Currently Available

Age and Size of Equipment and Facilities. The dry process industry is relatively new, therefore, the age of the mills is not a major factor. This coupled with the narrow size differential between plants is insufficient to substantiate the specifications for improvements in waste control indicated.

Total Cost of Application in Relation to Effluent Reduction Benefits. The dry process industry as a whole is a relatively minor wastewater source. The investment of a \$5,000 maximum per mill is an insignificant factor in the cost of producing hardboard.

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Engineering Aspects of Control Techniques Utilized. This level of technology is practicable because mills are presently utilizing this technology.

Process Changes. This technology requires no process changes, rather modifications in housekeeping techniques and existing process operation.

Non-Water Quality Environmental Impact. None.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF
BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE
FOR THE WET PROCESS HARDBOARD INDUSTRY.

Based upon the information contained in Sections III through VIII of this report, a determination has been made that the degree of effluent reduction attainable through the application of the best pollution control technology currently available would allow a final BOD₅ and suspended solids discharge of 1.7 kilograms per ton (3.4 pounds per ton) and 2.8 kilograms per ton (5.6 pounds per ton), respectively.

Identification of Best Pollution Control Technology
Currently Available

Best pollution control technology currently available for the wet process hardboard industry consists of the following recycle and reuse processes inplant, followed by end-of-line waste treatment facilities.

- (a) Recycle of process water as dilution water utilizing temperature control and suspended solids control to reduce the total plant discharge to 10.2 cubic meters per ton (2,700 gallons per ton), the BOD to 33.8 kilograms per ton (67.5 pounds per ton) and the suspended solids to 9 kilograms per ton (18 pounds per ton).
- (b) The total wastewater flow to be treated by screening, primary settling, activated sludge followed by an aerated lagoon.
- (c) Sludge to be either recycled inplant or aerobically digested and disposed of in sludge lagoons.

Rationale for the Selection of Best Pollution
Control Technology Currently Available

Age and Size of Equipment and Facilities. As set forth in this report, industry competition and general improvement in production concepts and wastewater management have led to the modernization of plant facilities throughout the industry.

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With the exception of one large mill, the size differential between mills is insufficient to substantiate the specifications for improvements in waste control as indicated. The one large mill should not be given special consideration.

Engineering Aspects of Control Technique Applications. This level of technology is practicable because 22 percent of the mills in the industry are presently achieving the effluent reductions set forth herein. The concepts are proven, available for implementation, and may be readily adopted through adaptation or modification of existing production units.

Process Changes. This technology does not require any significant inplant modifications as the majority of mills are presently discharging raw wastewater flows and concentrations less than those utilized in the selection of end of pipe treatment systems.

Non-Water Quality Environmental Impact. There is one essential impact upon major non-water elements of the environment: A potential effect on soil systems due to the need to utilize land for the ultimate disposal of waste sludge. With respect to this, it is addressed in a precautionary context only since no evidence has been discovered which even intimates a direct impact--all evidence points to the contrary. Technology and knowledge are available to assure land disposal of sludge can be done with no harmful effects to the environment.

Factors Which Might Affect Effluent Limitations

The major factor and the only factor which should be taken into consideration is temperature. Low temperatures can have a detrimental effect on biological systems, reducing their treatment efficiency, causing increased concentrations of BOD and suspended solids in the effluent. Effluent limitations are based on an average effluent BOD and suspended solids of 150 mg/l and 250 mg/l, respectively. It is felt that a well-designed system as described previously can maintain this treatment efficiency at temperatures such that the waste does not freeze. Special considerations should be given during periods of extreme low temperature when wastewater within the treatment systems actually begins to freeze.

BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE
GUIDELINES AND LIMITATIONS FOR THE WOOD PRESERVING INDUSTRY

Recommendations contained in this section for the wood preserving industry are based on data presented elsewhere in the report. Numerical limitations on specific constituents of discharges are based on the average of the best existing performance by plants in each subcategory. These limitations are to be achieved by existing plants no later than July 1, 1977.

A rigid application of the effluent limitation parameters is not practical in all instances because of differences among plants in age, availability of land, production, process used, and other factors. Factors that are pertinent in this regard are listed and described in terms of their effect on the achievability of the recommended effluent limitations. Consideration of these factors may require some modification of the effluent limitations in the case of particular plants.

Treatment and Control Technology Models

Treatment models representing "best practicable control technology currently available" are presented below. These models are not intended to dictate procedures or processes, but instead are meant to illustrate the methodology by which effluent limitation parameters can be achieved by July 1, 1977. Alternatives to biological treatments include activated carbon filtration and chemical oxidation. While these methods may give the same end results, they are not judged to be economically practical at present, except where the volume of waste is very small. Likewise, they have never been applied on a commercial scale to wood preserving wastewaters, and hence are not "currently available" in the sense of having a high degree of engineering reliability.

TREATMENT MODELS: ACHIEVABLE BY JULY 1, 1977

<u>Biological</u>	
"Q"	"R"
1. Oil Separation	1. Oil Separation
2. Equalization	2. Equalization
3. Chemical Coagulation	3. Chemical Coagulation
4. Sand Filtration	4. Sand Filtration
5. pH Control	5. pH Control
6. Biological Oxidation	6. Soil Irrigation
7. Secondary Clarification	
<u>Physical</u>	
"S"	"T"
1. Oil Separation	1. Oil Separation
2. Coagulation	2. Coagulation
3. Sand Filtration	3. Sand Filtration
4. Evaporation	4. pH Control
	5. Discharge to Sewer

General

Biological oxidation is the only wastewater treating method that is both currently available and economically feasible, by which the objectives of the Act can be achieved by July 1, 1977. The method adopted by individual plants will be determined in part by wastewater characteristics and in part by such factors as volume of waste, capital investment required, land area available, and the specific stream standards that must be met. For example, coagulation and filtration, both of which are shown in the two models for biological treatments, will not be required for wastewater from all plants. Secondary clarification is impractical where treatment is by soil irrigation. The treatment methodology used, whether extended aeration, aerated lagoon, or soil irrigation, will be determined to a large extent by the availability of land. Finally, it is probable that some plants will find it necessary to use a level of treatment beyond that indicated in Models Q and R in order to meet specific stream standards.

The cost of biological treatments is generally recognized to be the lowest among the possible methods of treatment that are compatible with current water quality standards. A major factor that must be considered where this method is used is cost of land. The best results achieved by exemplary plants were obtained where there was sufficient land available to provide lagoons with detention periods of from 120 to 180 days for the treated wastewater. Plants with insufficient land for this purpose were unable consistently to reduce phenol and COD content of their waste below about 2.0 and 450 mg/liter, respectively.

Models S and T, representing physical methods of waste disposal, are included as part of the control and treatment technology achievable by July 1, 1977 because the control methods indicated are both practical and currently available for certain plants. With regard to Model T, approximately 15 percent of the U.S. plants were discharging to publicly-owned sewers in 1972. It is estimated that this percentage will increase to at least 25 percent by 1977. However, the option to dispose of waste by discharging it to a sewer is not available to all plants, depending as it does upon the proximity of a plant to a sewer line and, in some instances, the treatment charge levied by the municipality involved.

Evaporation of wastewater is practical where the volume is small and, depending upon the method used, the waste is of a quality that will permit its reuse as cooling water. Two methods are currently used. In one, the wastewater is simply boiled in an open vat equipped with steam coils until it has all been evaporated. In the second, the process water is discharged to a cooling tower equipped with both a fan and either steam coils or a heat exchanger. The quantity of water in excess of that required for cooling purposes is disposed of by intermittent operation of the heating system. Costs of these methods of wastewater disposal are discussed in Section VIII. These costs are expected to increase significantly in the foreseeable future because of anticipated increases in fuel cost. The economic viability of the two methods is clearly questionable because of their high energy requirements, except where the volume of wastewater is very small.

Because the treatment and control methods indicated as best practicable control technology currently available are "end-of-the-line" processes, plant age is not considered to be a significant factor, except as indicated elsewhere in this section. This is likewise true of process changes that would need to be made to accommodate these methods. None would be required, except as regards disposal of wastewater via a cooling tower, as described above and indicated in Model S. This procedure is not amenable to plants in Subcategory 1 because of the relatively large volume of water involved and the high energy input that would be required to dispose of the excess water.

All of the methods proposed are standard in the sense that they are used by a number of plants. None of them present any unique problems from an engineering point of view.

In-Plant Control

In determining treatment and control technology achievable by July 1, 1977 the following assumptions were made:

- (a) Volume of wastewater will be minimized by making the necessary in-plant process changes to conserve water use.
- (b) Oil content of influent to biological treating systems will be limited to 100 mg/liter or less by installation of efficient oil recovery equipment.
- (c) Equipment and plumbing leaks will be eliminated and spills minimized by good housekeeping practices.
- (d) All discharges of contaminated water generated in processes employing salt-type preservatives and fire-retardant formulations will be recovered and reused as make-up water in preparing fresh batches of treating solution.
- (e) Existing non-pressure processing equipment will be modified to eliminate the introduction of water from precipitation in the treating tank and new equipment will be designed to achieve this result.

In-plant process changes which are currently in use in the industry, and which will minimize the volume of wastewater that must be treated, include the recirculation of direct-contact cooling water and segregation of contaminated and uncontaminated waste streams. Use of once-through, direct-contact cooling water and mixing of contaminated and uncontaminated waste streams are particularly incompatible with efforts to reduce wastewater flow rate and will be reduced in order to maintain treating costs at a reasonable level.

Uncontaminated process water includes condensate from heating coils and heat exchangers, and non-contact cooling water. Although such water could be discharged without treatment, its reuse is recommended. Reuse of condensate from heating coils for boiler make-up water is economically sound, since it is hot and essentially mineral free. The latter characteristic precludes the necessity of adding scale-inhibiting chemicals or otherwise treating it to reduce hardness.

Entrained oils are responsible for most of the pollution in the wood preserving industry. Because of their importance, it is essential that the efficient removal of oils be given primary consideration by plants in the development of wastewater treating systems. The use of modified closed steaming during conditioning and employment of low-speed, high volume pumps in the transfer of preservatives are recommended methods of reducing the incidence of emulsion formation. Removal of free oils can be accomplished efficiently by well-designed, API-type separators. Most of the residual oil in wastewater can be removed either by filtration through oil-absorbent materials or by chemical coagulation.

Control of storm water in the immediate vicinity of retorts and preservative storage tanks may be required because of the accumulation of oil from spillage in such locations. Normally, the total area involved for which collection of storm water is necessary should be quite small.

Collection and treatment of storm water from yards where treated products are stored are unnecessary, based on available data, and are not economically practicable. Storage yards encompassing areas of 8 hectares (20 acres) or more are common in regions having rainfall of 100 to 150 centimeters (40 to 60 inches) per year. Even if the water could be channeled into a lagoon--and this in itself would be a formidable task for plants located on hilly terrain--the cost of treating the 95 million liters (25 million gallons) of annual runoff from an 8-hectare (20 acre) yard, most of which would occur during a four-month period, would far exceed any environmental benefit that could be achieved.

Construction of a lagoon or other suitable structure at a location such that it will intercept major spills is recommended at all plants.

Discharge Limitations

Numerical limitations on discharges for each subcategory of the wood preserving industry are given in Tables 73 and 74. These values are expressed in the two tables as kilograms of pollutants per 1000 m³ of product treated and in effluent concentration, respectively, for information purposes only. The discharge from a plant must be limited on the basis of total weight of pollutant per day. Total allowable discharge should be computed from daily production data shown on the permit application.

TABLE 73 EFFLUENT LIMITATIONS BASED ON BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE: WOOD PRESERVING INDUSTRY
(kilograms of pollutants/1000 m³ of product)*

Sub-category	Wastewater Volume liters/m ³	Phenols	COD	BOD	Oil and Grease	Suspended Solids
1	267	0.658	109.236	69.272	11.989	33.304
1	(2.0 gal/ft ³)	(0.041)	(6.806)	(4.316)	(0.747)	(2.075)
2	--	No discharge of process water permitted				
3	--	No discharge of process water permitted				
4	--	No discharge of process water permitted				

*Values in parentheses are discharge equivalents in pounds/1000 ft³.

TABLE 74 EFFLUENT LIMITATIONS BASED ON BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE: WOOD PRESERVING INDUSTRY
(milligrams of pollutants/liter of water)

Sub-category	Wastewater Volume liters/m ³	Phenols	COD	BOD	Oil and Grease	Suspended Solids
1	267	2.50	410	260	45	125
	(2.0 gal/ft ³)					
2	--	No discharge of process water permitted				
3	--	No discharge of process water permitted				
4	--	No discharge of process water permitted				

Limitations are not placed on total water usage, color, and dissolved solids. However, when discharges containing color or dissolved solids may cause harm to the receiving waters, or cause a violation of existing water quality standards, limits must be established.

The pH of the final effluents from wood preserving plants should be within the range of 6.0 to 8.5.

NOTICE: THESE ARE TENTATIVE RECOMMENDATIONS BASED UPON INFORMATION IN THIS REPORT AND ARE SUBJECT TO CHANGE BASED UPON COMMENTS RECEIVED AND FURTHER INTERNAL REVIEW BY EPA.

If effluent limits based on best practicable treatment currently available fail to meet existing water quality standards, such limits will be upgraded as required.

Specific effluent parameters are given only for Subcategory 1 plants. The effluent limitations for BOD and phenols were based on concentrations of 2.50 mg/liter and 260 mg/liter, respectively. For oil and grease the value used was 45 mg/liter. The concentrations were applied to a flow volume equivalent to 267 liters per cubic meter (2.0 gallons/ft³) of wood treated. These flow rates were obtained from actual measurements made over a period of 24 hours at a number of plants and from data supplied by cooperating plants. Adjustments in measured flow were made to account for reductions in discharge that can be achieved by procedures considered normal for the industry and increases in discharge from storm water collected around treating cylinders and preservative storage areas.

Chemical oxygen demand may be used to monitor BOD where an appropriate correlation factor can be agreed upon. The equation, $BOD = 0.497 COD + 60$ expresses the relationship between the two parameters for BOD values of 150 and larger. However, the ratio of COD/BOD increases rapidly with decreasing BOD. For BOD values in the range of 20 to 50 mg/liter, the relationship is $BOD = 0.161 COD$.

In general, the individual plants in the wood preserving industry do not have the expertise required to make BOD determinations. There is, in addition, some question regarding the reliability of BOD data from plant to plant for this type of waste because of its characteristics. The waste is sterile, and thus must be inoculated with bacterial cultures previously acclimated to the waste. Differences of 200 percent in the efficiency with which several acclimated cultures of bacteria could utilize the same waste have been reported. Such differences would make plant-to-plant comparisons of BOD values meaningless.

Factors to be Considered in Applying Effluent Limitations

The above assessment of what constitutes the best practicable control technology currently available is predicated on the assumption of a degree of uniformity among plants within subcategories that, strictly speaking, does not exist. There are extenuating circumstances which make unrealistic a rigid application of the same effluent limitations to all plants within each subcategory. Some such factors are summarized here in the context of their effect on the achievability of the recommended effluent limitations.

Plant Age

The age of the production facilities is of primary significance in the case of plants within subcategories for which a zero discharge restriction is recommended. A zero discharge of pollutants from an operating wood preserving plant is improbable at best, and, in the case of old plants, is

virtually impossible because of spills and leaks of preservatives on plant property, adjacent roadways, and railroad right-of-way over the years, it is inevitable that small amounts of these materials will be picked up by storm water.

Recommended permissible discharge of pollutants in non-process water are given in Table 75 for plants in Subcategories 2, 3, and 4. The discharge is expressed in concentration only, since it is not related to quantity of product treated. No discharge limit is given for boron because best practical control technology currently available has not yet been determined for this element.

TABLE 75 RECOMMENDED PERMISSIBLE DISCHARGE OF SPECIFIC POLLUTANTS
IN NON-PROCESS WASTEWATER FROM WOOD PRESERVING PLANTS
IN SUBCATEGORIES 2, 3, AND 4

	Plants in Subcategory 3	Plants in Subcategories 2 and 4
Phenols	0.1	0.3
BOD	25.0	25.0
COD	155.0	155.0
Oil and Grease	5.0	5.0
Suspended Solids	15.0	15.0
Arsenic	.25	--
Boron*	--	--
Chromium	0.1	--
Copper	0.5	--
Fluoride	1.0	--
Zinc	1.0	--

*Best control technology for boron has not been determined.

Use of Salt- and Oil-Type Preservatives in One Retort

A no discharge requirement is practical for wastewaters from salt-type treatments (Subcategory 3) in plants where contaminated water from such treatments can be kept segregated from other plant discharges. This is not possible at plants where the same retort is used to treat with both salt-type and oil-type preservatives and at those plants which apply dual treatments. In spite of careful cleaning of all equipment preparatory to changing from a salt-type preservative or fire-retardant to an oil-type preservative, traces of the constituents in the former material remain in the equipment and are picked up by and discharged with wastewater from subsequent treatments using the oil-type preservative. Similarly, contamination of oily waste occurs when products treated with creosote are subsequently treated with salts.

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It is recommended that discharges of heavy-metal ions from plants in Subcategory 1 thus affected be permitted in the amounts indicated in Table 76. The proposed limitations on discharge per unit of production are based on the concentrations shown and on a flow rate of 267 liters per cubic meter (2.0 gallons/ft³).

The limits set for copper, chromium, fluorides, arsenic, and zinc are based on literature reports of the maximum percent removal that can practicably be obtained by standard chemical procedures involving reduction, lime flocculation, and sedimentation (122). Arsenic and fluorides are the most difficult materials to remove from solution, the latter because of the poor settling properties of calcium fluoride and the solubility (8 mg/liter) of this chemical in alkaline water. The maximum removal of arsenic by lime addition is 85 percent. Further removals--up to a maximum of about 95 percent--have been achieved by dual treatments involving lime addition and ferric chloride coagulant in laboratory studies.

History of Pollution Control Effort

Some plants, prompted by state imposed deadlines, have already invested heavily in pollution abatement and control programs (including the installation of equipment) designed to meet applicable stream standards. In some instances, the proposed effluent limitations are more stringent than those the plants are now required by state authorities to meet in order to protect the receiving streams. It would impose a financial hardship on these plants to require them to make additional outlays of capital to meet limitations imposed by the best practicable control technology currently available while still paying off the original debt. In addition, the plants would be placed in an unfair competitive position with other plants, which, for one reason or another, found it unnecessary to make the earlier investment. It is recommended, therefore, that prior investments in pollution control programs and facilities be considered in determining requirements for these plants, provided their effluents are compatible with existing stream standards.

Non-Conforming Plants with High Removal Rates

Because of the particular characteristics of their wastewater, it is possible that a few plants will be unable to conform to July 1, 1977 effluent limitations even after achieving reductions of 90 percent or more in the major pollutants identified in Section VI. It is recommended that a variance to these limitations be allowed for plants that achieve a minimum reduction of 95 percent in the major pollutants, provided that the discharge is compatible with existing stream standards.

TABLE 76
RECOMMENDED PERMISSIBLE DISCHARGES OF METALS FROM WOOD PRESERVING
PLANTS IN SUBCATEGORY 1 THAT EMPLOY THE SAME RETORT
FOR BOTH OIL-TYPE AND SALT-TYPE PRESERVATIVES

(Parenthetical values are discharge equivalents in pounds/1000 ft³)

Parameter	Concentration (mg/l)	Weight (kg/1000 m ³)
Arsenic	1.0	0.273 (0.017)
Boron*	--	--
Chromium	1.0	0.273 (0.017)
Copper	1.0	0.273 (0.017)
Fluorides	10.0	2.664 (0.166)
Zinc	2.0	0.532 (0.033)
Ammonia (as N)	5.0	1.332 (0.083)
Phosphorus	5.0	1.332 (0.083)

*Best practicable treatment for boron has not been determined.

Availability of Land

As mentioned elsewhere, the best performance among plants currently operating waste treating facilities is at those with sufficient land area to permit long-term containment of treated wastewaters. It is improbable that a conventional biological treatment, such as trickling filtration or extended aeration, will consistently reduce oxygen demand and phenol content values compatible with requirements of the best practicable control technology currently available. All of the plants visited that are applying a biological treatment to their waste prior to discharging it to a stream have multizone lagoons that provide a total detention time of up to 180 days after initial treatment by extended aeration or in aerated lagoons. Plants unable to acquire the land needed for lagoon construction should be given special consideration with regard to effluent limitation requirements.

Non-Pressure Processes

A zero discharge requirement is recommended for non-pressure plants. The control measure necessary to attain this level of pollution abatement requires only that water be kept out of the open tanks that are used in this process. This is not feasible in the case of a few plants in cold climates because of ice formation on stock prior to treatment. It is recommended that these plants be permitted a discharge during winter months equivalent to 25 percent of that allowed for plants in subcategory 1.

SECTION X

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF
THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE
EFFLUENT LIMITATIONS GUIDELINES

INTRODUCTION

The effluent limitations which must be achieved by July 1, 1973, are to specify the degree of effluent reduction attainable through the application of the best available technology economically achievable. The best available technology economically achievable is not based upon an average of the best performance within an industrial category, but is to be determined by identifying the very best control and treatment technology employed by a specific point source within the industrial category or subcategory, or where it is readily transferable from one industry process to another. A specific finding must be made as to the availability of control measures and practices to eliminate the discharge of pollutants, taking into account the cost of such elimination.

Consideration must also be given to:

- (a) the age of equipment and facilities involved;
- (b) the process employed;
- (c) the engineering aspects of the application of various types of control techniques;
- (d) process changes
- (e) cost of achieving the effluent reduction resulting from application of the best economically achievable technology;
- (f) non-water quality environmental impact (including energy requirements).

In contrast to the best practicable control technology currently available, the best economically achievable technology assesses the availability in all cases of in-process controls as well as control or additional treatment techniques employed at the end of a production process.

Those plant processes and control technologies which at the pilot plant, semi-works, or other level, have demonstrated both technological performances and economic viability at a level sufficient to reasonably justify investing in such facilities may be considered in assessing the best available economically achievable technology. The best available economically

achievable technology is the highest degree of control technology that has been achieved or has been demonstrated to be capable of being designed for plant scale operation up to and including "no discharge" of pollutants. Although economic factors are considered in this development, the costs for this level of control are intended to be the top-of-the-line of current technology subject to limitations imposed by economic and engineering feasibility. However, the best available technology economically achievable may be characterized by some technical risk with respect to performance and with respect to certainty of costs. Therefore, the best available technology economically achievable may necessitate some industrially sponsored development work prior to its application.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE--
EFFLUENT LIMITATIONS GUIDELINES FOR THE VENEER AND PLYWOOD INDUSTRY

The effluent limitations reflecting this technology is no discharge to navigable waters as developed in Section IX.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE--
EFFLUENT LIMITATIONS GUIDELINES FOR THE DRY PROCESS HARD-BOARD INDUSTRY

The effluent limitations reflecting this technology is no discharge to navigable waters as developed in Section IX.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE--
EFFLUENT LIMITATIONS GUIDELINES FOR THE WET PROCESS HARD-BOARD INDUSTRY

Based upon the information contained in Sections III through VIII of this report, a determination has been made that the degree of effluent reduction attainable through the application of the best available technology economically achievable would result in the discharge of 0.2 kilograms per ton (0.4 pounds per ton) of BOD and 1.1 kilograms per ton (2.1 pounds per ton) suspended solids.

Identification of Best Available Technology Economically Achievable

Best available technology economically achievable for the wet process hardboard industry is achieved by inplant

modifications, recycle and reuse of certain processes within the mill and with activated sludge treatment of the discharge water. To implement this requires:

- (a) Installation of a pre-press between the cyclone and stock chest to reduce wastewater to 4.5 cubic meters per ton (1,186 gallons per ton), the BOD to 33.8 kilograms per ton (67.5 pounds per ton), and the suspended solids to 9 kilograms per ton (18 pounds per ton).
- (b) Recycle of process water to cyclone and stock chest.
- (c) Discharge of process water only from the pre-press and the wet press.
- (d) Treatment of the process water discharge by screening, primary clarification and evaporation.
- (e) Recycle of a portion of the condensate water back to the process.
- (f) Activated sludge treatment of the excess condensate from the evaporator.

Rationale for the Selection of Best Pollution Control Technology Currently Available

Age and Size of Equipment and Facilities. As set forth in this report, industry competition and general improvement as set in production concepts and wastewater management have led to the modernization of plant facilities throughout the industry. With the exception of one large mill, the size differential between mills is insufficient to substantiate the specifications for improvements in waste control as indicated. The one large mill should not be given special consideration.

Engineering Aspects of Control Technique Applications. The process employed is presently being utilized by 22 percent of the industry and, therefore, can be stated to be considered as available technology.

Process Changes. This technology requires the installation of a pre-press and rearrangement of process water flow. At least one of the existing nine wet process hardboard mills is presently using the inplant process.

Non-Water Quality Environmental Impact. There is one essential impact upon major non-water elements of the environment: A potential effect on soil systems due to the need to utilize land as the ultimate disposition of waste sludge. With respect

to this, it is addressed in a precautionary context only since no evidence has been discovered which even intimates a direct impact--all evidence points to the contrary. Technology and knowledge are available to assure land disposal of sludge can be done with no harmful effects to the environment.

Factors Which Might Affect Effluent Limitations. The major factor and the only factor which should be taken into consideration is temperature. Low temperatures can have a detrimental effect on biological systems, reducing their treatment efficiency, causing increased concentrations of BOD and suspended solids in the effluent. Effluent limitations are based on an average effluent BOD and suspended solids of 45 mg/l and 250 mg/l, respectively. It is felt that a well designed system, as described previously, can maintain this treatment efficiency at temperatures such that the waste does not freeze. Special considerations should be given during periods of extreme low temperature when wastewater within the treatment systems actually begins to freeze.

BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE, GUIDELINES AND LIMITATIONS FOR THE WOOD PRESERVING INDUSTRY

Recommendations contained in this section for the wood preserving industry are based on data presented in other sections of this report. Numerical limitations on constituents of discharges are based in part on the existing performance of the best control and treatment technology employed by a specific plant within each category, and in part on the performance achieved by control and treatment technology demonstrated in plant studies. These limitations are to be achieved by existing plants no later than July 1, 1983.

Treatment and Control Technology Models

Treatment models representing best available technology economically achievable are presented below. There are many methods by which these effluent limitation requirements can be achieved. The models shown are presented for illustrative purposes only, and are not intended to limit the technology that may be applied.

As in the case of best practical control technology currently available, biological treatment is the primary "end-of-the-line" method by which plants can achieve the best available technology economically achievable requirements of best available technology economically achievable. Unlike best practical control

technology currently available, best available technology economically achievable includes additional treatment techniques, the purpose of which is to achieve a reduction in discharge beyond those capable of being achieved by July 1, 1983. These treatments include, but are not limited to, two-stage biological treatments and polishing treatments based on activated-carbon filtration and chlorination.

Treatment Models Achievable by July 1, 1983

Biological

<u>U</u>	<u>V</u>
1. Oil Separation	1. Oil Separation
2. Equalization	2. Equalization
3. Chemical Coagulation	3. Chemical Coagulation
4. Sand Filtration	4. Sand Filtration
5. pH Control	5. pH Control
6. Biological Oxidation	6. Soil Irrigation
7. Secondary Clarification	
8. Chlorination	

<u>W</u>	<u>X</u>
1. Oil Separation	1. Oil Separation
2. Equalization	2. Equalization
3. Chemical Coagulation	3. Chemical Coagulation
4. Sand Filtration	4. Sand Filtration
5. pH Control	5. pH Control
6. Biological Oxidation - 1	6. Biological Oxidation
7. Biological Oxidation - 2	7. Secondary Clarification
8. Secondary Clarification	8. Carbon Filtration

Physical

<u>Y</u>	<u>Z</u>
1. Oil Separation	1. Oil Separation
2. Equalization	2. Equalization
3. Chemical Coagulation	3. Chemical Coagulation
4. Evaporation	4. Discharge to Sewer

It is unlikely that a conventional single-stage biological treatment alone will consistently achieve the effluent limitations required by July 1, 1983. Polishing treatments employing chemical oxidation, carbon filtration, or further biological treatment will probably be needed. The capital

investments needed to install post-treatment carbon filtration and chlorination facilities are estimated to be \$8,000 and \$5,000, respectively. These costs are based on 1971 costs, a flow rate of 19,000 liters per day (5,000 gallons per day), and wastewater characteristics conforming with the July 1, 1977 requirements. The investment required to add a biological polishing treatment could vary widely depending upon the type of facility added. The type chosen would be influenced by the amount of land area available.

Soil irrigation is included as the best available technology economically achievable, since it provides a means by which zero discharge can be achieved by plants with land available for this use. Wastewater disposal by evaporation and by discharge to a sewer are included for the same reason. The extent to which evaporation by heating will be an economically viable method by 1983 will depend upon energy costs and volume of wastewater involved. It is anticipated that inplant process changes and recycling of water will reduce substantially the total volume of water that must be disposed of. Spray evaporation, if proven to be feasible at the several plants at which the method is under test, should provide a less costly alternative to evaporation by other means.

Among the factors that are pertinent in determining the technology economically achievable by July 1, 1983, the process employed in conditioning stock for treatment is of primary importance. Because of low flow rate and favorable wastewater characteristics, particularly the general absence of emulsions in process water, a zero discharge is a feasible requirement for plants that employ the Boulton process as the predominant method of conditioning. A similar requirement is not practical for plants using steam conditioning. Inplant process changes and reuse of some process water will reduce the volume of discharge from plants in the latter group, but to achieve zero discharge would require the disposal of a relatively large volume of excess water. Spray evaporation may prove to be a feasible method of disposal, but this method will be available only to those plants that have sufficient land area devotable to this use.

Plant age, peculiarities of plant layout, and the process changes needed to reduce or eliminate discharge are important from the standpoint of their effect on cost of complying with the 1983 requirements. However, these factors are not of overriding importance and do not require special considerations, except in cases mentioned elsewhere. Likewise, the engineering aspects of the application of the control techniques needed to

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achieve 1983 effluent limitations are not unique and should present little problem to plants with access to competent engineering service.

The importance of the application of 1983 technology on non-water quality environment will be minimal. Total energy requirements will depend upon the exact methodology employed; but for many plants, they will be reduced in total because of inplant process changes that must be made to reduce total water usage. These changes and their effect on energy requirements are covered elsewhere.

Inplant Control

The low wastewater flow rate and stringent limitations on discharges that must be achieved to conform with 1983 requirements will necessitate a high level of water reuse, changes in steaming technique among plants using open steaming, efficient oil recovery systems, and the initiation of an efficient preventive maintenance and housekeeping program. The following assumptions related to these factors were made in determining the best available technology economically achievable.

- (1) The volume of discharge will be minimized by:
 - (a) Recycling all direct-contact cooling water
 - (b) Reuse of a portion of the process water for cooling purposes
 - (c) Insulation of retorts and steam pipes to reduce the volume of cylinder condensate
 - (d) Use of closed steaming or modified-closed steaming to reduce the volume of cylinder condensate and to lessen the incidence of oil-water emulsion formation
 - (e) Reuse of all water contaminated with heavy metals in preparing treating solutions of salt-type preservatives and fire retardants
 - (f) Segregation of contaminated and uncontaminated waste streams
- (2) Oil-recovery systems will be modified or replaced, as required, to ensure efficient removal of oils.
- (3) Preventive maintenance and good housekeeping programs will be inaugurated to reduce spills and leaks and provide a standard procedure for cleaning up those that do occur.

Some of the methods of reducing waste flow are standard industry practice, and they would normally be adopted as early as

1977. These include waste stream segregation, recycling of contaminated cooling water, and reuse of wastewater from salt-type treatments. Use of process water to meet cooling water requirements is a common practice among plants in Subcategory 2. These practices are mentioned here because of their continued importance.

Closed steaming is applicable to virtually all plants using steam conditioning. It is the single most important inplant process change that a plant can make from the standpoint of both reducing the volume of wastewater that must be disposed of and also reducing emulsion formation. Modified-closed steaming, while reducing the volume of wastewater to a lesser extent than closed steaming, also lessens emulsion formation. In addition, this method substantially reduces steam requirements by retaining the hot steam condensate in the retort rather than discharging it as it forms.

Like closed steaming, insulation of cylinders and pipes used in steam transfer potentially can reduce both the volume of condensate formed and the energy requirements for steam generation. The heat loss from an uninsulated metal vessel amounts to 7.3 kilogram-calories per hour per square meter of surface area (2.7 BTU per hour per square foot) for each degree of temperature difference between the inside and outside of the vessel. For an uninsulated retort 2.13 meters (7 feet) in diameter and 36.57 meters (120 feet) long, the daily heat loss would be 7.56 million kilogram-calories (30 million BTU's) if the inside and ambient temperatures were 121°C and 27°C (250°F and 80°F), respectively. This loss can be cut by 70 percent by proper insulation. In addition, the volume of condensate produced would also be reduced significantly.

A well executed preventive maintenance and housekeeping program is an integral part of the treatment and control technology required to achieve 1983 limitations. Spills and leaks can largely negate the efforts directed toward other, more obvious aspects of wastewater management if they are ignored. The areas around and in the immediate vicinity of retorts and storage tanks are of particular importance because of the opportunity for storm water contamination from preservative drips and spills associated with freshly pulled charges and loss of preservative from plumbing and pump leaks. Consideration should be given to paving the area in front of retorts to permit channeling of drips and spills to a sump from which the oil can be recovered.

Discharge Limitations

Numerical effluent limitations to meet the best available technology economically achievable are given in Tables 77 and 78 for each subcategory of the industry. These values are expressed in the two tables as kilograms of pollutants per 1,000 cubic meters of product treated and in effluent concentrations for information purposes only. The discharge from a plant will be limited on the basis of total weight of pollutant per day. Total allowable discharge should be computed from daily production data shown on the permit application.

Limitations are not placed on total water usage, color, and dissolved solids. However, when discharges containing color and dissolved solids may cause harm to the receiving waters, or cause a violation of existing water-quality standards, limits will be established.

The pH of the final effluents from wood-preserving plants shall be within the range of 6.0 to 8.5.

Effluent limitations for BOD, phenols, suspended solids, and oil and grease are based on concentrations of 50, 0.5, 100 and 25 mg/l, respectively. A waste flow of 133 liters per cubic meter (1.0 gallons per square foot) was assumed in calculating permissible discharge per unit of production. A lower ratio of discharge to volume of production is achieved by several exemplary plants as a result of treating a much higher proportion of dry stock than is typical for the industry as a whole. A discharge of 133 liters per cubic meter (one gallon per square foot) of product is judged to be the lowest value that can be reasonably achieved by plants treating a normal proportion of unseasoned stock.

Chemical oxygen demand may be used to monitor BOD where an appropriate correlation factor can be determined. The equation $BOD = 0.497 COD + 60$ expresses the relationship between the two parameters for BOD values of 150 and larger. However, the ratio of BOD/COD increases rapidly with decreasing BOD. For BOD values of 50 and smaller, the relationship $BOD = 0.161 COD$ has been found to be applicable.

Factors to be Considered in Applying Effluent Limitations

The identification of treatment and control technology to attain the best available technology economically achievable for the various subcategories can be applied uniformly to most plants in the industry. The exceptions are those

TABLE 77 EFFLUENT LIMITATIONS BASED ON BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE
(kilograms of pollutants/1000 M³ of product)^a

Sub- Category	Wastewater Volume (liters/m ³)	Phenols	COD	BOD	Oil and Grease	Suspended Solids
1	133 (1.0 gal/ft ³)	0.064 (0.004)	41.301 (2.573)	6.662 (0.415)	3.338 (0.208)	13.323 (0.830)
2	-	No discharge of process water permitted				
3	-	No discharge of process water permitted				
4	-	No discharge of process water permitted				

^aValues in parentheses are discharge equivalents in pounds/1000 ft³.

TABLE 78 EFFLUENT LIMITATIONS BASED ON BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE
(milligrams of pollutants/liter of water)

Sub- Category	Wastewater Volume (liters/m ³)	Phenols	COD	BOD	Oil and Grease	Suspended Solids
1	133 (1.0 gal/ft ³)	0.50	310	50	25	100
2	-	No discharge of process water permitted				
3	-	No discharge of process water permitted				
4	-	No discharge of process water permitted				

plants which, because of age of equipment and facilities, availability of land, or other factors, are unable to conform to these requirements. Some of the factors which will have an effect on the ability of individual plants to meet the recommended effluent limitations are summarized in this section.

Age of Plant. The effect of plant age on the achievability of zero discharge was previously discussed. The previous justification for a variance of requirements to permit trace amounts of pollutants in non-process wastewater to be discharged is equally applicable in this section.

Use of Salt- and Oil-Type Preservatives in one Retort. The inability of plants in Subcategory 1 which use a single retort for both salt-type and oil-type preservatives, or which apply dual treatments, to prevent contamination of oily wastewater with metals from preservatives of the former type was previously discussed. Most of the plants in this group are small, the operation consisting of a single retort. It is recommended that a variance to the no-discharge requirement for plants treating with inorganic preservatives and fire retardants that are in this group be permitted under 1983 requirements. The proposed limitations on discharge per unit of production given in Table 79 are based on the concentrations shown and a flow rate of 133 liters per cubic meter (1.0 gallon per cubic foot) of product treated.

TABLE 79 RECOMMENDED PERMISSIBLE DISCHARGES OF METALS
FROM PLANTS IN SUBCATEGORY 1 THAT EMPLOY ONE
RETORT TO APPLY PRESERVATIVE TREATMENT WITH
OIL-TYPE AND SALT-TYPE PRESERVATIVES

Parameter	Concentration (mg/l)	Weight ^a (Kg/1000 m ³)
Boron ^b	-	-
Arsenic	1.0	0.128 (0.008)
Chromium	1.0	0.128 (0.008)
Copper	1.0	0.128 (0.008)
Fluorides	10.0	1.330 (0.083)
Zinc	2.0	0.273 (0.017)
Ammonia (as N)	5.0	0.666 (0.041)
Phosphorus	5.0	0.666 (0.041)

^aValues in parentheses are pounds/1000 ft³.

^bBest control technology for boron has not been determined.

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

INTRODUCTION

This level of technology is to be achieved by new sources. The term "new source" is defined in the Act to mean "any source, the construction of which is commenced after the publication of proposed regulations prescribing a standard of performance." New source technology shall be evaluated by adding to the consideration underlying the identification of best available technology economically achievable a determination of what higher levels of pollution control are available through the use of improved production processes and/or treatment techniques. Thus, in addition to considering the best in-plant and end-of-process control technology, identified in best available technology economically achievable, new source technology is to be based upon an analysis of how the level of effluent may be reduced by changing the production process itself. Alternative processes, operating methods or other alternatives must be considered. However, the end result of the analysis will be to identify effluent standards which reflect levels of control achievable through the use of improved production processes (as well as control technology), rather than prescribing a particular type of process or technology which must be employed. A further determination which must be made for new source technology is whether a standard permitting no discharge of pollutants is practicable.

Specific Factors To Be Taken Into Consideration

At least the following factors should be considered with respect to production processes which are to be analyzed in assessing new source technology:

- a. The type of process employed and process changes;
- b. Operating methods;
- c. Batch as opposed to continuous operations;
- d. Use of alternative raw materials and mixes of raw materials;
- e. Use of dry rather than wet processes (including substitution of recoverable solvents for water); and
- f. Recovery of pollutants as by-products.

NEW SOURCE PERFORMANCE STANDARDS FOR THE VENEER AND PLYWOOD INDUSTRY

The effluent limitations for new sources is no discharge to navigable waters as developed in Section IX.

NEW SOURCE PERFORMANCE STANDARDS FOR THE DRY PROCESS HARDBOARD INDUSTRY

The effluent limitations for new sources is no discharge to navigable waters as developed in Section IX.

NEW SOURCE PERFORMANCE STANDARDS FOR THE WET PROCESS HARDBOARD INDUSTRY

The effluent limitations for new sources is the same as those shown in Section X for application of the Best Available Technology Economically Achievable -- 0.2 kilograms per metric ton (0.4 pounds per ton) BOD, and 1.0 kilograms per metric ton (2.1 pounds per ton) suspended solids.

Before discharge to a publicly-owned activated sludge or trickling filter wastewater treatment plant, a wet process hardboard mill should subject its discharge to primary treatment to remove a majority of fiber in the wastewater. In addition, the pH may have to be adjusted to 6.0 to 6.5. This would have to be decided on a plant-to-plant basis with consideration given to the relative volume of hardboard mill discharge compared to the domestic waste being treated.

There are no known contaminants which will pass through such a system.

NEW SOURCE PERFORMANCE STANDARDS AND PRETREATMENT STANDARDS FOR THE WOOD PRESERVING INDUSTRY

General

The technology by which zero discharge of process water from new plants in Subcategories 2, 3, and 4 can be achieved is both practical and currently available. Performance standards for new plants in these groups will remain unchanged from those outlined in the two preceding sections. The remarks which follow pertain to plants in Subcategory 1.

The process by which wood is treated by plants in Subcategory 1 is direct and simple. Basically, it consists of placing the stock in a pressure retort, conditioning it using steam or vapors of an organic solvent, and impregnating it with a preservative or fire retardant. The opportunity for change in the production process of an operation of this type is limited. Alternative raw materials are not available. Replacement of existing preservatives with new or different chemicals is not feasible in the foreseeable future. Modification of preservatives to reduce pollution is practical in the case of pentachlorophenol. Two processes which use recoverable solvents for this chemical are being used by a limited number of plants. However, both processes are proprietary and may be used only by licensees.

A consideration of the over-all operation reveals only two processing steps in which the opportunity exists for changes that can lead to reduced discharge. Both are related to preparation of stock for preservative treatment, and both are expensive in terms of the capital investment

required. One of the methods is to treat dry stock, and thereby abrogate the need to steam condition it. The other method is to steam condition or vapor dry stock in a separate retort from the one in which the preservative treatment is applied. Both methods, which are used to some extent by existing plants, serve to separate conditioning operations from treating operations and thereby prevent contamination of water with preservatives.

Approximately 30 percent of the plants in the United States currently kiln dry a portion of their stock prior to treatment. Only about 10 percent use kiln drying for all their stock. There are two main reasons why kilns are not used more widely than they are. First, the capital investment is high, amounting to \$60,000 per kiln. A minimum of five kilns would be required if all the material treated by a typical three-retort plant were dried prior to preservative treatment. Secondly, kiln drying darkens the surface of poles so that some poles do not meet the color standards under which an increasing percentage of the ones treated with pentachlorophenol are sold.

The investment required to install a sufficient number of retorts so that steam conditioning and treating are not conducted in the same vessel would be similar to that required above. For a plant with a design capacity of 850 m³ (30,000 ft³) of production per week, a minimum of three conditioning cylinders 2.13 m x 36.58 m (7' x 120') would be required to supply the 15 charges of conditioned poles needed each week. The investment required for that portion of the plant devoted to steaming, including steam generating and vacuum equipment, would amount to an estimated \$260,000. The plant would still have wastewater to treat, albeit water that would be much less contaminated than that from a plant steaming and treating in the same retort.

A detailed discussion of the costs associated with kiln drying and steaming is presented in Section VIII.

A reduction in the volume of discharge can also be obtained by air seasoning stock before treating it. Some air seasoning takes place in the normal processing of material on the yard, and most plants ordinarily maintain an inventory of untreated stock in open stacks to expedite the filling of orders. Any seasoning that occurs here lessens the conditioning time required when the material is treated. To air season thoroughly, certain items, such as poles and piling, take up to six months. The large inventory required for this imposes a financial burden on the owners and is not practical during a prolonged period of high demand such as currently exists. Furthermore, deterioration is a problem in the South when stock is stored for the time required for it to air season.

It is apparent from the foregoing discussion that there is no simple, economically viable method to reduce the volume of discharge from plants in

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Subcategory 1 below that based on the best available technology economically achievable. It is recommended that new sources performance standards for plants in Subcategory 1 remain the same as those developed in Section X.

Treatment And Control Technology Models

Treatment models applicable to new source performance standards are presented below. The models are the same as those suggested in Section X, except that polishing treatments involving chlorination and activated carbon filtration are not included. The use of the latter methods will be added to the recommended methods of wastewater treatment for new sources when additional data on their applicability to wood preserving effluents become available.

TREATMENT MODELS: NEW SOURCE PERFORMANCE STANDARDS

Biological

"U₁"

1. Oil Separation
2. Equalization
3. Chemical Coagulation
4. Sand Filtration
5. pH Control
6. Soil Irrigation

"W"

1. Oil Separation
2. Equalization
3. Chemical Coagulation
4. Sand Filtration
5. pH Control
6. Biological Oxidation - 1
7. Biological Oxidation - 2
8. Secondary Clarification

Physical

"Y"

1. Oil Separation
2. Equalization
3. Chemical Coagulation
4. Evaporation

"Z"

1. Oil Separation
2. Equalization
3. Chemical Coagulation
4. Discharge to Sewer

Discharge Limitations

Numerical limitations for new source performance standards are given in Tables 80 and 81 for each subcategory of the wood preserving industry. These values are expressed in the two tables as kilograms of pollutants per 1000 m³ of product treated and in effluent concentrations for information purposes only. The discharge from a plant will be limited on the basis of total weight of pollutant per day. Total allowable discharge should be computed from daily production data shown on the permit application.

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Limitations are not placed on total water usage, color, and dissolved solids. However, when discharges containing color and dissolved solids may cause harm to the receiving waters, or cause a violation of existing water quality standards, limits will be established.

The pH of the final effluents from wood preserving plants shall be within the range of 6.0 to 8.5.

TABLE 80 STANDARDS OF PERFORMANCE FOR NEW SOURCES
(kilograms of pollutants/1000 m³ of product)*

Parameter	Subcategory			
	1	2	3	4
Phenols	0.064 (0.004)**	No discharge of process water permitted for plants in Sub-categories 2, 3, and 4.		
COD	41.301 (2.573)			
BOD	6.662 (0.415)			
Oil and Grease	3.338 (0.208)			
Suspended Solids	13.323 (0.830)			

*Based on a flow rate of 133 liters/m³ (1.0 gal/ft³).

**Parenthetical values are pounds/1000 ft³.

TABLE 81 STANDARDS OF PERFORMANCE FOR NEW SOURCES
(milligrams of pollutants/liter of water)

Parameter	Subcategory			
	1	2	3	4
Phenols	0.50	No discharge of process water permitted for plants in Sub-categories, 2, 3, and 4		
COD	310			
BOD	50			
Oil and Grease	25			
Suspended Solids	100			

Effluent limitations for BOD, phenols, suspended solids, and oil and grease are based on concentrations of 50, 0.5, 100, and 25 mg/liter, respectively. A waste flow of 133 liters per cubic meter (1.0 gallons/ft³) was assumed in calculating permissible discharge per unit of production. A lower ratio of discharge to volume of production is achieved by several exemplary plants as a result of treating a much high proportion of dry stock than is typical for the industry as a whole. A discharge of 133 liters per cubic foot (1.0 gallons/1000 ft³) of product is judged to be the lowest value than can be reasonably achieved by plants treating a normal proportion of unseasoned stock.

Chemical oxygen demand may be used to monitor BOD where an appropriate correlation factor can be determined. The equation $BOD = 0.497 COD + 60$ expresses the relationship between the two parameters for BOD values of 150 and larger. However, the ratio of BOD/COD increases rapidly with decreasing BOD. For BOD values of 50 or smaller, the relationship $BOD = 0.161 COD$ has been found to be applicable.

Factors To Be Considered In Applying Effluent Limitations

The identification of standards of performance for new sources for the various subcategories can be applied uniformly to most plants in the industry. The exceptions are those plants which, because of age of equipment and facilities, availability of land, or other factors, are unable to attain these performance levels. Some of the factors which will have an effect on the ability of individual plants to meet the recommended performance standards are summarized in this section.

Use of Salt- and Oil-Type Preservatives in One Retort - The inability of plants in Subcategory 1 that use a single retort for both salt-type and oil-type preservatives, or that apply dual treatments, to prevent contamination of oily wastewaters with metals from preservatives of the former type was discussed in Section IX. Most of the plants in this group are small, the operation consisting of a single retort. It is recommended that a variance to the no discharge requirement for plants treating with inorganic preservatives and fire retardants that are in this group be permitted under new source performance standards. The proposed limitations on discharge per unit of production given in Table 82 are based on the concentrations shown and a flow rate of 133 liters per cubic meter (1.0 gallons/ft³) of product treated.

Pretreatment Requirements

Effluents from preservative treatments with oily preservatives contain no constituent that is incompatible with a well designed and operated municipal wastewater treating plant. This statement presupposes that the concentrations of phenolic compounds and oils are within the range

TABLE 82 RECOMMENDED PERMISSIBLE DISCHARGE OF METALS:
PLANTS APPLYING DUAL TREATMENTS OF SALT-TYPE AND
OIL-TYPE PRESERVATIVES, AND PLANTS USING A SINGLE
RETORT TO APPLY BOTH PRESERVATIVES

Parameter	Concentration (mg/l)	Weight* (Kg/1000 m ³)
Boron**	-	-
Arsenic	1.0	0.128 (0.008)
Chromium	1.0	0.128 (0.008)
Copper	1.0	0.128 (0.008)
Fluorides	10.0	1.330 (0.083)
Zinc	2.0	0.273 (0.017)
Phosphates	5.0	0.666 (0.041)
Nitrogen (NH ₃)	5.0	0.666 (0.041)

*Parenthetical values in pounds/1000 ft³ of product treated

**Best control technology for boron has not been determined

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considered normal for such wastes. Approximately 15 percent of the plants in the U.S. currently are disposing of their waste in this manner. The contractor is not aware of any instance where this practice has had a deleterious effect on the operation of a municipal sewage facility.

Disposal of raw wastewater from treatments employing inorganic salt preservatives is not recommended. Copper, chromium, and arsenic are toxic to microorganisms in low concentrations and, based on the work of Jones (46) are capable of disrupting a biological wastewater treating system. Treatment of such waste to precipitate most of the heavy metals prior to discharge to the sewer is suggested.

SECTION XII
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Mr. Wallace N. Corry - Boise Cascade
Mr. W. D. Page - American Plywood Association
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American Wood-Preservers' Institute

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SECTION XIII

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SECTION XIV

GLOSSARY

"Act" - The Federal Water Pollution Control Act Amendments of 1972.

Activated Sludge - Sludge floc produced in raw or settled wastewater by the growth of zooglycal bacteria and other organisms in the presence of dissolved oxygen and accumulated in sufficient concentration by returning floc previously formed.

Activated Sludge Process - A biological wastewater treatment process in which a mixture of wastewater and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated wastewater (mixed liquor) by sedimentation and wasted or returned to the process as needed.

Aerated Lagoon - A natural or artificial wastewater treatment pond in which mechanical or diffused-air aeration is used to supplement the oxygen supply.

Aerobic - Condition in which free, elemental, oxygen is present.

Additive - Any material introduced prior to the final consolidation of a board to improve some property of the final board or to achieve a desired effect in combination with another additive. Additives include binders and other materials. Sometimes a specific additive may perform more than one function. Fillers and preservatives are included under this term.

Air Drying - Drying veneer by placing the veneer in stacks open to the atmosphere, in such a way as to allow good circulation of air. It is used only in the production of low quality veneer.

Air-felting - Term applied to the forming of a fiberboard from an air suspension of wood or other cellulose fiber and to the arrangement of such fibers into a mat for board.

Anaerobic - Condition in which free elemental oxygen is absent.

Asplund Method - An attrition mill which combines the steaming and defibering in one unit in a continuous operation.

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Attrition Mill - Machine which produces particles by forcing coarse material, shavings, or pieces of wood between a stationary and a rotating disk, fitted with slotted or grooved segments.

Back - The side reverse to the face of a panel, or the poorer side of a panel in any grade of plywood that has a face and back.

Bag Barker - See debarker

Blue Stain - A biological reaction caused by a stain producing fungi which causes a blue discoloration of sapwood, if not dried within a short time after cutting.

Biological Wastewater Treatment - Forms of wastewater treatment in which bacterial or biochemical action is intensified to stabilize, oxidize, and nitrify the unstable organic matter present. Intermittent sand filters, contact beds, trickling filters, and activated sludge processes are examples.

Blowdown - The removal of a portion of any process flow to maintain the constituents of the flow at desired levels.

BOD - Biochemical Oxygen Demand is a measure of biological decomposition of organic matter in a water sample. It is determined by measuring the oxygen required by microorganisms to oxidize the organic contaminants of a water sample under standard laboratory conditions. The standard conditions include incubation for five days at 20°C.

Bolt - A short log cut to length suitable for peeling in a lathe.

Boultonizing

A conditioning process in which unseasoned wood is heated in an oily preservative under a partial vacuum to reduce its moisture content prior to injection of the preservative.

Casein - A derivative of skimmed milk used in making glue.

Caul - A steel plate or screen on which the formed mat is placed for transfer to the press, and on which the mat rests during the pressing process.

CCA-Type Preservative - Any one of several inorganic salt formulations based on salts of copper, chromium, and arsenic.

DRAFT

Chipper - A machine which reduces logs or wood scraps to chips.

Clarifier - A unit of which the primary purpose is to reduce the amount of suspended matter in a liquid.

Clipper - A machine which cuts veneers to various widths and also may remove defects.

Closed Steaming - A method of steaming in which the steam required is generated in the retort by passing boiler steam through heating coils that are covered with water. The water used for this purpose is recycled.

COD - Chemical Oxygen Demand. Its determination provides a measure of the oxygen demand equivalent to that portion of matter in a sample which is susceptible to oxidation by a strong chemical oxidant.

Coil Condensate - The condensate formed in steam lines and heating coils.

Cold Pressing - See pressing

Commercial Veneer - See veneer; hardwood

Composite Board - Any combination of different types of board, either with another type board or with another sheet material. The composite board may be laminated in a separate operation or at the same time as the board is pressed. Examples of composite boards include veneer-faced particle board, hardboard-faced insulation board and particle board, and metal-faced hardboard.

Conditioning - The practice of heating logs prior to cutting in order to improve the cutting properties of the wood and in some cases to facilitate debarking.

Construction - Arrangement of veneers, lumber or wood composition board in plywood.

Container Veneer - See veneer; hardwood

Cooling Pond - A water reservoir equipped with spray aeration equipment from which cooling water is drawn and to which it is returned.

Core - Also referred to as the center. The innermost portion of plywood. It may be of sawn lumber joined and glued, or it may be of veneer, or of wood composition board.

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Creosote - A complex mixture of organic materials obtained as a by-product from coking and petroleum refining operations that is used as a wood preservative.

Crossband, v. - To place the grain of the layers of veneer at right angles in order to minimize swelling and shrinking.

Crossband, n. - The layers of veneer whose grain direction is at right angles to that of the face piles, applied particularly to five-ply plywood and lumber core panels, and more generally to all layers between the core and the faces.

Curing - The physical-chemical change that takes place either to thermosetting synthetic resins (polymerization) in the hot presses or to drying oils (oxidation) used for oil-treating board. The treatment to produce that change.

Cutterhead Barker - See debarker.

Cylinder Condensate - Steam condensate that forms on the walls of the retort during steaming operations.

Debarker - Machines which remove bark from logs. Debarkers may be wet or dry, depending on whether or not water is used in the operation. There are several types of debarkers including drum barkers, ring barkers, bag barkers, hydraulic barkers, and cutterhead barkers. With the exception of the hydraulic barker, all use abrasion or scraping actions to remove bark. Hydraulic barkers utilize high pressure streams of water.

All types may utilize water, and all wet debarking operations may use large amounts of water and produce effluents with high solids concentrations.

Decay - The decomposition of wood caused by fungi.

Defiberization - The reduction of wood materials to fibers.

Delamination - Separation of the plies through failure of the adhesive.

Digester - 1) Device for conditioning chips using high pressure steam, 2) A tank in which biological decomposition (digestion) of the organic matter in sludge takes place.

Disc Pulpers - Machines which produce pulp or fiber through the shredding action of rotating and stationary discs.

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DO - Dissolved Oxygen is a measure of the amount of free oxygen in a water sample. It is dependent on the physical, chemical, and biochemical activities of the water sample.

Drum Barker - See debarker.

Dry-clipping - Clipping of veneer which takes place after drying.

Dry Decking - See log storing.

Dryers - Most commonly long chambers equipped with rollers on belts which advance the veneer longitudinally through the chamber. Fans and heating coils are located on the sides to control temperature and humidity. Lumber kilns are also sometimes used. See also veneer drying.

Dry-felting - See air-felting.

Dry Process - See air-felting.

Durability - As applied to wood, its lasting qualities or permanence in service with particular reference to decay. May be related directly to an exposure condition.

End-checking - Cracks which form in logs due to rapid drying out of the ends when stacked on land for storage.

Exterior - A term frequently applied to plywood, bonded with highly resistant glues, that is capable of withstanding prolonged exposure to severe service conditions without failure in the glue bonds.

Face - The better side of a panel in any grade of plywood calling for a face and back; also either side of a panel where the grading rules draw no distinction between faces.

Face Veneer - See veneer; hardwood.

Fiber (Fibre) - The slender thread-like elements of wood or similar cellulosic material, which, when separated by chemical and/or mechanical means, as in pulping, can be formed into fiberboard.

Fiberboard - A sheet material manufactured from fibers of wood or other ligno-cellulosic materials with the primary bond deriving from the arrangement of the fibers and their inherent adhesive properties. Bonding agents or other materials may be added during manufacture to increase

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strength, resistance to moisture, fire, insects or decay, or to improve some other property of the product. Alternative spelling: fibreboard, Synonym: fibre building board.

Fiber Preparation - The reduction of wood to fiber or pulp, utilizing mechanical, thermal, or explosive methods.

Figure - Decorative natural designs in wood which are prized in the furniture and cabinet making industries.

Finishing - The final preparation of the product. Finishing may include redrying, trimming, sanding, sorting, molding, and storing, depending on the operation and product desired.

Fire Retardant - A formulation of inorganic salts that imparts fire resistance when injected into wood in high concentrations.

Flitch - A part of a log which has been so sectioned as to best display a particular grain configuration or figure in the resulting veneer.

Flotation - The raising of suspended matter to the surface of the liquid in a tank as scum--by aeration, the evolution of gas, chemicals, electrolysis, heat, or bacterial decomposition--and the subsequent removal of the scum by skimming.

Formation (Forming) - The felting of wood or other cellulose fibers into a mat for fiberboard. Methods employed: air-felting and wet-felting.

Glue - Adhesive which is used to join alternate ply veneers together in plywood. There are three types most often used in the manufacture of plywood, depending on raw material and intended product usage. They are 1) protein, 2) phenol formaldehyde, and 3) urea formaldehyde. The first is extracted from plants and animals while the other two are synthetic and thermosetting.

Glue Spreaders - Means of applying glue to veneer, either by the use of power driven rollers or spray curtain-coater applicators.

Glue Line - The part of the plywood production process where the glue is applied to the veneer and the plywood layers assembled.

GPD - Gallons per day.

GPM - Gallons per minute.

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Grading - The selection and categorization of different woods as to its suitability for various uses. Criteria for selection include such features of the wood as color, defects, and grain direction.

Grain - The direction, size, arrangement, and appearance of the fibers in wood or veneer.

Green Clipper - A clipper which clips veneer prior to being dried.

Green Stock - Unseasoned wood.

Hardboard - A compressed fiberboard of 0.80 to 1.20 g/cm³ (50 to 75 pounds per cubic foot) density. Alternative term: fibrous-felted hardboard.

Hardboard Press - Machine which completes the reassembly of wood particles and welds them into a tough, durable, grainless board.

Hardwood - Wood from deciduous or broad-leaf trees. Hardwoods include oak, walnut, lavan, elm, cherry, hickory, pecan, maple, birch, gum, cativo, teak, rosewood, and mahogany.

Heartwood - The inner core of a woody stem composed of non-living cells and usually differentiated from the outer enveloping layer (sapwood).

Heat-treated Hardboard - Hardboard that has been subjected to special heat treatment after hot-pressing to increase strength and water resistance.

Holding Ponds - See impoundment.

Hot Pressing - See pressing.

Humidification - The seasoning operation to which newly pressed hardboard are subjected to prevent warpage due to excessive dryness.

Hydraulic Barker - See debarker.

Impoundment - A pond, lake, tank, basin, or other space, either natural or created in whole or in part by the building of engineering structures, which is used for storage, regulation, and control of water, including wastewater.

Industry Categorization - Subdivision of the industry into categories in order that separate effluent limitations and

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standards may be developed for each category, if it is determined that separate regulation is necessary.

Kiln Drying - A method of preparing wood for treatment in which the green stock is dried in a kiln under controlled conditions of temperature and humidity.

Kjld-N - Kjeldahl Nitrogen - Total organic nitrogen plus ammonia of a sample.

Lagoon - A pond containing raw or partially treated wastewater in which aerobic or anaerobic stabilization occurs.

Land Decking - Another term for dry-decking. See log storing.

Leaching - Mass transfer of chemicals to water from wood which is in contact with it.

Log Bed - Device which holds a log and moves it up and down past a stationary blade which slices sheets of veneer.

Log Ponding - See log storing.

Log Storing - Retaining large inventories of logs to maintain a continuous supply throughout the year. The three common methods are:

- 1) Dry-decking - stacking logs on land
- 2) Wet-decking - sprinkling land-decked logs with water to minimize end-checking.
- 3) Log Ponding - storing logs by floating them in a body of water. This method is used for long term storage.

MGD - Million gallons per day.

mg/l - Milligrams per liter (equals parts per million, ppm, when the specific gravity is one).

ml/l - Milliliters per liter.

Modified Steaming - A technique for conditioning logs which is a variety of the steam vat process in that steam is produced by heating water with coils set in the bottom of the vat.

Moisture - Water content of wood or a timber product expressed as a percentage of total weight or as percentage of the weight of dry wood.

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Non-Pressure Process - A method of treating wood at atmospheric pressure in which the wood is simply soaked in hot or cold preservative.

Nutrients - The nutrients in contaminated water are routinely analyzed to characterize the food available for micro-organisms to promote organic decomposition. They are:

Ammonia Nitrogen (NH₃), mg/l as N

Kjeldahl Nitrogen (ON), mg/l as N

Nitrate Nitrogen (NO₃), mg/l as N

Total Phosphate (TP), mg/l as P

Ortho Phosphate (OP), mg/l as P

Oil-Recovery System - Equipment used to reclaim oil from wastewater.

Oily Preservative - Pentachlorophenol-petroleum solutions and creosote in the various forms in which it is used.

Open Steaming - A method of steam conditioning in which the steam required is generated in a boiler.

Particle - Distinct fraction of wood or other lignocellulosic material produced mechanically for use as the aggregate for a particle board. Types of particles include:

Flake - Specially generated thin flat particles, with the grain of the wood essentially parallel to the surface of the flake, prepared with the cutting action of the knife in a plane parallel to the grain but at an angle to the axis of the fiber.

Flax Shives - Fine rectangular-shaped particles of lignocellulosic material obtained by longitudinal division of the stalk of the flax plant during scutching of the retted flax.

Granule - A particle in which length, width and thickness are approximately equal, such as a sawdust particle.

Shaving - A thin slice or strip of wood pared off with a knife, plane or other cutting

instrument, with the knife action approximately along the axis of the fiber, such as the shavings produced in planing the surface of wood.

Sliver - Particle of nearly square or rectangular cross-section with a length parallel to the grain of the wood of at least four times the thickness.

Splinter - An alternate term for sliver.

Strand - A relatively long (with respect to thickness and width) shaving.

Wood-wood (Excelsior) - Curly slender strands of wood used as an aggregate component for particle board, also used in mineral-bonded boards and as packing for fragile articles.

Particle Board - A sheet material manufactured from small pieces of wood or other ligno-cellulosic materials (e.g. chips, flakes, splinters, strands, shives, etc.) agglomerated by use of an organic binder together with one or more of the following agents: heat, pressure, moisture, a catalyst, etc. (Wood-wood and other particle boards with inorganic binders are excluded.)

Pearl Benson Index - A measure of color producing substances.

Pentachlorophenol - A chlorinated phenol with the formula $\text{Cl}_5\text{C}_6\text{OH}$ and formula weight of 266.35 that is used as a wood preservative. Commercial grades of this chemical are usually adulterated with tetrachlorophenol to improve its solubility.

pH - pH is a measure of the acidity or alkalinity of a water sample. It is equal to the negative log of the hydrogen ion concentration.

Phenol - The simplest aromatic alcohol.

Pitch - An organic deposit composed of condensed hydrocarbons which forms on the surface of dryers.

Plant Sanitation - Those aspects of plant housekeeping which reduce the incidence of water contamination resulting from equipment leaks, spillage of preservative, etc.

Plywood - An assembly of an odd number of layers of wood, or veneers, joined together by means of an adhesive. Plywood consists of two main types:

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- 1) hardwood plywood - has a face ply of hardwood and is generally used for decorative purposes.
- 2) softwood plywood - the veneers typically are of softwood and the usage is generally for construction and structural purposes.

Plywood Pressing Time - The amount of time that plywood is in a press. The time ranges from two minutes to 24 hours, depending on the temperature of the press and the type of glue used.

Point Source - A discrete source of pollution.

Pressing - The step in the production operation in which sheets are subjected to pressure for the purpose of consolidation. Pressing may be accomplished at room temperature (cold pressing) or at high temperature (hot pressing).

Press Pit - A sump under the press.

Pressure Process - A process in which wood preservatives and fire retardants are forced into wood using air or hydrostatic pressure.

Radio Frequency Heat - Heat generated by the application of an alternating electric current, oscillating in the radio frequency range, to a dielectric material. In recent years this method has been used to cure synthetic resin glues.

Resin - Secretions of saps of certain plants or trees. It is an oxidation or polymerization product of the terpenes, and generally contains "resin" acids and ethers.

Retort - A steel vessel in which wood products are pressure impregnated with chemicals that protect the wood from biological deterioration or that impart fire resistance. Also called treating cylinder.

Ring barker - See debarker.

Rotary lathing - See veneer cutting.

Roundwood - Wood that is still in the form of a log, i.e. round.

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Saw Kerf - Wastage of wood immediately adjacent to a saw blade due to the cut-cleaning design of the blade, which enlarges the cut slightly on either side.

Sawn Veneer - See veneer cutting.

Sedimentation Tank - A basin or tank in which water or wastewater containing settleable solids is retained to remove by gravity a part of the suspended matter.

Segment Saw - A modern veneer saw which consists of a heavy metal tapering flange to which are bolted several thin, steel saw segments along its periphery. The segment saw produces considerably less kerf than conventional circular saws.

Semi-Closed Steaming - A method of steam conditioning in which the condensate formed during open steaming is retained in the retort until sufficient condensate accumulates to cover the coils. The remaining steam required is generated as in closed steaming.

Settling Ponds - An impoundment for the settling out of settleable solids.

Slicing - See veneer cutting.

Sludge - The accumulated solids separated from liquids, such as water or wastewater, during processing.

Smooth-two-sides (S-2-S) - Hardboard, or other fiberboard or particle board produced when a board is pressed from a dry mat to give a smooth surface on both sides.

Softwood - Wood from evergreen or needle bearing trees.

Soil Irrigation - A method of land disposal in which wastewater is sprayed on a prepared field. Also referred to as soil percolation.

Solids - Various types of solids are commonly determined on water samples. These types of solids are:

Total Solids (TS) - The material left after evaporation and drying a sample at 103-105°C.

Suspended Solids (SS) - The material removed from a sample filtered through a standard glass fiber filter. Then it is dried at 103-105°C.

Dissolved Solids (DS) - The difference between the total and suspended solids.

Volatile Solids (VS) - The material which is lost when the sample is heated to 550°C.

Settleable Solids (STS) - The material which settles in an Imhoff cone in one hour.

Spray Evaporation - A method of wastewater disposal in which the water in a holding lagoon equipped with spray nozzles is sprayed into the air to expedite evaporation.

Spray Irrigation - A method of disposing of some organic wastewaters by spraying them on land, usually from pipes equipped with spray nozzles.

Steam Conditioning - A conditioning method in which unseasoned wood is subjected to an atmosphere of steam at 120°C (249°F) to reduce its moisture content and improve its permeability preparatory to preservative treatment.

Steaming - Treating wood material with steam to soften it.

Sump - (1) A tank or pit that receives drainage and stores it temporarily, and from which the drainage is pumped or ejected, (2) A tank or pit that receives liquids.

Synthetic Resin (Thermosetting) - Artificial resin (as opposed to natural) used in board manufacture as a binder. A combination of chemicals which can be polymerized, e.g. by the application of heat, into a compound which is used to produce the bond or improve the bond in a fiberboard or particle board. Types usually used in board manufacture are phenol formaldehyde, urea formaldehyde, or melamine formaldehyde.

Tapeless Splicer - A machine which permits the joining of individual sheets of veneer without the use of tape. Individual sheets are glued edge to edge, and cured, thus saving on tape costs and sanding time during finishing.

Taping Machine - A machine which joins individual sheets of veneer by taping them together. The tape is later sanded off during the finishing operations.

Tempered Hardboard - Hardboard that has been specially treated in manufacture to improve its physical properties

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considerably. Includes, for example, oil-tempered hardboard. Synonymous: superhardboard.

Thermal Conductivity - The quantity of heat which flows per unit time across unit area of the subsurface of unit thickness when the temperature of the faces differs by one degree.

Thermosetting - Adhesives which, when cured under heat or pressure, "set" or harden to form films of great tenacity and strength. Subsequent heating in no way softens the bending matrix.

TOC - Total Organic Carbon is a measure of the organic contamination of a water sample. It has an empirical relationship with the biochemical and chemical oxygen demands.

T-PO₄-P - Total phosphate as phosphorus.

Turbidity - (1) A condition in water or wastewater caused by the presence of suspended matter, resulting in the scattering and absorption of light rays. (2) A measure of the fine suspended matter in liquids. (3) An analytical quantity usually reported in arbitrary turbidity units determined by measurements of light diffraction.

Underflow - (wet decking) - water which runs off the logs.

Vacuum Water - Water extracted from wood during the vacuum period following steam conditioning.

Vapor Drying - A process in which unseasoned wood is heated in the hot vapors of an organic solvent, usually xylene, to season it prior to preservative treatment.

Vat - Large metal containers in which logs are "conditioned," or heated prior to cutting. The two basic methods for heating are by direct steam contact in "steam vats," or by steam heated water in "hot water vats."

Veneer - A thin sheet of wood of uniform thickness produced by peeling, slicing, or sawing logs, bolts, or flitches. Veneers may be categorized as either hardwood or softwood, depending on the type of woods used and the intended purpose.

Softwood Veneer is used in the manufacture of softwood plywood and in some cases the inner plies of hardwood faced plywood.

Hardwood Veneer can be categorized according to use, the three most important being:

- (1) face veneer - the highest quality used to make panels employed in furniture and interior decoration.
- (2) commercial veneer - used for crossbands, cores, backs of plywood panels and concealed parts of furniture.
- (3) container veneer - inexpensive veneers used in the making of crates, hampers, baskets, kits, etc.

Veneer Cutting - There are four basic methods:

- (1) rotary lathing - cutting continuous strips by the use of a stationary knife and a lathe.
- (2) slicing - consists of a stationary knife and an upward and downward moving log bed. On each down stroke a slice of veneer is cut.
- (3) stay log - a flitch is attached to a "stay log," or a long, flanged, steel casting mounted in eccentric chucks on a conventional lathe.
- (4) sawn veneer - veneer cut by a circular type saw called a segment saw. This method produces only a very small quantity of veneer. (see also "segment saw.")

Veneer Drying - Freshly cut veneers are ordinarily unsuited for gluing because of their wetness and are also susceptible to molds, fungi, and blue stain. Veneer is usually dried, therefore, as soon as possible, to a moisture content of about 10 percent.

Veneer Preparation - A series of minor operations including grading and matching, redrying, dry-slipping, joining, tapping and splicing, inspecting and repairing. These operations take place between drying and gluing.

Water-Borne Preservative - Any one of several formulations of inorganic salts, the most common which are based on copper, chromium, and arsenic.

Water Balance - The water gain (incoming water) of a mill versus water loss (water discharged or lost).

Wet Barkers - See debarker.

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Wet-Felting - Term applied to the forming of a fiberboard from a suspension of pulp in water usually on a cylinder, deckle box or Fourdrinier machine; the interfelting of wood fibers from a water suspension into a mat for board.

Wet Process - See Wet-Felting.

Wet Scrubber- An air pollution control device which involves the wetting of particles in an air stream and the impingement of wet or dry particles on collecting surfaces, followed by flushing.

Wood Extractives - A mixture of chemical compounds, primarily carbohydrates, removed from wood during steam conditioning.

Wood Preservatives - A chemical or mixture of chemicals with fungistatic and insecticidal properties that is injected into wood to protect it from biological deterioration.

APPENDIX A
INVENTORY OF VENEER AND PLYWOOD MILLS IN THE UNITED STATES

APPENDIX A

LIST OF VENEER AND PLYWOOD MILLS IN THE UNITED STATES

SOFTWOOD PLYWOOD PLANTS

ALABAMA

Birmingham Forest Products, Inc.
Div. of U. S. Steel &
Champion International

Dixon Plywood
Div. of Dixon Lumber Company
Andalusia, Alabama

MacMillan Bloedel Inc.
Div. of MacMillan Bloedel Ltd.
Pine Hill, Alabama

Scotch Plywood Company
Fulton, Alabama

Sumter Veneer Works
Eutaw, Alabama

Union Camp Corporation
Building Products Division
Chapman, Alabama

Georgia-Pacific Corporation
Crossett Division, Plant #2
Crossett, Arkansas

Georgia-Pacific Corporation
Crossett Division, Fordyce Plant
Fordyce, Arkansas

Olinkraft, Inc.
Sub. of Olin Corporation
Huttig, Arkansas

The Singer Company
Wood Products Division
Trumann, Arkansas

Weyerhaeuser Company
Dierks, Arkansas

Weyerhaeuser Company
Mt. Pine, Arkansas

CALIFORNIA

ARIZONA

Arizona Building Components
Prescott, Arizona

American Forest Products Corp.
Sub. of The Bendix Corp.
Amador-Calaceras Division
Martell, California

ARKANSAS

Arkla Chemical Corporation
Div. of Arkansas Louisiana Gas Co.
Gurdon, Arkansas

Arcata Plywood Corporation
Arcata, California

Boise Cascade Corporation
Union Lumber Company Div.
Fort Bragg, California

Georgia-Pacific Corporation
Crossett Division, Plant #1
Crossett, Arkansas

Cloverdale Plywood Company
Div. of Fibreboard Corporation
Cloverdale, California

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Diamond International Corporation
California Lumber Division
Red Bluff, California

Fortuna Veneer Company
Div. of Arcata Plywood Corp.
Fortuna, California

Georgia-Pacific Corporation
Samoa, California

International Paper Company
Long-Bell Division
Weed Operations
Weed, California

The Pacific Lumber Company
Scotia, California

Pickering Lumber Company
Div. of Fibreboard Corporation
Standard, California

Plywood Fabricators, Inc.
Redwood Valley, California

Simpson Timber Company
Mad River Plywood Plant Div.
Arcata, California

Simpson Timber Company
Fairhaven Plywood Plant Div.
Eureka, California

Standard Veneer & Timber Company
Crescent City, California

COLORADO

Montezuma Plywood Company
Sub. of Southwest Forest Ind., Inc.
Cortex, Colorado

FLORIDA

Boise Cascade Corporation
Pensacola Plywood
Cantonment, Florida

Georgia-Pacific Corporation
Chiefland, Florida

GEORGIA

Georgia-Pacific Corporation
Monticello, Georgia

Georgia-Pacific Corporation
Savannah, Georgia

Great Northern Plywood Co.
Sub. of Great Northern
Nekoosa Corporation
Cedar Springs, Georgia

Tolleson Lumber Company
Perry, Georgia

U. S. Plywood
Div. of Champion International
Waycross, Georgia

IDAHO

Idaho Veneer Company
Post Falls, Idaho

Potlatch Forests, Inc.
Clearwater Plywood
Lewiston, Idaho

Potlatch Forests, Inc.
Jaype Plywood Plant
Pierce, Idaho

Potlatch Forests, Inc.
St. Maries Plywood Co. Sub.
St. Maries, Idaho

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LOUISIANA

Anthony Forest Products Company
Plywood Division
Plain Dealing, Louisiana

Georgia-Pacific Corporation
Crossett Division
Urania, Louisiana

Louisiana Plywood Corporation
Aff. of Willamette Industries, Inc.
Dodson, Louisiana

Olinkraft, Inc.
Plywood Operation
Sub. of Olin Corp.
Winnfield, Louisiana

Santiam Southern Company
Aff. of Willamette Industries, Inc.
Ruston, Louisiana

Tremont Lumber Company
Joyce, Louisiana

U. S. Plywood
Div. of Champion International
Holden, Louisiana

Vanply Incorporated
Florien, Louisiana

Vanply Incorporated
Oakdale, Louisiana

Wilmar Plywood, Inc.
Aff. of Willamette Ind., Inc.
Natchitoches, Louisiana

Woodard-Walker-Willamette, Inc.
Aff. of Willamette Ind., Inc.
Minden, Louisiana

MARYLAND

Chesapeake Bay Plywood Corp.
Div. Champion International
Pocomoke City, Maryland

MICHIGAN

Iron Wood Products Corp.
Bessemer, Michigan

MISSISSIPPI

Delta Pine Plywood Company
Beaumont, Mississippi

Georgia-Pacific Corporation
Crossett Division
Gloster, Mississippi

Georgia-Pacific Corporation
Crossett Division
Louisville, Mississippi

Georgia-Pacific Corporation
Crossett Division
Taylorsville, Mississippi

International Paper Company
Long-Bell Division
Wiggins Operations
Wiggins, Mississippi

Weyerhaeuser Company
Philadelphia Operations
Philadelphia, Mississippi

MONTANA

C & C Plywood Corporation
Kalispell, Montana

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Evans Products Company
Van-Evans Operations
Missoula, Montana

Pack River Plywood Company
Polson, Montana

Plum Creek Lumber Company
Columbia Falls, Montana

St. Regis Paper Company
Forest Products Division
Libby, Montana

NEW HAMPSHIRE

Frye & Son, Inc.
Wilton, New Hampshire

NORTH CAROLINA

Evans Products Company
Building Materials Group
Kings Mountain, North Carolina

Prescott Products Corporation
Elizabeth City, North Carolina

Thomason Plywood Corporation
Fayetteville, North Carolina

Triangle Plywood Corporation
Sub. of Boise Cascade Corp.
Moncure, North Carolina

Weyerhaeuser Company
Jacksonville, North Carolina

Weyerhaeuser Company
Plymouth, North Carolina

OKLAHOMA

Weyerhaeuser Company
Wright City, Oklahoma

OREGON

Agnew Plywood
Div. of Fourply, Inc.
Grants Pass, Oregon

Alpine Veneers, Inc.
Portland, Oregon

Astoria Plywood Corporation
Astoria, Oregon

Bate Plywood Company, Inc.
Div. of Fibreboard Corp.
Merlin, Oregon

Bohemia Lumber Company, Inc.
Culp Creek, Oregon

Boise Cascade Corporation
N. W. Oregon Region
Albany Division
Albany, Oregon

Boise Cascade Corporation
Mt. Emily Division
Elgin, Oregon

Boise Cascade Corporation
N. W. Oregon Region
Independence Division
Independence, Oregon

Boise Cascade Corporation
Southern Oregon Region
Medford, Oregon

Boise Cascade Corporation
N. W. Oregon Region
Sweet Home Division
Sweet Home, Oregon

Boise Cascade Corporation
N. W. Oregon Region
Valsetz Division
Valsetz, Oregon

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Brand S Corporation
Alsea, Oregon

Brand S Corporation
Corvallis, Oregon

Brookings Plywood Corporation
Brookings, Oregon

Brooks-Willamette Corporation
Aff. of Willamette Industries, Inc.
Redmond, Oregon

Cabax Mills
Plywood Division
Eugene, Oregon

Carolina Pacific Plywood, Inc.
Sub. of Southwest Forest Industries
Grants Pass, Oregon

Carolina Pacific Plywood Inc.
Sub. of Southwest Forest Industries
White City, Oregon

Coos Head Timber Company
Coos Bay, Oregon

Drain Plywood Company
Drain, Oregon

Ellingson Timber Company
Plywood Division
Baker, Oregon

Eugene Stud & Veneer Inc.
Eugene, Oregon

Fir Ply Incorporated
White City, Oregon

Georgia-Pacific Corporation
Coos Bay, Oregon

Georgia-Pacific Corporation
Coquille, Oregon

Georgia-Pacific Corporation
Springfield Division
Camp Adair Plant
Corvallis, Oregon

Georgia-Pacific Corporation
Eugene Division
Eugene, Oregon

Georgia-Pacific Corporation
Springfield Division
Springfield, Oregon

Georgia-Pacific Corporation
Toledo, Oregon

Georgia-Pacific Corporation
Yarnell Plywood Division
Yarnell, Oregon

Giustina Bros. Lumber &
Plywood Company
Eugene, Oregon

Glendale Plywood Company
Sub. of The Robert Dollar Co.
Glendale, Oregon

Hines Lumber Company
Hines, Oregon

Hines Lumber Company
Westfir, Oregon

International Paper Company
Long-Bell Division
Gardiner Operations
Gardiner, Oregon

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International Paper Company
Long Bell Division
Vaughn Operations
Veneta, Oregon

Lane Plywood Incorporated
Eugene, Oregon

Leadings Plywood Corporation
Eugene, Oregon

Linnton Plywood Association
Portland, Oregon

Medford Corporation
Medford, Oregon

Medford Veneer & Plywood Corp.
White City, Oregon

Mid Plywood Incorporated
Sweet Home, Oregon

Millwaukie Plywood Corporation
Millwaukie, Oregon

Multnomah Plywood Corporation
St. Helens, Oregon

Nordic Plywood, Inc.
Aff. with Nordic Veneers, Inc.
Sutherlin, Oregon

North Santiam Plywood Co.
Mill City, Oregon

Oregon-Washington Plywood Co.
Garibaldi, Oregon

Publishers Paper Company
Dwyer Division
Portland, Oregon

Rogue Valley Plywood, Inc.
White City, Oregon

Rosboro Lumber Company
Springfield, Oregon

Roseburg Lumber Company
Dillard, Oregon

Roseburg Lumber Company
Roseburg, Oregon

Roseburg Lumber Company
Riddle, Oregon

Roseburg Lumber Company
Coquille, Oregon

SWF Plywood Company
Div. of Southwest Forest Industries
Grants Pass, Oregon

SWF Plywood Company
Div. of Southwest Forest Industries
Springfield, Oregon

Simpson Timber Company
Albany Plywood Plant
Albany, Oregon

Southern Oregon Plywood Inc.
Grants Pass, Oregon

Structural Laminates, Inc.
Beaverton, Oregon

Tillamook Veneer Company
Tillamook, Oregon

Tim-Ply Company
Division of Timber Products Co.
Grants Pass, Oregon

U. S. Plywood
Div. of Champion International
Gold Beach, Oregon

U. S. Plywood
Div. of Champion International
Mapleton, Oregon

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U. S. Plywood
Div. of Champion International
Roseburg, Oregon

U. S. Plywood
Div. of Champion International
Willamina, Oregon

Warm Springs Forest Products
Mardas, Oregon

Western States Plywood Cooperative
Port Orford, Oregon

Weyerhaeuser Company
Cottage Grove, Oregon

Weyerhaeuser Company
Klamath Falls, Oregon

Weyerhaeuser Company
Coos Bay Branch
North Bend, Oregon

Weyerhaeuser Company
Springfield, Oregon

White City Plywood Company
McMinnville, Oregon

White City Plywood Company
White City, Oregon

Willamette Industries, Inc.
Dallas Division
Dallas, Oregon

Willamette Industries, Inc.
Foster Division
Sweet Home, Oregon

Willamette Industries, Inc.
Griggs Division
Lebanon, Oregon

Willamette Industries, Inc.
Lebanon Division
Lebanon, Oregon

Willamette Industries, Inc.
Springfield Division
Springfield, Oregon

Willamette Industries, Inc.
Sweet Home Division
Sweet Home, Oregon

SOUTH CAROLINA

Cheraw Plywood Company, Inc.
Cheraw, South Carolina

Georgia-Pacific Corporation
Russellville, South Carolina

Holly Hill Lumber Co., Inc.
Holly Hill, South Carolina

TEXAS

Blodkstein Company
Houston, Texas

Georgia-Pacific Corporation
Corrigan, Texas

Georgia-Pacific Corporation
Crossett Division
New Waverly, Texas

International Paper Company
Long-Bell Division
Nacogdoches Operations
Nacogdoches, Texas

Kirby Lumber Corporation
Silsbee, Texas

Owens-Illinois, Inc.
Jasper, Texas

Owens-Illinois, Inc.
Lufkin, Texas

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Temple Industries, Inc.
Plywood Division
Diboll, Texas

Walker Plywood
Kirby Lumber Corporation
Cleveland, Texas

VIRGINIA

Georgia-Pacific Corporation
Emporia, Virginia

WASHINGTON

Biles-Coleman Lumber Company
Omak, Washington

Bingen Plywood Company
Bingen, Washington

Boise Cascade Corporation
Kettle Falls, Washington

Boise Cascade Corporation
Yakima, Washington

Centralia Plywood Inc.
Centralia, Washington

Elma Plywood Corporation
Elma, Washington

Evans Products Company
Building Materials Group
Softwood Lumber & Plywood Div.
Harbor Mill
Aberdeen, Washington

Everett Plywood Corporation
Everett, Washington

Farwest Plywood Company
Tacoma, Washington

Fort Vancouver Plywood Company
Vancouver, Washington

Hardel Mutual Plywood Corp.
Olympia, Washington

Hoquaim Plywood Company, Inc.
Hoquaim, Washington

International Paper Company
Long-Bell Division
Chelatchie Operations
Amboy, Washington

Lacey Plywood Company, Inc.
Lacey, Washington

Lyle Wood Products Inc.
Tacoma, Washington

Mt. Baker Plywood Inc.
Bellingham, Washington

North Pacific Plywood, Inc.
Tacoma, Washington

Peninsula Plywood Corporation
Sub. of ITT
Port Angeles, Washington

Pope & Talbot, Inc.
Kalama, Washington

Publishers Forest Products Co.
Div. of Publishers Paper Co.
Anacortes, Washington

Puget Sound Plywood, Inc.
Tacoma, Washington

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Simpson Timber Company
McCleary, Washington

Simpson Timber Company
Olympic Plant
Shelton, Washington

Stevenson Co-Ply, Inc.
Stevenson, Washington

U. S. Plywood
Div. of Champion International
Grays Harbor Division
Hoquaim, Washington

Weyerhaeuser Company
Longview, Washington

Weyerhaeuser Company
Snoqualmine Falls, Washington

SOFTWOOD VENEER PLANTS

ARKANSAS

Beisel Veneer Hoop Company
West Helena, Arkansas

FLORIDA

Franklin Crates, Inc.
Micanopy, Florida

CALIFORNIA

Carolina Pacific Plywood, Inc.
Sub. of Southwest Forest Ind.
Slayer, California

GEORGIA

Pearson Basket Mills
Fort Valley, Georgia

Carolina Pacific Plywood, Inc.
Sub. of Southwest Forest Ind.
Happy Camp, California

MARYLAND

Stenersen Mahogany Corp.
Cockeysville, Maryland

Hoopa Veneer Company
Hoopa, California

MINNESTOA

Wahkon Veneer Mill
Wahkon, Minnesota

Medford Veneer & Plywood Corp.
Crescent City, California

NEW JERSEY

Rapp Package Company
Carpentersville, New Jersey

Miller Redwood Company
Sub. of Stimson Lumber Company
Crescent City, California

NORTH CAROLINA

Armentrout Veneer Company
High Point, North Carolina

Orleans Veneer & Lumber Company
Div. of Arcata Plywood Corp.
Orleans, California

Rochlin Veneer & Plywood Co.
Willow Creek, California

West Coast Veneer Company
Crescent City, California

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Collins-Davis Chair Company
Hudson, North Carolina

Lenderink Incorporated
Wilson, North Carolina

Mayo Veneers, Inc.
Whitakers, North Carolina

Thomasville Veneer Company
Thomasville, North Carolina

Weyerhaeuser Company
Jacksonville, North Carolina

OREGON

Baflam Veneer Corporation
Corvallis, Oregon

Boise Cascade Corporation
Chemult, Oregon

Coburg Veneer Corporation
Coburg, Oregon

Conrad Veneers, Inc.
Tualatin, Oregon

Dillard Veneer Company
Riddle, Oregon

The Robert Dollar Company
Glendale, Oregon

Douglas Lumber Company
Roseburg, Oregon

Firwood Lumber Company, Inc.
Sandy, Oregon

Freres Lumber Company, Inc.
Lyons, Oregon

G L Pine Incorporated
John Day, Oregon

Georgia-Pacific Corporation
Norply Veneer Division
Norway, Oregon

Georgia-Pacific Corporation
Powers Veneer Division
Powers, Oregon

Georgia-Pacific Corporation
Rogue River Veneer Division
Rogue River, Oregon

Georgia-Pacific Corporation
Sutherlin Division
Sutherlin, Oregon

Goshen Veneer Inc.
Goshen, Oregon

Edward Hines Lumber Company
Mount Vernon, Oregon

Kogap Manufacturing Company
Medford, Oregon

Lawyer Veneer Company
White City, Oregon

Menasha Corporaiton
Doyle Veneer Division
Myrtle Point, Oregon

The Murphy Company
Florence, Oregon

Nordic Veneers, Inc.
Roseburg, Oregon

Olympic Manufacturing Co.
Gresham, Oregon

Pope & Talbot, Inc.
Oakridge, Oregon

DRAFT

Rex Veneer Company
Philomath, Oregon

Roseburg Lumber Company
Dixonville, Oregon

Stimson Lumber Company
Forest Grove, Oregon

Sun Studs, Inc.
Sun Veneer Division
Roseburg, Oregon

Sweet Home Veneer, Inc.
Sweet Home, Oregon

Timber Products Company
Medford, Oregon

Triangle Veneer Inc.
Eugene, Oregon

Zip-O-Log Veneer, Inc.
Eugene, Oregon

SOUTH CAROLINA

Highland Crate Co-op.
St. Stephen, South Carolina

TEXAS

Solver Crate & Lumber Mill Co.
Rusk, Texas

VIRGINIA

Ferrum Veneer Corporation
Ferrum, Virginia

WASHINGTON

Allen Logging & Veneer Co.
Forks, Washington

Bay Veneer Incorporated
Townsend, Washington

Cowlitz Stud Company
Randle, Washington

Hegewald Timber, Inc.
Stevenson, Washington

Ly-Col Veneer, Inc.
Roslyn, Washington

Mt. Adams Veneer Company
Randle, Washington

Oregon Washington Plywood Co.
Tandle, Washington

Solid Wood, Inc.
Olympia, Washington

Winlock Veneer
Winlock, Washington

WISCONSIN

Dufeck Manufacturing Co.
Denmark, Wisconsin

Menasha Corporation
Neenah, Wisconsin

DRAFT

HARDWOOD PLYWOOD

ALABAMA

Alabama Veneer & Panel Company
Mexia, Alabama

Belcher Lumber Company, Inc.
Centerville, Alabama

Decatur Box & Basket Company, Inc.
Decatur, Alabama

Dixie Veneer Company
Abbeville, Alabama

Fox Lumber Company
Centerville, Alabama

Howell Plywood Corporation
Dothan, Alabama

Taylor Veneer Company, Inc.
Demopolis, Alabama

Thompson & Swaim Plywood, Inc.
Tuscaloosa, Alabama

Union Camp Corporation
Building Products Division
Chapman, Alabama

ARKANSAS

Chicago Mill & Lumber Company
West Helena, Arkansas

Delta Plywood Corporation
Cotton Plant, Arkansas

Evans Products Company
West Memphis, Arkansas

McKnight Veneer & Plywoods, Inc.
West Helena, Arkansas

CALIFORNIA

Birchwood of Los Angeles, Inc.
Los Angeles, California

General Veneer Manufacturing Co.
South Gate, California

Karpen Plywood Company
Div. of U. S. Plywood-
Champion Papers, Inc.
Compton, California

Lorenz Lumber Company
Div. of Fibreboard Corp.
Burney, California

Plywood Manufacturing of Calif.
Torrance, California

Sunset Plywood, Inc.
Los Angeles, California

FLORIDA

Boise Cascade Corporation
Pensacola Division
Cantonment, Florida

Costal Variety Works, Inc.
Blountstown, Florida

Florida Plywoods, Inc.
Greenville, Florida

DRAFT

GEORGIA

Bradley Plywood Corporation
Savannah, Georgia

The Day Company
Cuthbert, Georgia

Georgia-Pacific Corporation
Savannah, Georgia

Georgia Plywood Corporation
Dublin, Georgia

Patat Plywood Corporation
Rockmart, Georgia

Pearson Basket Mills
Fort Valley, Georgia

ILLINOIS

Jasper Wood Products Co., Inc.
Newton, Illinois

INDIANA

General Plywood Corp., Inc.
Indiana Division
New Albany, Indiana

Hoosier Panel Company, Inc.
New Albany, Indiana

Jasper Stylemasters, Inc.
Div. of Jasper Corporation
Jasper, Indiana

Jasper Veneer Mills, Inc.
Jasper, Indiana

Jasper Wood Products Co., Inc.
Jasper, Indiana

Paramount Plywood Products, Inc.
New Albany, Indiana

KENTUCKY

Gamble Brothers, Inc.
Louisville, Kentucky

LOUISIANA

Chicago Mill & Lumber Co.
Tullulah, Louisiana

U. S. Plywood
Div. of Champion International
Hammond, Louisiana

MAINE

J. M. Huber Corporation
Patten, Maine

Kennebec, Inc.
Bingham, Maine

Allen Quimby Veneer Company
Div. of Scoville Mfg. Co.
Bingham, Maine

MICHIGAN

Contour Products, Inc.
Bay City, Michigan

Ironwood Products Corp.
Bessemer, Michigan

DRAFT

Ply Curves Incorporated
Grand Rapids, Michigan

Plycoma Veneer Corporation
Nashville, Michigan

MINNESOTA

Buffalo Veneer & Plywood Co.
Buffalo, Minnesota

Mill City Plywood Company
Minneapolis, Minnesota

MISSISSIPPI

Chicago Mill & Lumber Co.
Greenville, Mississippi

The Day Company
Waynesboro, Mississippi

Iron Wood Products
Bessemer, Mississippi

Pavco Industries, Inc.
Pascagoula, Mississippi

Perry County Plywood Corp.
Beaumont, Mississippi

Tuscaloosa Veneer Company
Meridian, Mississippi

NEW HAMPSHIRE

Frye & Son Incorporated
Wilton, New Hampshire

Keller Products, Inc.
Manchester, New Hampshire

NEW YORK

Jamestown Plywood Division
AVM Corporation
Jamestown, New York

U. S. Veneer Company, Inc.
Div. of John Lagenbacher
Bronx, New York

NORTH CAROLINA

Beck Brothers Veneer Co., Inc.
Zubulon, North Carolina

Benson Veneer Company, Inc.
Benson, North Carolina

Boise Cascade Corporation
Face Veneers Division
Pelham, North Carolina

Boliva Lumber Company
Wilmington, North Carolina

Calypso Plywood Company, Inc.
Calypso, North Carolina

Carolina Panel Company, Inc.
Lexington, North Carolina

Carolina Plywood Company, Inc.
Apex, North Carolina

Columbia Panel Manufacturing Co.
Thomasville, North Carolina

Davis Wood Products, Inc.
Lexington, North Carolina

Denny Plywood Company, Inc.
Roseboro, North Carolina

DRAFT

Doxey Plywood Corporation
Fayetteville, North Carolina

Hasty Plywood Company
Maxton, North Carolina

Hayworth Roll & Panel Co.
High Point, North Carolina

Horner Veneer Company
New Bern, North Carolina

Ingram Plywoods, Inc.
Thomasville, North Carolina

Lea Lumber & Plywood Co.
Div. of Lea Industries, Inc.
Windsor, North Carolina

Lenoir Veneer Company
Lenoir, North Carolina

McLeod Plywood Box Co., Inc.
Wadesboro, North Carolina

Rankin Brothers Company
Fayetteville, North Carolina

Rowland Wood Products Co., Inc.
Rowland, North Carolina

Rural Hall Veneer Company
Rural Hall, North Carolina

Southern Box & Plywood, Inc.
Wilmington, North Carolina

Statesville Plywood & Veneer Co.
Statesville, North Carolina

Thomason Industries, Inc.
Fayetteville, North Carolina

Weldon Veneer Company, Inc.
Weldon, North Carolina

Whiteville Plywood Company
Whiteville, North Carolina

OREGON

Columbia Plywood Corporation
Klamath Plywood Division
Klamath Falls, Oregon

Dougals Fir Plywood Company
Coquille, Oregon

Georgia-Pacific Corporation
Eugene/Springfield Division
Junction City, Oregon

Publishers Paper Company
Dwyer Division
Portland, Oregon

Roseburg Lumber Company
Dillard, Oregon

Southern Oregon Plywood, Inc.
Grants Pass, Oregon

States Veneer, Inc.
Div. of Wood Slicing Corp.
Eugene, Oregon

Timber Products Company
Medford, Oregon

PENNSYLVANIA

Jasper Wood Products Co., Inc.
Watsontown, Pennsylvania

Thompson Mahogany Company
Philadelphia, Pennsylvania

DRAFT

Timber Products Company
Medford, Pennsylvania

Westavco Corporation
Tyrone, Pennsylvania

SOUTH CAROLINA

Carolina Veneer & Plywood Co.
Florence, South Carolina

Cheraw Plywood Company, Inc.
Cheraw, South Carolina

Darlington Veneer Company
Darlington, South Carolina

Davis Wood Products, Inc.
S. C. Division
Blenheim, South Carolina

Dillon Veneer & Plywood Company
Dillon, South Carolina

Furniture Veneers, Inc.
Conway, South Carolina

Georgia-Pacific Corporation
Williams Furniture Division
Sumpter, South Carolina

King Veneer Company, Inc.
Florence, South Carolina

Marsh Plywood Corporation
Paplico, South Carolina

The Plywood Company
Sumpter, South Carolina

Powe Veneer Company
Camden, South Carolina

Standard Plywoods, Inc.
Clinton, South Carolina

Stilley Plywood Company, Inc.
Conway, South Carolina

Tinsley Plywood Corporation
Florence, South Carolina

U. S. Plywood
Div. of Champion International
Orangeburg, South Carolina

Winnsboro Plywood Company
Winnsboro, South Carolina

TENNESSEE

Panoply Corporation
Lexington, Tennessee

Southern Laminating Company
Memphis, Tennessee

Tennessee Veneer Company
Memphis, Tennessee

Tri-State Veneer & Plywood Co.
Memphis, Tennessee

TEXAS

Bruce Company of Texas
Div. of Cook Industries, Inc.
Center, Texas

Center Plywood Company, Inc.
Center, Texas

Liberty Veneer & Panel Co.
Liberty, Texas

VERMONT

Bradford Veneer & Panel Co.
Bradford, Vermont

DRAFT

Consolidated Electronics Ind-
ustries Corporation
Atlas Plywood Division
Morrisville, Vermont

Rutland Plywood Corporation
Rutland, Vermont

Vermont-Pacific Corporation
Bethel, Vermont

Weyerhaeuser Company
Wood Products Division
Hancock, Vermont

VIRGINIA

Atkins Plywood Company, Inc.
Atkins, Virginia

Boise Cascade Corporation
Decorative Paneling Division
Danville, Virginia

Burkeville Veneer Company
Burkeville, Virginia

Day Companies, Inc.
Suffolk, Virginia

Eastern Door & Panel Corp.
Danville, Virginia

Henry County Plywood Corp.
Ridgeway, Virginia

Multi-Ply Corporation
Danville, Virginia

Old Dominion Plywood Corp.
Bristol, Virginia

Virginia-Carolina Veneer Corp.
Danville, Virginia

Virginia Plywood Corporation
Danville, Virginia

Whittle Plywood Corporation
Chatham, Virginia

WASHINGTON

Buffelen Woodworking Company
Tacoma, Washington

Everett Plywood Corporation
Everett, Washington

Mt. Baker Plywood, Inc.
Bellingham, Washington

North Pacific Plywood, Inc.
Tacoma, Washington

Pasquier Panel Products, Inc.
Sumner, Washington

WEST VIRGINIA

Allegheny Lumber Company
Elkins, West Virginia

WISCONSIN

All-Wood Incorporated
Bayfield, Wisconsin

Birchwood Manufacturing Co.
Rice Lake, Wisconsin

Blum Brothers
Marshfield, Wisconsin

Eggers Plywood Company
Two Rivers, Wisconsin

Gillett Veneer & Plywood Co.
Gillett, Wisconsin

Larson Plywood Company, Inc.
Sheboygan, Wisconsin

Linwood Incorporated
Gillett, Wisconsin

DRAFT

Lullabye Furniture Company
Div. of Questor Corporation
Stevens Point, Wisconsin

Marion Plywood Corporation
Marion, Wisconsin

Nelson Plywood Corporation
Gillett, Wisconsin

Pluswood Industries
Oshkosh, Wisconsin

U. S. Plywood
Div. of Champion International
Algoma Operations
Algoma, Wisconsin

Warvel Products, Inc.
Gillett, Wisconsin

Weber Veneer & Plywood Co.
Shawano, Wisconsin

Weyerhaeuser Company
Marshfield, Wisconsin

Wisconsin Laminates, Inc.
Pewaukee, Wisconsin

DRAFT

HARDWOOD VENEER

ALABAMA

Bacon-McMillan Veneer
Manufacturing Co., Inc.
Stockton, Alabama

Browder Veneer Works
Montgomery, Alabama

Sumpter Veneer Works
Eutaw, Alabama

Winborn Veneer Company
Allen, Alabama

FLORIDA

Franklin Crates, Inc.
Micanopy, Florida

Grower's Container Co-op., Inc.
Leesburg, Florida

Highland Crate Co-op.
Jacksonville, Florida

Telley's Box Company, Inc.
Palatka, Florida

GEORGIA

Alexander Wood Products, Inc.
Athens, Georgia

C & H Veneer Company
Hawkinsville, Georgia

Cornelia Veneer Company
Cornelia, Georgia

Perry Veneer Company
Perry, Georgia

Truax Veneer Company, Inc.
Sub. of Lenderink, Inc.
Lyons, Georgia

ILLINOIS

Swords Veneer & Lumber Co.
Sub. of General Woods and
Veneers, Ltd.
Rock Island, Illinois

INDIANA

Amos-Thompson Corporation
Sub. of National Lead Company
Edinburg, Indiana

Central Veneer Incorporated
Indianapolis, Indiana

Cummings Veneers, Inc.
New Albany, Indiana

Curry & Sons, Inc.
New Albany, Indiana

Farrell Box Company, Inc.
Decker, Indiana

Hill Brothers Veneer Co.
Div. of Hammerhill Paper Co.
Edinburg, Indiana

Hoosier Veneer Company, Inc.
New Albany, Indiana

Indiana Veneers, Inc.
Indianapolis, Indiana

National Veneer & Lumber Co.
Seymour, Indiana

Pierson-Hollowell Co., Inc.
Lawrenceburg, Indiana

DRAFT

Roberts & Strack Veneer Co., Inc.
Clarksville, Indiana

Chester B. Stem, Inc.
New Albany, Indiana

David R. Webb Company
Div. of The Walter Reade Org., Inc.
Edinburg, Indiana

IOWA

Bacon Veneer Company
Hubbard Walnut Division
Dubuque, Iowa

Spencer Veneers, Inc.
Spencer, Iowa

KENTUCKY

The Freeman Corporation
Winchester, Kentucky

Laminating Services
Sub. of American Standard Corp.
Louisville, Kentucky

Robins Veneer Company
Louisville, Kentucky

Wood Mosaic Corporation
Sub. of Olin Mathierson Chemical Co.
Louisville, Kentucky

LOUISIANA

Louisiana Veneer Co., Inc.
Chathan, Louisiana

Winnfield Veneer Company
Winnfield, Louisiana

Wood Mosaic Corporation
New Orleans, Louisiana

MAINE

Indian Head Plywood Corp.
Presque Isle, Maine

MARYLAND

Stenersen Mahogany Corporation
Div. of Universal Oil Prod. Co.
Escanaba, Michigan

Manthei Incorporated
Petoskey, Michigan

Soo Veneer Mill
Sault Ste. Marie, Michigan

MINNESOTA

Elk River Box Factory
Elk River, Minnesota

Wahkon Veneer Mill
Wahkon, Minnesota

MISSISSIPPI

Central Box Company
Crystal Springs, Mississippi

Natchez Veneer & Lumber Co., Inc.
Natchez, Mississippi

Rhymes Veneer Incorporated
Collins, Mississippi

MISSOURI

Enterprise Veneer Corporation
Pleasant Hill, Missouri

DRAFT

Missouri Valley Veneers
Div. of C & D Sales, Inc.
St. Joseph, Missouri

NEW JERSEY

Ichabod T. Williams & Sons, Inc.
Carteret, New Jersey

NEW YORK

Gross Veneer Company
Potsdam, New York

Knight Veneer & Panel Corp.
Sub. of Maddox Table Co.
Falconer, New York

Riverside Veneer Company, Inc.
Heuvelton, New York

Robbins Veneer, Inc.
Falconer, New York

Webster Basket Company
Webster, New York

NORTH CAROLINA

Armentrout Veneer Co., Inc.
High Point, North Carolina

Atlantic Veneer Corporation
Beaufort, North Carolina

Beaufort Face Veneer Co., Inc.
Beaufort, North Carolina

Carolina Veneer Company
Thomasville, North Carolina

Chadbourn Veneer Company
Chadbourn, North Carolina

Chowan Veneer Company, Inc.
Edenton, North Carolina

Coastal Veneer Company, Inc.
Wilhan, North Carolina

Davidson Veneer Company, Inc.
Lexington, North Carolina

Duplin Face Veneer Co., Inc.
Mount Olive, North Carolina

Lenderink Incorporated
Wilson, North Carolina

Linwood Manufacturing Co.
Linwood, North Carolina

Quality Veneer Company, Inc.
Liberty, North Carolina

Southern Veneer Company, Inc.
Thomasville, North Carolina

Stubbs Veneer Company
Windsor, North Carolina

Thomasville Veneer Company
Thomasville, North Carolina

Timber Products Company
Div. of Fitco, Inc.
Murphy, North Carolina

U. S. Plywood
Div. of Champion International
Guilford Veneer Operations
High Point, North Carolina

Wilson Veneer Company, Inc.
Wilson, North Carolina

Womble Veneer Company
Southern Pines, North Carolina

DRAFT

OHIO

Edon Manufacturing Company
Edon, Ohio

Hartzell Hardwoods, Inc.
Piqua, Ohio

OREGON

Conrad Veneers, Inc.
Tulatin, Oregon

The Dean Company
Olympic Manufacturing Co. Div.
Gresham, Oregon

Northwest Veneer, Inc.
Grande Ronde, Oregon

Olympic Manufacturing Co.
Sub. of the Dean Company
Gresham, Oregon

PENNSYLVANIA

Cornelia Veneer Company
Philadelphia, Pennsylvania

J. A. Habig Veneer Company
Montgomery, Pennsylvania

Weyerhaeuser Company
Ridgeway, Pennsylvania

Williamson Veneer Company
Sub. of Evans Products Co.
New Freedom, Pennsylvania

Woody Veneer & Lumber Co., Inc.
Glen Rock, Pennsylvania

SOUTH CAROLINA

Beaufort-Wood-Products Co., Inc.
Yemassee, South Carolina

Bennettsville Veneer Company
Bennettsville, South Carolina

Carolina Wirebounds, Inc.
Springfield, South Carolina

Denmark Veneer Company
Denmark, South Carolina

Elloree Veneer Company
Elloree, South Carolina

Kearse Manufacturing Co., Inc.
Olar, South Carolina

TENNESSEE

Ashby Veneer & Lumber Company
Jackson, Tennessee

Dyer Fruit Box Company
Dyer, Tennessee

VERMONT

Indian Head Plywood Corp.
Div. of Columbia Plywood Corp.
Newport, Vermont

VIRGINIA

Blue Ridge Veneer & Plywood Corp.
Waynesboro, Virginia

Ferrum Company
Sub. of Mead Corporation
Ferrum, Virginia

Helms Veneer Corporation
Rocky Mount, Virginia

Penrod, Jurden & Clark Co.
Norfolk, Virginia

Stubbs Veneer Company, Inc.
Div. of Henry County Plywood Corp.
Ridgeway, Virginia

U. S. Plywood
Div. of Champion International
Champion Veneer Works
Pulaski, Virginia

Virginia Log Company, Inc.
West Point, Virginia

WEST VIRGINIA

Breece Veneer Company
Kenova, West Virginia

Martinsburg Veneer Corp.
Martinsburg, West Virginia

WISCONSIN

Bennett Box & Veneer Company
Rice Lake, Wisconsin

Ebner Box Incorporated
Cameron, Wisconsin

Hatley Veneer Company, Inc.
Hatley, Wisconsin

Houghton Wood Products, Inc.
Wausau, Wisconsin

DRAFT

SOFTWOOD AND HARDWOOD PLYWOOD

ALABAMA

Sumpter Veneer Works
Eutaw, Alabama

Union Camp Corporation
Building Products Div.
Chapman, Alabama

FLORIDA

Boise Cascade Corporation
Pensacola Plywood
Cantonment, Florida

GEORGIA

Georgia-Pacific Corporation
Savannah, Georgia

MICHIGAN

Iron Wood Products Corp.
Bessemer, Michigan

NEW HAMPSHIRE

Frey & Son, Inc.
Wilton, New Hampshire

NORTH CAROLINA

Thomason Plywood Corporation
Fayetteville, North Carolina

OREGON

Georgia-Pacific Corporation
Eugene Division
Eugene, Oregon

Publishers Paper Company
Dwyer Division
Portland, Oregon

Southern Oregon Plywood Inc.
Grants Pass, Oregon

SOUTH CAROLINA

Cheraw Plywood Company, Inc.
Cheraw, South Carolina

TEXAS

Walker Plywood
Kirby Lumber Corporation
Cleveland, Texas

WASHINGTON

Everett Plywood Corporation
Everett, Washington

Mt. Baker Plywood, Inc.
Bellingham, Washington

North Pacific Plywood, Inc.
Tacoma, Washington

Puget Sound Plywood, Inc.
Tacoma, Washington

DRAFT

SOFTWOOD AND HARDWOOD VENEER

FLORIDA

Franklin Crates Incorporated
Micanopy, Florida

GEORGIA

Pearson Basket Mills
Fort Valley, Georgia

MARYLAND

Stenersen Mahogany Corp.
Cockeysville, Maryland

MINNESOTA

Wahkon Veneer Mill
Wahkon, Minnesota

NORTH CAROLINA

Armentrout Veneer Co., Inc.
High Point, North Carolina

Lenderink Incorporated
Wilson, North Carolina

Thomasville Veneer Company
Thomasville, North Carolina

OREGON

Conrad Veneers, Inc.
Tualatin, Oregon

Olympic Manufacturing Co.
Gresham, Oregon

Timber Products Company
Medford, Oregon

VIRGINIA

Ferrum Veneer Corporation
Ferrum, Virginia

APPENDIX B
ENGLISH-METRIC CONVERSION TABLE

CONVERSION TABLE

Multiply (English Units)		by	To Obtain (Metric Units)	
English Unit	Abbreviation	Conversion	Abbreviation	Metric Unit
acre	ac	0.405	ha	hectares
acre-feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram-calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories per kilogram
cubic feet per minute	cfm	0.028	cu m/min	cubic meters per minute
cubic feet per second	cfs	1.7	cu m/min	cubic meters per minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	°F	$0.555(^{\circ}\text{F}-32)^1$	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters

¹Actual conversion, not a multiplier

CONVERSION TABLE (CONTINUED)

Multiply (English Units)		by	To Obtain (Metric Units)	
English Unit	Abbreviation	Conversion	Abbreviation	Metric Unit
gallon per minute	gpm	0.0631	l/sec	liters per second
gallon per ton	gal/ton	4.173	l/kg	liters per metric ton
horsepower	hp	0.7457	kw	kilowatts
inches	in	2.54	cm	centimeters
inches of Mercury	in Hg	0.03342	atm	atmospheres (absolute)
pounds	lb	0.454	kg	kilograms
pound per ton	lb/ton	0.5005	kg/kg	kilograms per metric ton
million gallons per day	mgd	3,785	cu m/day	cubic meters per day
mile	mi	1.609	km	kilometer
pounds per square inch (gauge)	psig	$(0.06805 \text{ psig} + 1)^1$	atm	atmospheres (absolute)

¹Actual conversion, not a multiplier

CONVERSION TABLE (CONTINUED)

Multiply (English Units)		by	To Obtain (Metric Units)	
English Unit	Abbreviation	Conversion	Abbreviation	Metric Unit
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
tons (short)	t	0.907	kkg	metric tons (1000 kilograms)
yard	y	0.9144	m	meters