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Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the

PLYWOOD, HARDBOARD, AND WOOD PRESERVING

Segment of the Timber Products Processing Point Source Category

APRIL 1974

U.S. ENVIRONMENTAL PROTECTION AGENCY
Washington, D.C. 20460

DEVELOPMENT DOCUMENT

for

EFFLUENT LIMITATIONS GUIDELINES

and

NEW SOURCE PERFORMANCE STANDARDS

for the

PLYWOOD, HARDBOARD AND WOOD PRESERVING SEGMENT OF THE TIMBER PRODUCTS PROCESSING POINT SOURCE CATEGORY

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ABSTRACT

A study was made of the plywood, hardboard and wood preserving segment of the timber products processing point source category. The purpose of the study was to develop information to assist the Agency in establishing effluent limitation guidelines for existing sources, new source performance standards and pretreatment standards as required by Sections 304, 306, and 307 of the Federal Water Pollution Control Act Amendments of 1972.

The plywood, hardboard and wood preserving segment of the industry was divided into 8 subcategories based primarily on distinctions generated from differences in the type of product manufactured and the specific processes involved. Best practicable control technology currently available for six of the subcategories was determined to be no discharge of process waste water pollutants into navigable waters. These subcategories are: Barking, Veneer, Plywood, Hardboard - Dry Process, Wood Preserving, and Wood Preserving - Boultonizing. Discharges are allowed for hydraulic barking operations and direct steam conditioning in the veneer manufacturing operations. Quantitative limitations are determined for the Hardboard-Wet Process and the Wood Preserving-Steam subcategories.

Best available technology economically achievable will result in the elimination of discharge the barking subcategory and the veneer subcategory.

The new source performance standards for six subcategories is no discharge of process waste water pollutants into navigable waters. For the remaining subcategories, limitations are equivalent to the levels achievable by application of the best available technology economically achievable. A discharge is allowed for effluents from hydraulic barking operations.

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Pretreatment standards allow the discharge of process waste water from these eight subcategories into publicaly owned treatment works per 40 CFR Part 128, except for Section 128.133.

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SECTION I

CONCLUSIONS

For the purpose of establishing effluent limitations guidelines and standards of performance, the plywood, hardboard and wood preserving segment of the timber products processing category has been divided into eight subcategories as follows: (1) Barking, (2) Veneer, (3) Plywood, (4) Hardboard-Dry Process, (5) Hardboard-Wet Process, (6) Wood Preserving, (7) Wood Preserving-Steam, and (8) Wood Preserving-Boultonizing.

Readily apparent disparities between the type of products manufactured and between the different processes employed in the production of a given product form the primary justification for the above subcategorization. Distinctions related to raw material, plant size and age, and air pollution problems are not contributary to the subcategorization, as the factors involved are minor non-existent: quantitative differences in wastes generated serve to reinforce the subcategorization.

Presently, 20 to 30 percent of the veneer and plywood manufacturing plants are achieving the no discharge limitation as described herein. Many additional plants are utilizing manufacturing practices and procedures that result in no discharge of waste water from unit operations within the veneer and plywood manufacturing process. A small number of mills utilizing direct steam conditioning may be unable to meet the no discharge limitation for 1977, and unwilling or unable to make the change to a different method at this time. The Agency feels that retention of direct steam conditioning is reasonable for the present and has thus promulgated quantitative limitations for these particular operations, for the 1977 standards. 1983 standards, however, recognize that technology is available, the application of which would result in no discharge of process waste water. Twenty-five percent of the dry process hardboard manufacturers and 22 percent of the 9 wet process hardboard manufacturers are achieving the no discharge limitations set forth. Of the 390 wood preserving manufacturing operations, at least 5 are currently meeting the no discharge recommendation in the Wood Preserving-Boultonizing subcategory, and approximately 10 percent of the Wood Preserving-Steam subcategory manufacturers are achieving the recommended limitations. It is believed that all wood preserving operations excluding those in the Wood Preserving-Steam subcategory can reach the no discharge level by July 1, 1977.

It is estimated that the capital costs of achieving such limitations and standards by all plants within this segment of the timber products processing industry would be less than $38 million.

These costs would result in an increase in capital investment by approximately $38 million. As a result, the increased costs of the products covered in this segment would range from 1-2 percent under present conditions. The above cost data reflects conditions where it is assumed no pollution control measures exist within the industry. Because much of the suggested technology has already been purchased or is in place, the figures are higher than the real costs involved.

The increased capital costs would result in an estimated cost increase of from 0 to 1 percent as compensation for pollution control measures in all but the hardboard subcategory. Hardboard prices could rise as much as 8 percent for industrial board, and 4 to 5 percent for other hardboard products, but the rise cannot be attributed solely or even primarily to the cost of additional pollution control.

SECTION II

RECOMMENDATIONS

The recommended effluent limitations guidelines based upon (1) best practicable control technology currently available, (2) best available technology economically achievable, and (3) performance standards for new sources are summarized below. The effluent limitations as set forth herein are developed in depth in the following sections of this document.

RECOMMENDED EFFLUENT LIMITATIONS BASED ON BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

SUBCATEGORY — EFFLUENT LIMITATION

BARKING

A. No discharge of waste water pollutants to navigable waters for barking operations excluding those using hydraulic barkers.

B. For barking operations using hydraulic barkers:

	30-Day Average kg/cu m (lb/cu ft)	Daily Maximum kg/cu m (lb/cu ft)
BOD_5	0.5 (0.03)	1.5 (0.09)
TSS	2.3 (0.144)	6.9 (0.431)

VENEER

A. No discharge of waste water pollutants to navigable waters, except for those veneer operations using direct steam conditioning.

B For veneer manufacturing operations using direct steam conditioning:

	BOD	
	30-Day Average kg/cu m (lb/cu ft)	Daily Maximum kg/cu m (lb/cu ft)
Softwood Veneer	0.24 (0.015)	0.72 (0.045)
Hardwood Veneer	0.54 (0.034)	1.62 (0.10)

PLYWOOD — No discharge of waste water pollutants to navigable waters.

HARDBOARD -DRY — No discharge of waste water pollutants to navigable waters.

HARDBOARD -WET

	30-Day Average kg/kkg (lb/ton)	Daily Maximum kg/kkg (lb/ton)
BOD5	2.6 (5.2)	7.8 (15.6)
TSS	5.5 (11.0)	16.5 (33.0)
pH Range	6.0-9.0	6.0-9.0

WOOD PRESERVING — No discharge of waste water pollutants to navigable waters

WOOD PRESERVING-BOULTONIZING — No discharge of waste waters pollutants to navigable waters.

WOOD PRESERVING-STEAM

	30-Day Average kg/1000 cu m (lb/1000 cu ft)	Daily Maximum kg/1000 cu m (lb/1000 cu ft)
COD	550 (34.5)	1100 (68.5)
Phenols	0.65 (0.04)	2.18 (0.14)
Oil & Grease	12.0 (0.75)	24.0 (1.5)
pH	6.0-9.0	6.0-9.0

RECOMMENDED EFFLUENT LIMITATIONS BASED ON BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

SUBCATEGORY	EFFLUENT LIMITATION
BARKING	No discharge of waste water pollutants to navigable waters.
VENEER	No discharge of waste water pollutants

to navigable waters.

PLYWOOD

No discharge of waste water pollutants to navigable waters.

HARDBOARD - DRY

No discharge of waste water pollutants to navigable waters.

HARDBOARD - WET

	30-Day Average kg/kkg (lb/ton)	Daily Maximum kg/kkg (lb/ton)
BOD5	0.9 (1.8)	2.7 (5.4)
TSS	1.1 (2.2)	3.3 (6.6)
pH Range	6.0-9.0	6.0-9.0

WOOD PRESERVING

No discharge of waste water pollutants to navigable waters.

WOOD PRESERVING-
BOULTONIZING

No discharge of waste water pollutants to navigable waters.

WOOD PRESERVING-

	30-Day Average kg/1000 cu m (lb/1000 cu ft)	Daily Maximum kg/1000 cu m (lb/1000 cu ft)
COD	110 (6.9)	220 (13.7)
Phenols	0.064 (0.004)	0.21 (0.014)
Oil& Grease	3.4 (0.21)	6.9 (0.42)
pH Range	6.0-9.0	6.0-9.0

RECOMMENDED EFFLUENT LIMITATIONS AND NEW SOURCE PERFORMANCE STANDARDS

SUBCATEGORY — EFFLUENT LIMITATION

BARKING

A. No discharge of waste water pollutants to navigable waters for barking operations, excluding those which use hydraulic barkers.

B. For new sources using hydraulic barkers:

	30-Day Daily kg/cu m (lb/cu ft)	Daily Maximum kg/cu m (lb/cu ft)
BOD5	0.5 (0.03)	1.5 (0.09)
TSS	2.3 (0.144)	6.9 (0.431)

VENEER No discharge of waste water pollutants to navigable waters.

PLYWOOD No discharge of waste water pollutants to navigable waters.

HARDBOARD - DRY No discharge of waste water pollutants to navigable waters.

HARDBOARD - WET

	30-day Average kg/kkg (lb/ton)	Daily Maximum kg/kkg (lb/ton)
BOD5	0.9 (1.8)	2.7 (5.4)
TSS	1.1 (2.2)	3.3 (6.6)
pH Range	6.0-9.0	6.0-9.0

WOOD PRESERVING No discharge of waste water pollutants to navigable waters.

WOOD PRESERVING-BOULTONIZING No discharge of waste water pollutants to navigable waters.

WOOD PRESERVING-STEAM

	30-Day Average kg/1000 cu m (lb/1000 cu ft)	Maximum Daily Average kg/1000 cu m (lb/1000 cu ft)
COD	110 (6.9)	220 (13.7)
Phenols	0.064 (0.004)	0.21 (0.014)

Oil & Grease	3.4 (0.21)	6.9 (0.42)
pH Range	6.0-9.0	6.0-9.0

SECTION III

INTRODUCTION

PURPOSE AND AUTHORITY

Section 301(b) of the Federal Water Pollution Control 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 practicable control technology currently available and 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 selected segments of the timber products processing category.

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 intent to establish, under Section 306, standards of performance applicable to new sources within the timber products processing category.

Similar studies will be undertaken and published by the EPA in future months. Segments of the timber products processing industry to be covered at that time will include machining operations, storage of fractionalized wood, insulation board manufacture, particle board manufacture, storage operations (including log ponding and wet-decking), logging camps and contractors, saw and planing mills, prefabricated wood structures, special purpose sawmills, millwork, and other wood products not elsewhere classified.

BASIS FOR GUIDELINES DEVELOPMENT

The effluent limitations guidelines and standards of performance recommended in this report were developed in the following manner.

Both detailed and general information was obtained on the manufacturing plants identified as currently in operation. The sources and type of information consisted of:

- Applications of the Corps of Engineers for Permits to Discharge under the Refuse Act Permit Program (RAPP), obtained for exemplary plants. The RAPP applications provided data on the characteristics of intake and effluent waters, water usage, waste water treatment and control practices employed, daily production, and raw materials used.

- Internal reports furnished by the industry and various manufacturers. The information included: (a) raw materials utilized and relative amounts, (b) schematic diagrams of inplant processes (with a definition of process type) showing waste water discharge and recycle systems, (c) production rates, (d) definition of sources of waste water from inplant processes, including flow and waste water chemical composition, (e) definition of total waste water flows and chemical composition, (f) present methods of waste water handling or treatment, including schematic diagrams of treatment systems with a definition of chemical composition after each unit process of the treatment systems, (g) description of solid wastes resulting from treatment systems and the methods of handling and disposal of the wastes, (h) energy requirements per unit of production (i) inplant methods of waste water reduction or control (reuse, conservation, etc.) and, (j) effects of waste water handling on air pollution and solid waste disposal.

- On-site visits and interviews at timber products processing plants throughout the U.S.

- Other sources of information, including EPA technical reports and personnel, trade literature, industry personnel, and special consultants. References used in this study are tabulated in Section XIII.

This information was compiled by data processing techniques and analyzed for the following:

- Identification of distinguishing features that could potentially provide a basis for subcategorization of these selected portions of the timber products processing category.

- Determination of the waste water usage and waste water characteristics for each subcategory, as developed in Section IV and discussed in Section V, including (1) the source and volume of water used in the particular process employed and the source of wastes and waste waters in the plant, and (2) the constituents (including thermal) of all waste waters, including pollutants, and other constituents which result in taste, odor, and color in water or aquatic organisms.

- Identification of those constituents discussed in Section V and Section VI which are characteristic of the industry and present in measurable quantities, thus being pollutants subject to effluent limitations guidelines and standards.

- The full range of control and treatment technologies existing within each subcategory, including an identification of each distinct control and treatment technology existent or capable of being designed for each subcategory, 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.

- 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

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

The information 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, including 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 (including energy requirements), process changes, non-water quality environmental impact 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.

GENERAL DESCRIPTION OF THE INDUSTRY SEGMENT

The timber products processing category includes a broad spectrum of operations ranging from cutting and removing the timber from the forest to the processing of the timber into a wide variety of finished products, encompassing such diverse items as finished lumber, and cooked, molded, or compressed wood fibers reconstituted into a number of sheet form flexible and rigid products. The wide variety of processing steps and products in the timber products processing industry are, in many instances, similar only in the fact that the basic raw material is wood.

This development document addresses the segment of the timber products processing industry which has been estimated to be responsible for the greatest water pollution problems. The first segment of the study of the timber products processing industry includes barking, veneer manufacturing, plywood manufacturing, hardboard manufacturing, and wood preserving operations.

BARKING

Barking may be the common starting point throughout the (post harvest, transport and delivery) timber products processing industry. If barking is required, logs are taken to a barker where the bark is removed through one of several wet or dry barking procedures. The logs may be cut to required lengths before or after barking (figure 1).

Types of barking machines include (1) drum barkers, (2) ring barkers, (3) bag barkers, (4) hydraulic barkers and, (5) cutterhead barkers.

Drum barkers range in size from 2.4 to 4.9 m (8 to 16 ft) in diameter and up to 22.8 m (75 ft) in length. A drum barker consists primarily of a cylindrical shell rotating on its

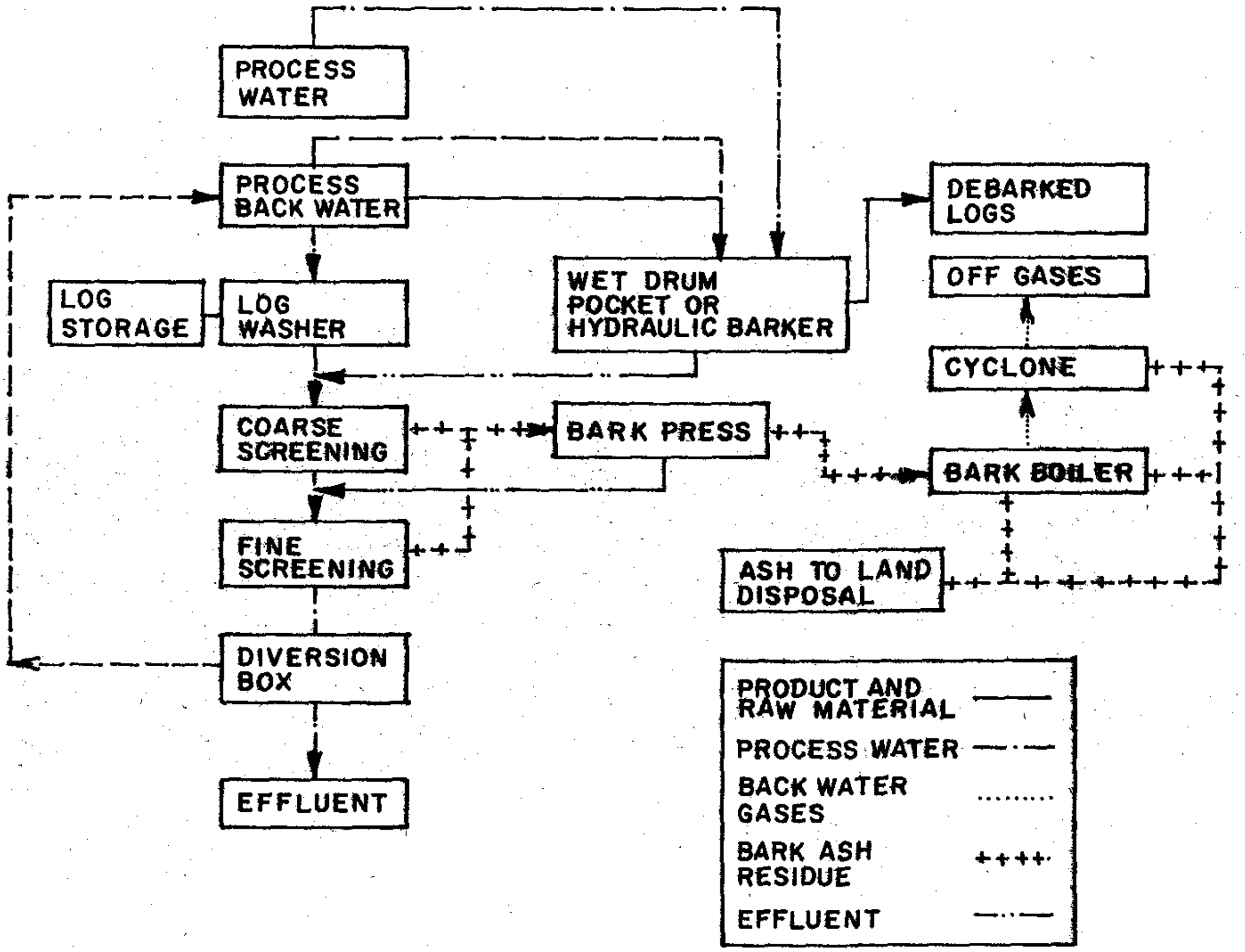


FIGURE 1 - WET BARKING PROCESS DIAGRAM

longitudinal axis. Logs are fed into one end and 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 cm (84 in) 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 described for the drum barkers.

Cutterhead barkers remove bark by the milling action of a cylindrical cutterhead as it rotates parallel to the axis of the logs which are fed through the unit. No water is employed in this operation.

The hydraulic barker uses a high pressure water jet to blast bark from a log. Pressures from 55.4 to 109.9 atm (800 to 1615 psi) are used with flow in the range of 25.2 to 101 1/sec (400 to 1600 gal/min). Because of the large volumes of low solids content water required for this operation, there is an apparent inability to recycle water from this operation, which results in a relatively large volume waste water discharge. Hydraulic barkers are slowly being phased out because of water requirements and because the large diameter logs they process are becoming unavailable.

VENEER AND PLYWOOD

Plywood is an assembly of layers of wood (veneer) joined together by means of an adhesive. It is a multi-use material characterized by its ability to be designed and engineered for construction and 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 is generally used for construction and structural purposes, and the veneers are of wood from coniferous or needle bearing trees.

Raw Materials

A great assortment of woods are utilized in the manufacture of veneers. A high percentage of veneer produced in the northwestern U.S. is manufactured from Douglas fir, with lesser quantities of veneer made from ponderosa pine and hemlock. In the southeast U.S., southern pine is the predominant raw material. Veneer is classified as softwood or hardwood. Softwood veneer is manufactured on the west coast, in the Rocky Mountain region, and in the southeastern U.S.. The species that are used in the western U.S. 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 U.S. are beech, birch, maple, basswood, red gum, yellow poplar, cottonwood, tupelo, sycamore, oak, walnut, lavan, elm, cherry, hickory, pecan, cativo, teak, rosewood, and mahogany.

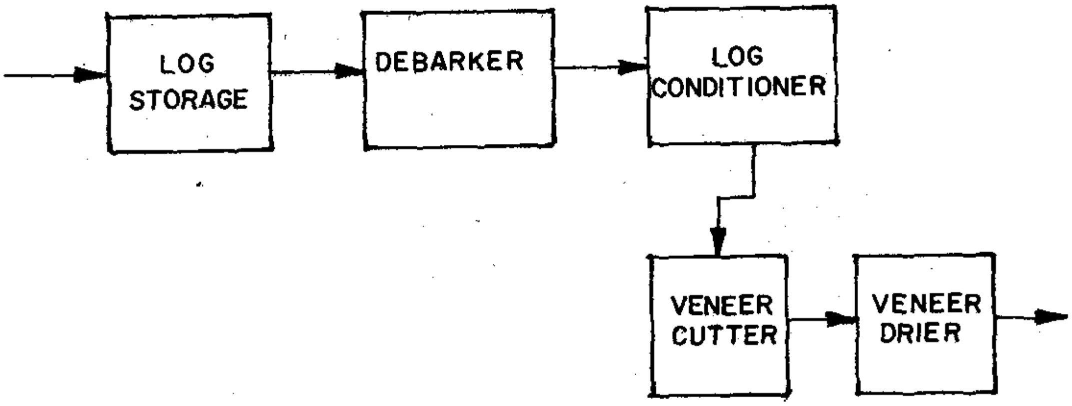
Softwood veneer is almost exclusively used in the manufacturing of softwood plywood. Small quantities are used as center stock and cross-banding for panels made with hardwood faces. Hardwood veneer uses can be categorized as (1) face veneer, (2) commercial veneers, and (3) veneers for containers. Face veneers are of the highest quality and are used to make plywood panels employed in the manufacture of furniture and interior decorative panels. There are more than 50 such manufacturers throughout the eastern U.S.. 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.

Plywood is manufactured in 36 states. The majority of softwood plywood is produced on the Pacific Coast while the majority of the hardwood plywood is manufactured in the southeastern states. The hardwood plywood industry is made up of a large number of small factories distributed widely over the eastern U.S..

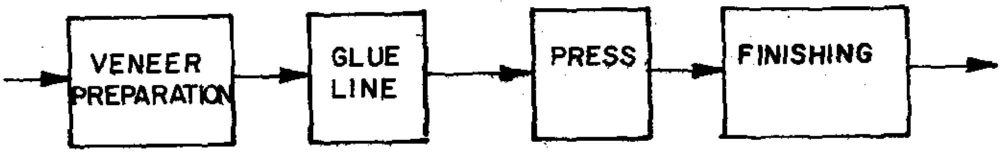
Manufacturing Process

The various operations for converting roundwood into veneer and finally into plywood are chiefly mechanical. A simplified process flow diagram for the production of veneer and plywood from roundwood is shown in Figure 2. A detailed flow diagram o the veneer and plywood manufacturing process is shown in Figure 3.

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. Prior to the cutting of veneer, logs may be heated, or "conditioned"; this serves to improve the cutting properties of wood, particularly hardwood. Historically, both hardwood and softwood mills have practiced log conditioning. There was in recent years a trend away from log conditioning in the softwood industry, but the current trend is again toward this practice.



VENEER OPERATION



PLYWOOD OPERATION

FIGURE 2 - SIMPLIFIED PROCESS FLOW DIAGRAM FOR VENEER AND PLYWOOD PRODUCTION

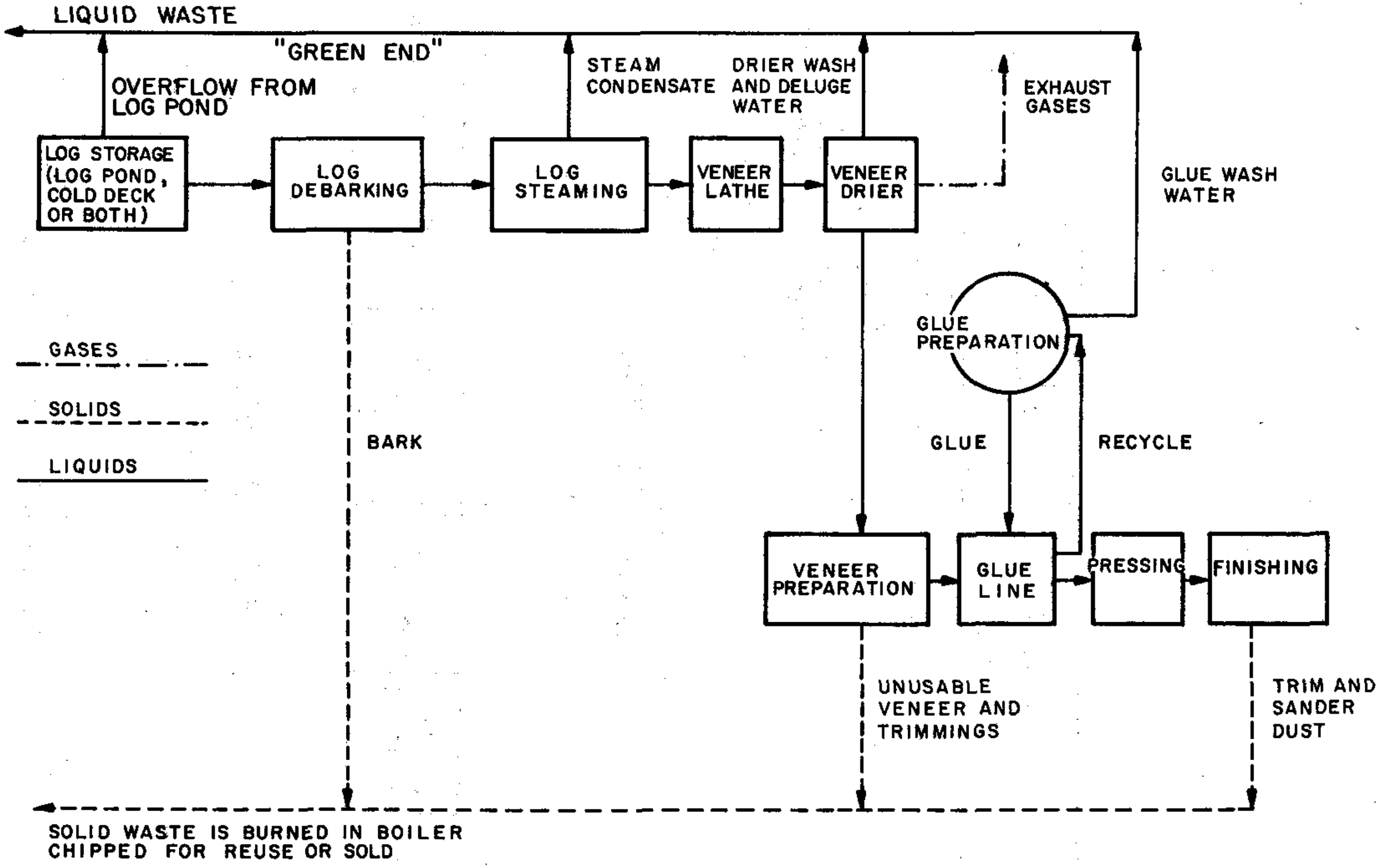


FIGURE 3 - DETAILED PROCESS FLOW DIAGRAM FOR VENEER AND PLYWOOD

When conditioning of logs occurs not only prior to veneering, but prior to debarking, it facilitates the barking operation. This has been a common practice in the past. With the increasing use of ring and cutterhead barkers whose operations are not aided by prior heating, heating commonly occurs between the barking 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 by (2) 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, and 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, such as poplar, bass wood, cottonwood, and certain conifers, can be cut satisfactorily without such conditioning.

Veneer Cutting

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

Currently more than 90 percent of all veneer is rotary cut. In this method of cutting, a log or "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 a thin sheet of veneer is peeled from the log as it turns. Lathes capable of peeling logs from 3.66 to 4.88 m (12 to 16 ft) in length are not uncommon, but more often veneer is cut in lengths ranging from 0.61 to 2.4 m (2 to 8 ft). The bolts that are to be veneered are usually cut from 10 to 15 cm (4 to 6 in) longer than the width of veneer to be cut from them.

Most slicers consist of a stationary knife. The section of a log or "flitch" to be cut is attached to a log bed which moves up and down, and 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 small quantity of veneer is cut by sawn veneering. A circular type saw with a thin, segmented blade, called a segment saw, turns on an arbor. The thin blade reduces the wastage or 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 0.254 to 9.54 mm (1/10 to 3/8 in). Most of the rotary cut veneers are either 3.6, 3.2, 2.5, 1.7, or 1.3 mm (1/7, 1/8, 1/10, 1/ 15, or 1/20 in) thick. Sliced veneer usually ranges from 1.27 to 0.635 mm (1/20 to 1/40 in). Sawn veneers vary from 6.35 to 0.795 mm (1/4 to 1/32 in) in thickness.

After rotary veneers are cut, they may go directly to a clipper or they may be stored temporarily on horizontal storage decks or on reels. Usually the veneer coming from the lathe is cut to rough green size, and defects are removed at the green clipper. From here the veneers are conveyed to the dryers.

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 rapidly, and veneers are usually dried to a moisture content of less than 10 percent. This is a level compatible with gluing, and consistent with the moisture content to which plywood products will be exposed while in service.

Several methods for drying veneers are in use. The most common type of dryer is a long chamber equipped with rollers on belts which advance the veneer longitudinally through the 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 or 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 or repair the veneer stock. These operations may include grading and matching, redrying, dry-clipping, jointing, taping and splicing, and inspecting. These operations are self-descriptive and completely mechanical or manual except for jointing and splicing which may use some sort of adhesive. 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 and is thermoplastic, while the other two are synthetic, thermosetting glues. Typical ingredients of protein glues are water, dried blood, soya flour, lime, sodium silicate, caustic soda and a formaldehyde doner for thickening. Typical ingredients of urea-formaldehyde glues are water, defoamer, extender (wheat flour) and urea formaldehyde resin. Typical ingredients of phenol-formaldehyde glues are water, furafil, wheat flour, phenolic formaldehyde resin, caustic soda and soda ash.

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 urea-formaldehyde, but it is waterproof and is practically the only glue used to make exterior plywood. Phenol-formaldehyde, is being increasingly used to produce both interior and exterior plywood so that the use of phenolformaldehyde is increasing rapidly. Table 1 shows the breakdown 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. However, while cold pressing is a simpler and cheaper operation, it is only satisfactory for interior plywood.

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

TABLE 1

CURRENT AND PROJECTED ADHESIVE CONSUMPTION IN THE PLYWOOD INDUSTRY

	(Millions of Kilograms)					
	1965			1975		
Plywood Type	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	--

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 more recent spray curtain-coater glue applicators require less washing than the conventional rollers.

Pressing

After gluing, the layers of veneer are subjected to pressure to insure proper alignment and an intimate contact between the wood layers 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 some protein and 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 atm (75 to 250 psi). Cold presses are operated at room temperatures, while hot presses are operated at temperatures ranging to 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. Usually, 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 questionable whether this method of heating is economically worthwhile, however. It is technically applicable for curing the resin in 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, may be taken. These operations include (1) redrying, (2) trimming, (3) sanding, (4) sorting, (5) molding and (6) storing.

Inventory of Veneer and Plywood Manufacturers

There are approximately 500 veneer and plywood mills in the U.S., 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 U.S.. Hardwood and softwood mills are located according to availability of raw materials, and their

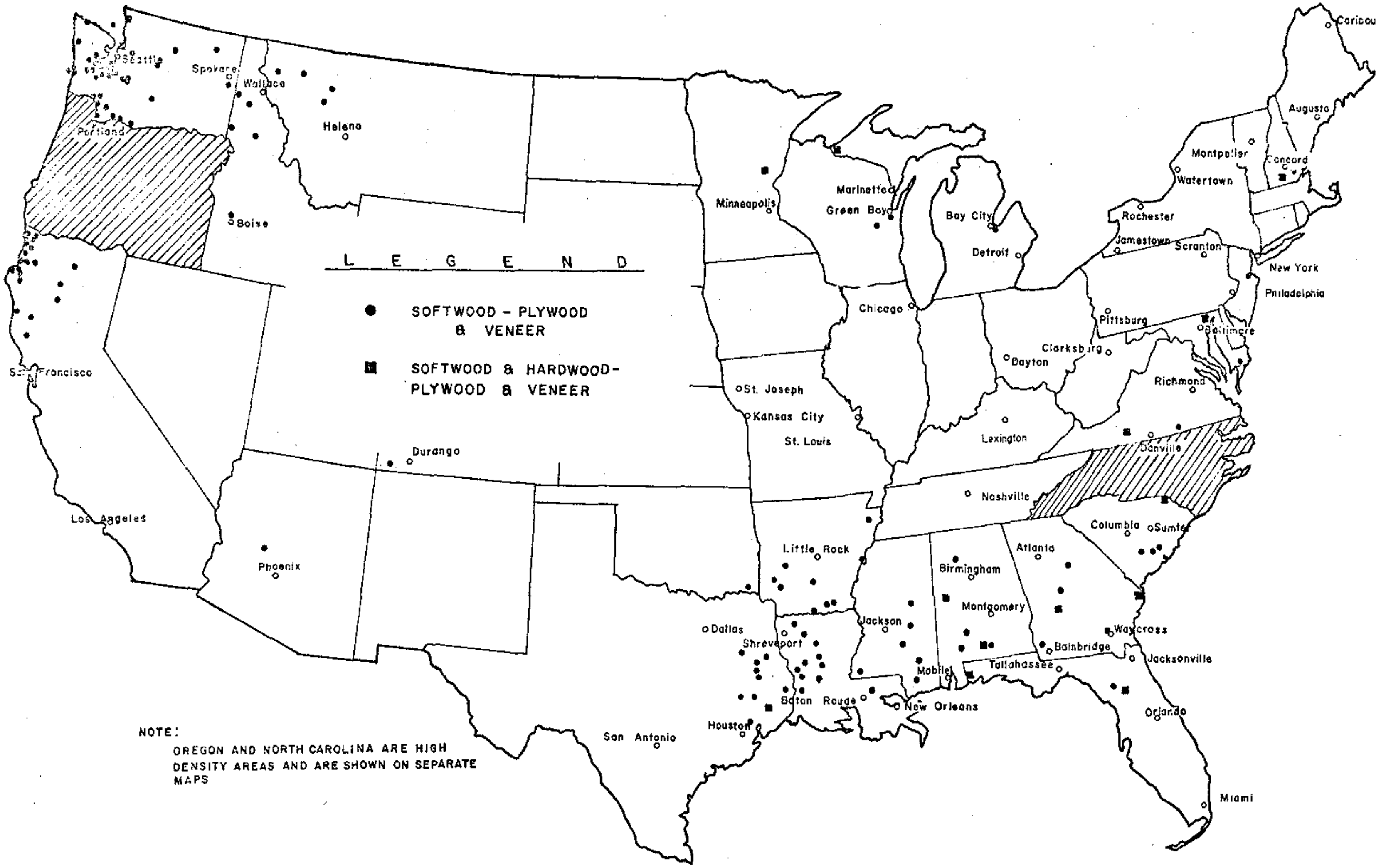
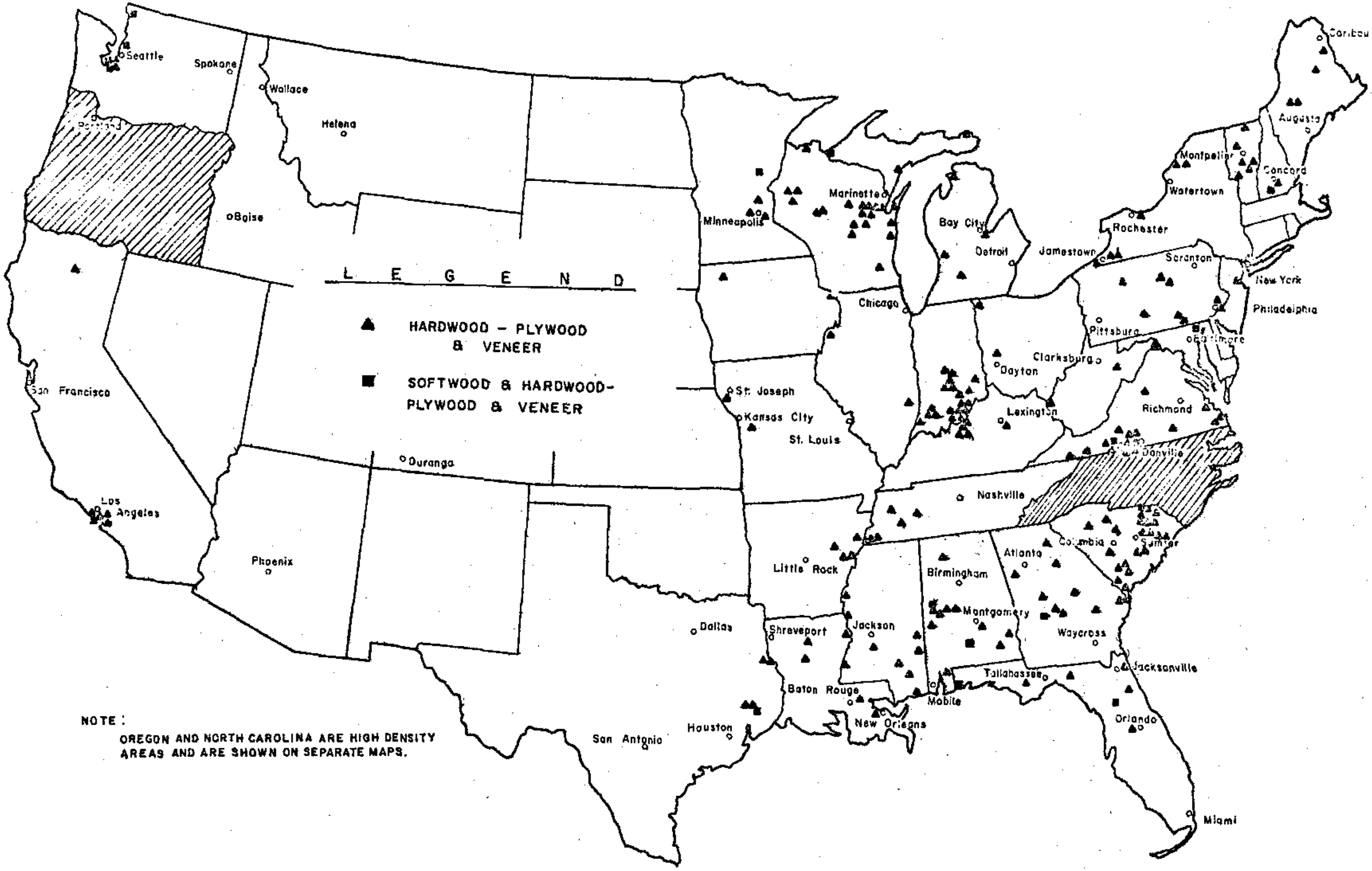


FIGURE 4 - DISTRIBUTION OF SOFTWOOD VENEER AND PLYWOOD MILLS THROUGHOUT THE UNITED STATES



NOTE:
OREGON AND NORTH CAROLINA ARE HIGH DENSITY AREAS AND ARE SHOWN ON SEPARATE MAPS.

FIGURE 5 - DISTRIBUTION OF HARDWOOD VENEER AND PLYWOOD MILLS THROUGHOUT THE UNITED STATES

TABLE 2

SUMMARY OF VENEER AND PLYWOOD PLANTS IN THE UNITED STATES

SOFTWOOD PLYWOOD	
Alabama	6
Arizona	1
Arkansas	8
California	15
Colorado	1
Florida	2
Georgia	5
Idaho	5
Louisiana	12
Maryland	1
Michigan	2
Mississippi	6
Montana	4
New Hampshire	1
North Carolina	6
Oklahoma	1
Oregon	81
South Carolina	3
Texas	9
Virginia	1
Washington	29
TOTAL	199

SOFTWOOD VENEER	
Arkansas	1
California	8
Florida	1
Georgia	1
Maryland	1
Minnesota	1
New Jersey	1
North Carolina	6
Oregon	31
South Carolina	1
Texas	1
Virginia	1
Washington	9
Wisconsin	2
TOTAL	65

TABLE 2 CONTINUED

HARDWOOD PLYWOOD		HARDWOOD VENEER	
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	16	Wisconsin	4
TOTAL	157	TOTAL	107

TABLE 2 CONTINUED

SOFTWOOD & HARDWOOD PLYWOOD	
Alabama	2
Florida	1
Michigan	1
New Hampshire	1
North Carolina	1
Oregon	3
South Carolina	1
Texas	1
Washington	4
TOTAL	16

SOFTWOOD & HARDWOOD VENEER	
Florida	1
Georgia	1
Minnesota	1
North Carolina	3
Oregon	3
Virginia	1
TOTAL	11

TOTAL PLYWOOD PLANTS - 340
TOTAL VENEER PLANTS - 161

distribution, therefore, follows the timber distribution as shown in Figure 7. A summary inventory of the mills in the U.S. 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 U.S. was about 1.4 billion sq m on a 0.953 cm basis (15 billion sq ft on a 3/8 in basis), while that of hardwood plywood was slightly more than 186 million sq m on a 0.635 cm basis (2 billion sq ft on a 1/4 in basis). Included in Table 3 are statistics from the 1968 survey. More recent data collected as a result of correspondence with the industry association show that in 1972, softwood plywood production was 1.71 billion sq m on a 0.953 cm basis (18.3 billion sq ft on a 3/8 in basis), that of hardwood plywood was estimated as 205 million sq m on a 0.635 cm basis (2.2 billion sq ft on a 1/4 in basis).

During the decade 1950-1960, the world's production of plywood rose by 150 percent. The U.S. accounted for about 50 percent of the world's plywood production. More important, however, is that the U.S. 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 U.S. was produced in the Pacific Northwest from Douglas fir. In the past ten years the industry has expanded into the southeastern U.S. and the use of southern pine now accounts for 30 percent of the Nation's softwood plywood production (Table 4).

Hardwood plywood production has remained fairly constant over the past 20 years (Tables 5 and 6, and Figure 8).

HARDBOARD

Hardboard is a generic term for a panel manufactured primarily from interfelted ligno-cellulosic fibers consolidated under heat and pressure in a hot press to a density of 0.5 g/cu cm (31 lb/cu ft) or greater. Other materials may be added to improve certain properties, such as stiffness, hardness, finishing properties, resistance to abrasion and moisture, as well as to increase strength, durability and utility.

There are two major hardboard manufacturing processes 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. Air serves that function in the dry process. The hardboard industry in the U.S. developed from a defiberization process originated by William H.

TABLE 3

FOREST INDUSTRIES 1968 PLYWOOD STATISTICS

Region	Number of Softwood Plywood Plants	Softwood Plywood Production In Square meters (9.53 mm Basis)	Number of Hardwood Plywood Plants	Hardwood Plywood Production In Square meters (6.35 mm - Basis)
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	175	1,411,500,000	205	197,750,000

TABLE 4

SOFTWOOD PLYWOOD PRODUCTION FOR 1972

State	Sq. Meters-9.53 mm Basis
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

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

TABLE 6

SOFTWOOD PLYWOOD PRODUCTION IN THE UNITED STATES

Year	Sq. Meters Surface Areas	No. of Plants
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	--

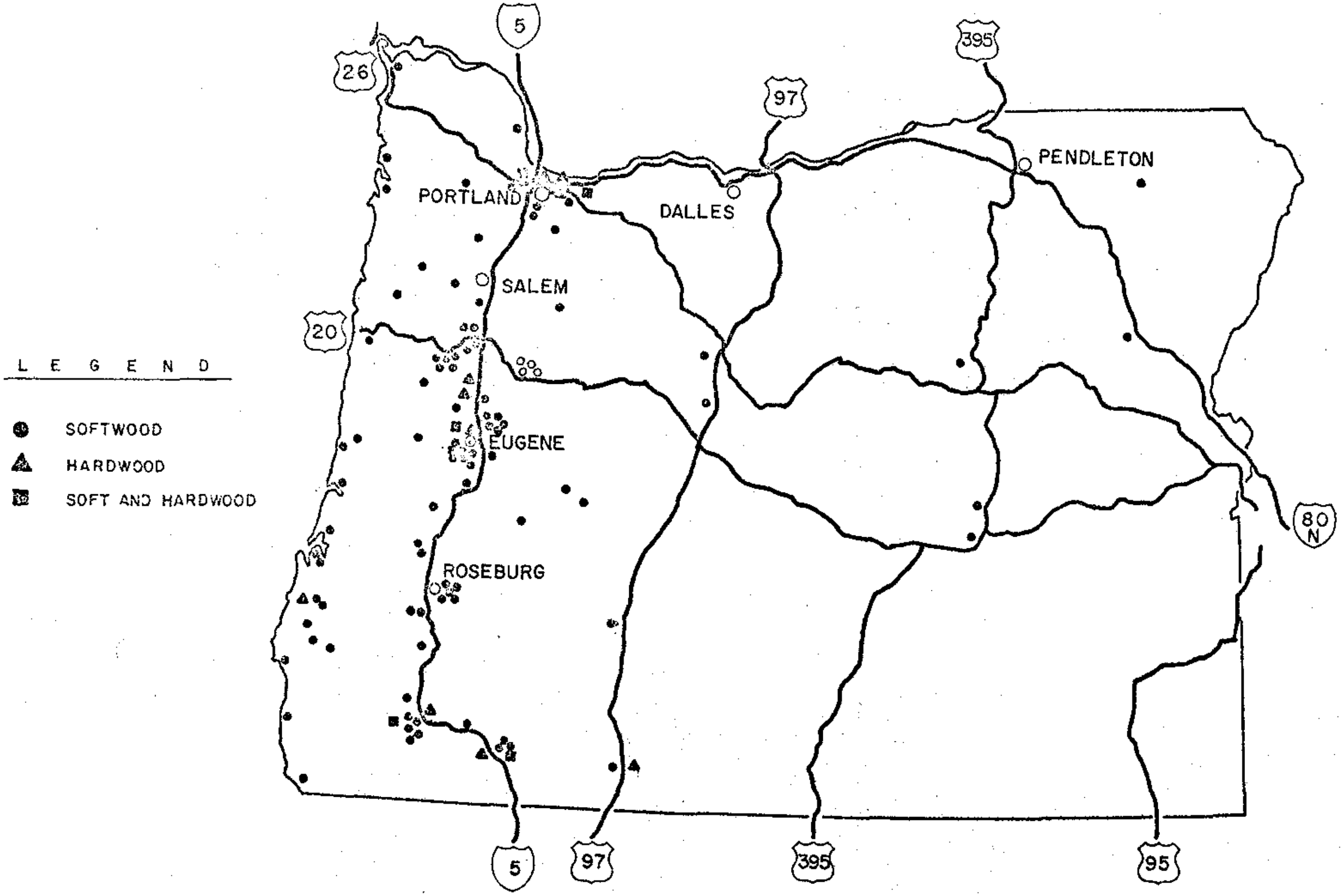


FIGURE 6 - DISTRIBUTION OF VENEER AND PLYWOOD MILLS IN THE STATE OF OREGON

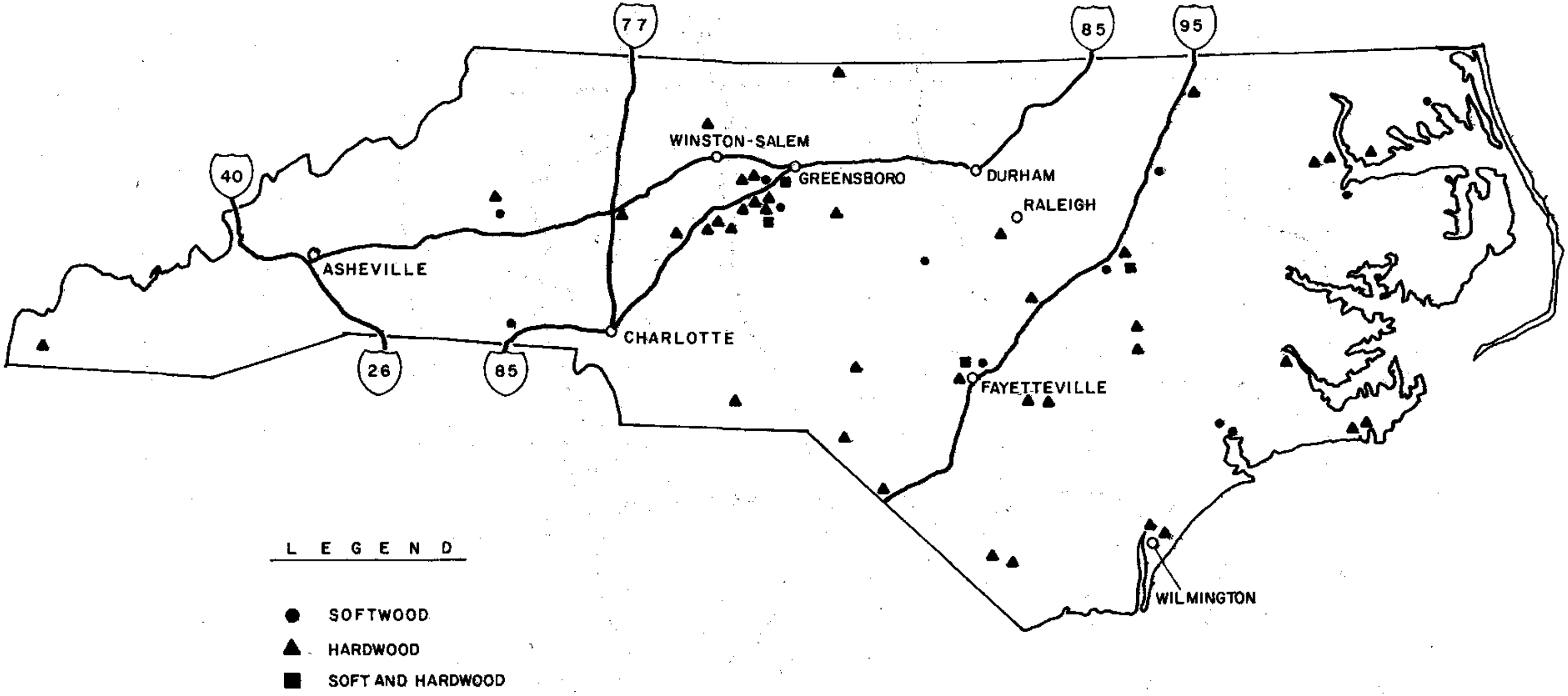


FIGURE 7- DISTRIBUTION OF VENEER AND PLYWOOD MILLS IN THE STATE OF NORTH CAROLINA

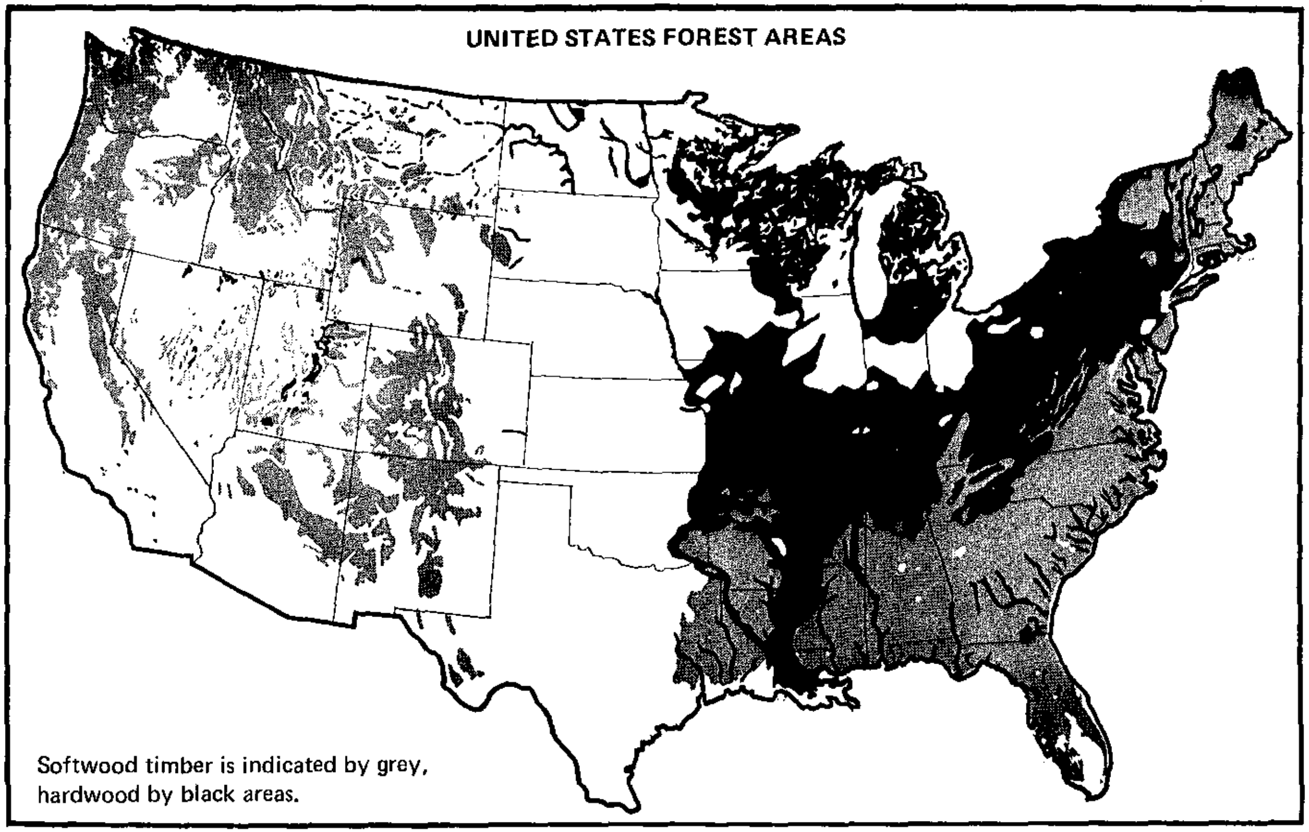


FIGURE 8 - UNITED STATES FOREST AREAS

Mason during the 1920's. It was the prototype of wet process hardboard. Other methods of fiber preparation were later developed. 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.

Fiber preparation in the dry process is similar to that in the wet process. After fiber preparation, water is removed 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 and in one mill any water added is evaporated in the pressing operation.

Process Description

The raw material for hardboard production is essentially all wood. This wood may be in the form of round wood, wood chips 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 9.

Figure 10 shows a typical process diagram of a dry process hardboard mill and Figure 11 shows a typical inplant process diagram of a wet process hardboard mill. The principal difference between the two processes is the manner in which the fibers are carried and formed into a mat.

Chipping

Logs or wood scraps must be either processed to chips at the hardboard manufacturing plant 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 control size. Screens may be of the rotating, vibrating, or gyrating types with vibrating and gyrating screens being the most common.

Chips are stockpiled in the open, under a roof, or enclosed in chip silos. As least one mill presently washes chips to remove dirt and other trash which would cause maintenance problems in the fiber preparation stages. The quantity of dirt in chips depends upon many factors. In the future, hardboard mills project utilizing the complete tree, including bark, limbs, and leaves, which will cause additional dirt to be brought in with the chips. There is a general industrial trend toward use of lower quality fiber because of the increased demand for timber

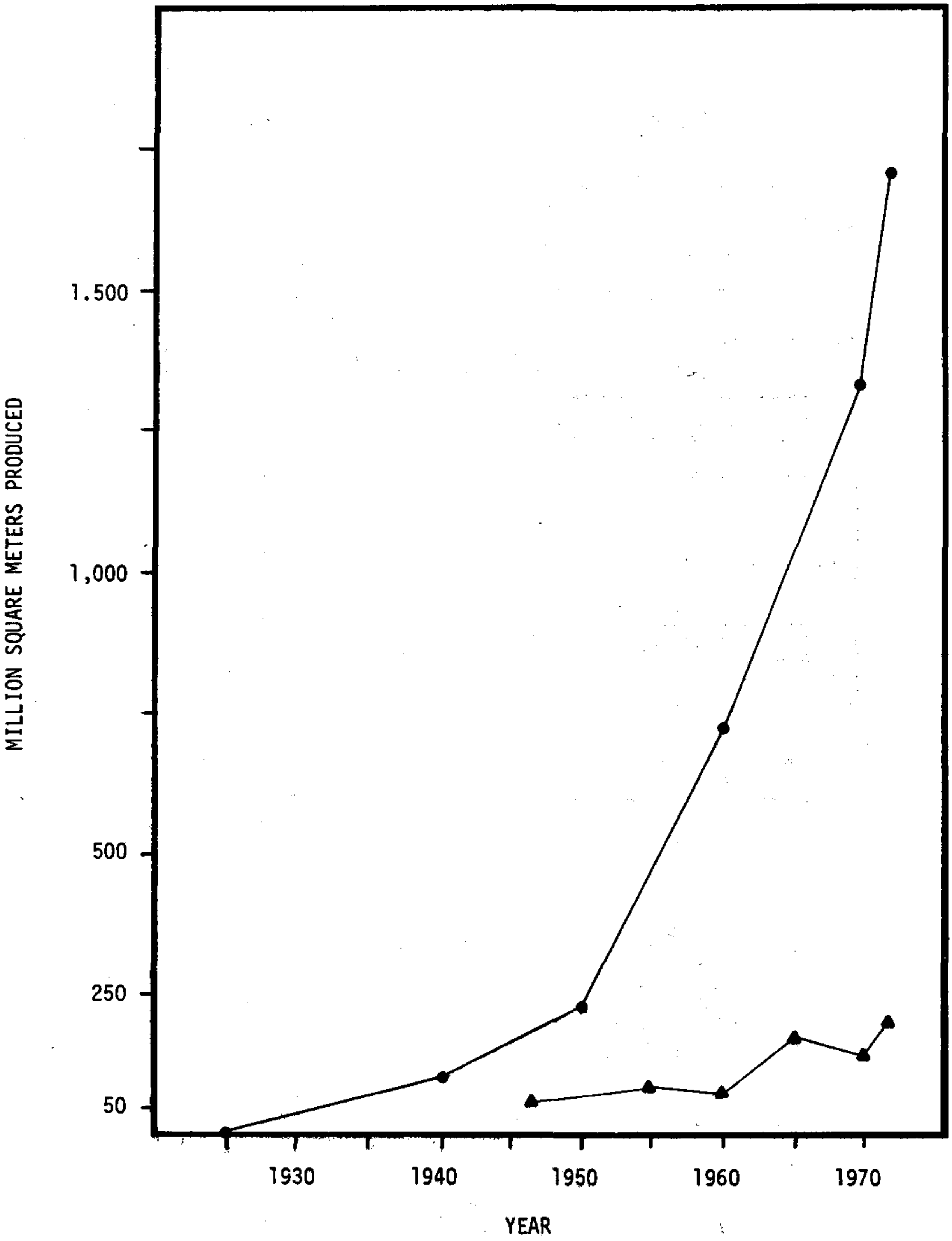


FIGURE 9 - GROWTH OF THE PLYWOOD INDUSTRY IN THE UNITED STATES

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

● - HARDWOOD PLYWOOD PRODUCTION ON A 6.35mm (1/4") BASIS

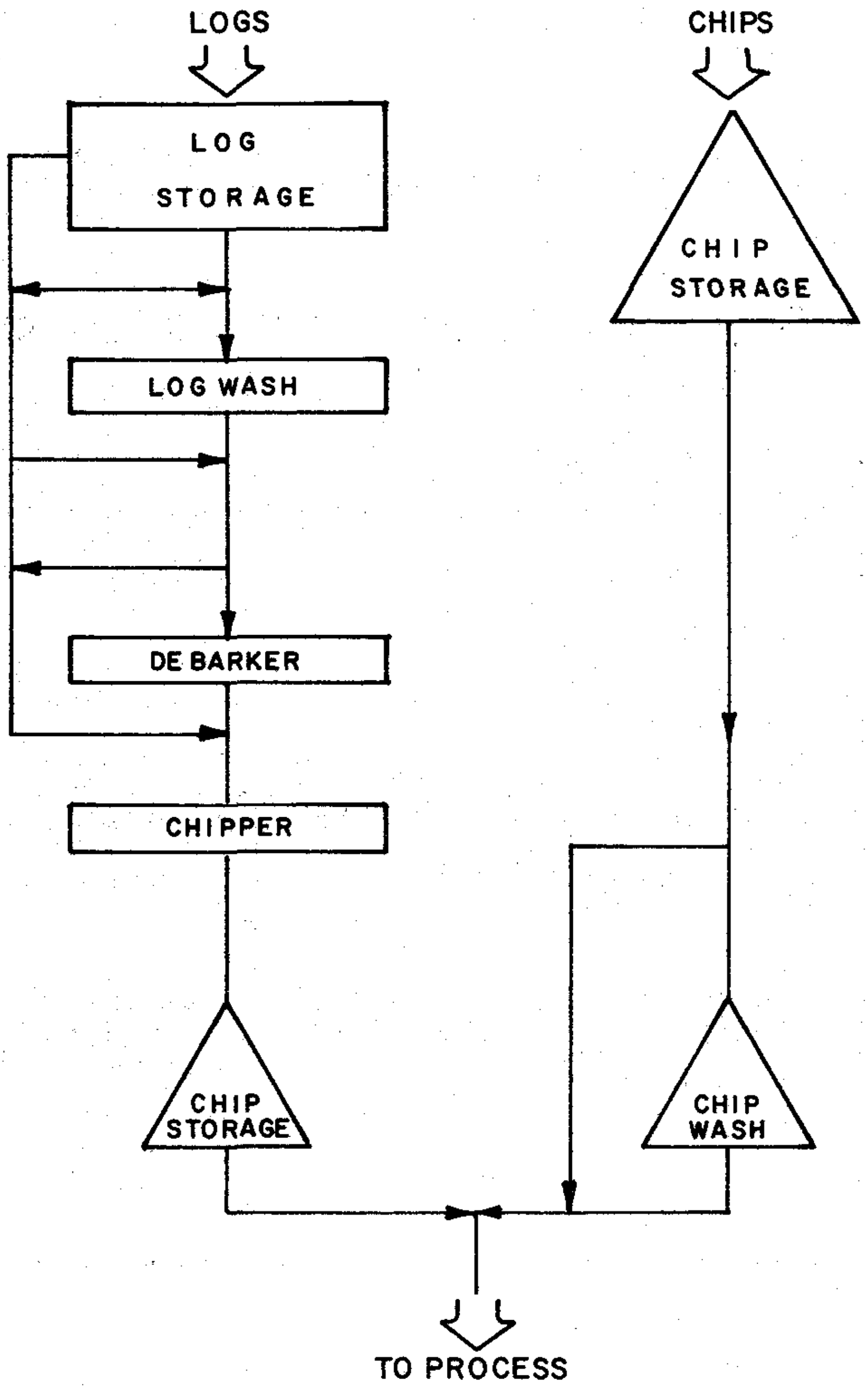


FIGURE 10 - RAW MATERIAL HANDLING IN THE HARDBOARD INDUSTRY

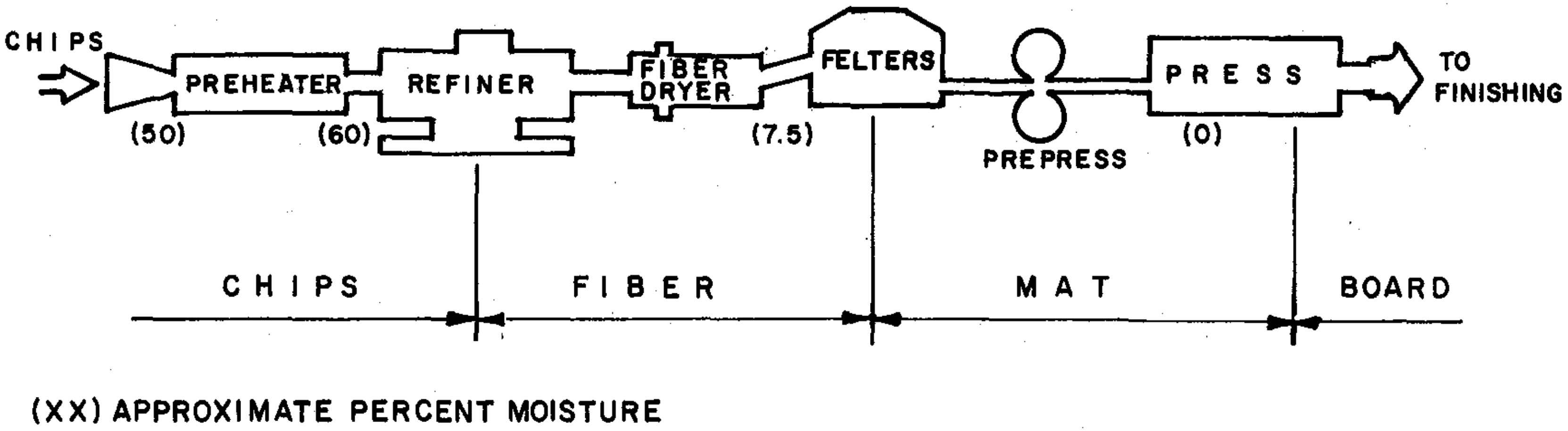


FIGURE 11 - TYPICAL DRY PROCESS HARDBOARD MILL

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. Weather conditions during logging operations have a significant effect upon quantity of dirt picked up. Chip washing is also useful in thawing frozen chips in more northern climates.

Fiber Preparation

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. This pre-treatment operation is carried out in digesters under a variety of conditions of time and temperature.

There are two basic methods of fiber preparation, but a wide range of variations exist within each basic method. These two basic methods are the (1) explosion process, and (2) thermal plus mechanical refining.

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. 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 lignocellulosic material. Chips approximately 1.9 cm (3/4 in) square, prepared in conventional chippers and screened, are fed into 50.8 cm (20 in) caliber guns or high pressure vessels. Each vessel is filled and closed, and the chips are steamed to 41.8 atm (600 psi) for about one minute. The pressure is then quickly raised to about 69.0 atm (1000 psi), at 285°C (550°F) and held for about 5 seconds. The time of treatment at this high pressure is critical, and is dependent upon the species and the desired quality of the product. The pressure is suddenly released, and the wood chips burst into a brown, fluffy mass of fiber. The steam is condensed as it enters the cyclone 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 pulping procedures, largely as a result the hydrolysis of hemicellulosic material under conditions of steaming at high pressure. The explosion process is used in only two hardboard mills in the U.S..

By far the most widely used fiber preparation method consists of a combination of thermal and mechanical pulping. 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 wood 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 many possibilities of variation in pre-steaming, of plate pattern, of plate clearances, and in a number of refining steps, there is considerable flexibility in the production of pulps which possess 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, coarse fiber bundles and few abraded fibers.

In one process the chips are brought to a temperature of 170°C to 190°C (340°C to 375°F) in a period of 20 to 60 seconds by means of steam pressure between 7.8 and 12.2 atm (100 to 165 psi) and at this temperature are passed through a disc refiner. It is claimed that because to the short steaming period, little hydrolysis takes place and that there is little loss of wood substance, the yield ranging from 90 to 93 percent.

In the dry process, similar equipment can be used. However, the wood may be subjected to lower steam pressures of 3.1 to 9.2 atm (31 to 220 psi) for somewhat longer periods (1 to 2 min) 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.

Refiners (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 60 to 100 cm (23 to 40 in) in diameter and operate at 400 to 1,200 revolutions/min.

Double disc attrition mills, with the discs rotating in opposite directions, do more work on the fiber and result in a higher stock temperature. Such equipment, when operating on wood chips, produces well fiberized material. Where development of 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, plate design, plate clearance, rate of feed, consistency, temperature, and speed of rotation. The effect of these variables can only be determined by experiment. Plate clearances usually vary from 1.30 mm (0.050 in) 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. Also because of the production of more fines, however, the rate of drainage is reduced. An improved quality of stock may be obtained by using a plate clearance of about 0.25 mm (0.01 in), 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 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 kw/kkg (100 to 400 hp/ton) depending on species and pre-treatment.

The consistency of pulp leaving the attrition mill in a wet process hardboard mill may vary over a wide range, but in general it is between 30 and 40 percent. 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, the pulp 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.

There are various attrition mills on the market for the preparation of pulp. The Asplund system 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 kkg/day (10 to 50 ton/day) of dry wood, 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 necessary a vibrating or rotary-type screen may be used.

Forming Hardboard

The manufacture of hardboard consists basically of reducing wood materials to the fibrous state 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 the pulp which increase 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 (wet matting) process or the air-felting (dry matting) process.

Wet-Felting: In the wet process the mat is usually formed on a fourdrinier type machine similar 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 by weight. The stock flows rapidly and smoothly from the head box onto an endless traveling wire screen. 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 table rolls carry stock onward for about 9 m (27 ft) while water is withdrawn through the wire screen. The water is first removed by gravity. As the screen advances, additional water is removed when it passes over one or more suction boxes. At this point, the 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. More water is removed as the press rollers gradually apply pressure to the wetlap, in a process which is similar to the wringing action of a washing machine.

When the wetlap emerges from press rollers it still has a high moisture content (50 to 75 percent), yet it is strong enough to support its own weight over a small span. At this point, it leaves the forming screen and continues on a conveyor. The wet mat is then trimmed to width and cut off to length by a traveling saw which moves across the traveling 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. 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 air-feltingor dry matting process, and the wet-felting process is that in the dry process fibers are suspended in air rather than in water. The unit developed for laying down a continuous mat of dry fibers is called a felter. The prepared fibers are fed by volumetric feeders to the felting unit at a controlled rate. A nozzle in the unit then distributes fibers to the top of the felter chamber and the fibers fall to the floor of the felter. This snowing action produces an interwoven mat of fibers.

The floor of the felter is a moving screen which is synchronized with the volumetric feeders, and 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 0.32 cm (1/8 in) is desired, the height of the mat as it emerges from the felting chamber may be as much as 10 to 15 cm (4 to 6 in). 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

When the reassembly of wood particles is completed, fibers are welded together into a tough, durable grainless board, on the hardboard press. Hardboard presses are massive, consisting of heavy steel heads and bases, each of which may weigh 45 kkg (50 ton) or more, held together by steel columns 25 to 30 cm (10 to 12 in) in diameter and as long as 9 to 12 m (30 to 40 ft). 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 bond 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 cm (3 to 10 in) 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 103 atm (500 to 1500 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 m by 4.9 m (4 ft by 16 ft), 1.2 m by 2.4 m (4 ft by 8 ft), 1.2 m by 5.5 m (4 ft by 18 ft), and 1.5 m by 4.9 m (5 ft by 16 ft). The first press size is the most common production size.

The combination of heat and pressure applied to mats in the press welds the fibers together. The actual amount of time required for pressing and the details of temperature and pressure vary widely, depending on 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 Operations: 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 2 or 3 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 by 4.9 m) 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. Once in the press however, the combination of heat, pressure, and time consolidates the soft, fluffy material into a rigid, durable product.

Oil Tempering

After being discharged from the press, hardboard may 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 increase absorption of the oils and removes any excess. The oil is then stabilized by baking the sheet from one to 4 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

Sheets of hardboard removed from the press or the tempering oven are very hot and dry, and 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.

Further Processing

The final operation includes trimming the board to the required size. Hardboard may also be finished by an assortment of techniques, including simulating wood grain finishes, applying paint for a variety of uses, embossing, and scoring.

Inventory of Hardboard Industry

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 6 insulation board plants, but the waste water aspects of these will be considered along with that segment of the timber products processing category. It has been estimated that in 1972, the total production of hardboard in the U.S., on a 3.2 mm (1/8 in) basis, was 0.54 billion sq m (518 billion sq ft). The geographical distribution of the hardboard industry is shown graphically in Figure 12.

From the viewpoint of total utilization of the forest resource, those segments of the timber products processing category which are relatively indiscriminant 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 residues 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. 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 0.32 cm (1/8 in) basis increased from 0.09 billion sq m (0.96 billion sq ft) in 1948 to 0.14 billion sq m (1.5 billion sq ft) in 1955. In 1968, 27 hardboard plants in the U.S. produced approximately 0.39 billion sq m (4.2 billion sq ft) of product. During the first part of 1973, plans for 3 new dry process plants were completed and construction was begun.

A U.S. Forest Service survey published in 1964, based on information collected in 1962, established that the amount of timber consumed in the U.S. has increased to 0.37 billion cu m (13 billion cu ft) annually. It projected a demand of 0.79 billion cu m (28 billion cu ft) 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 sq m (10 billion sq ft) by 1980. Ten plants with an annual capacity of 39 million sq m (420 million sq ft) each would have to be completed to meet this demand.

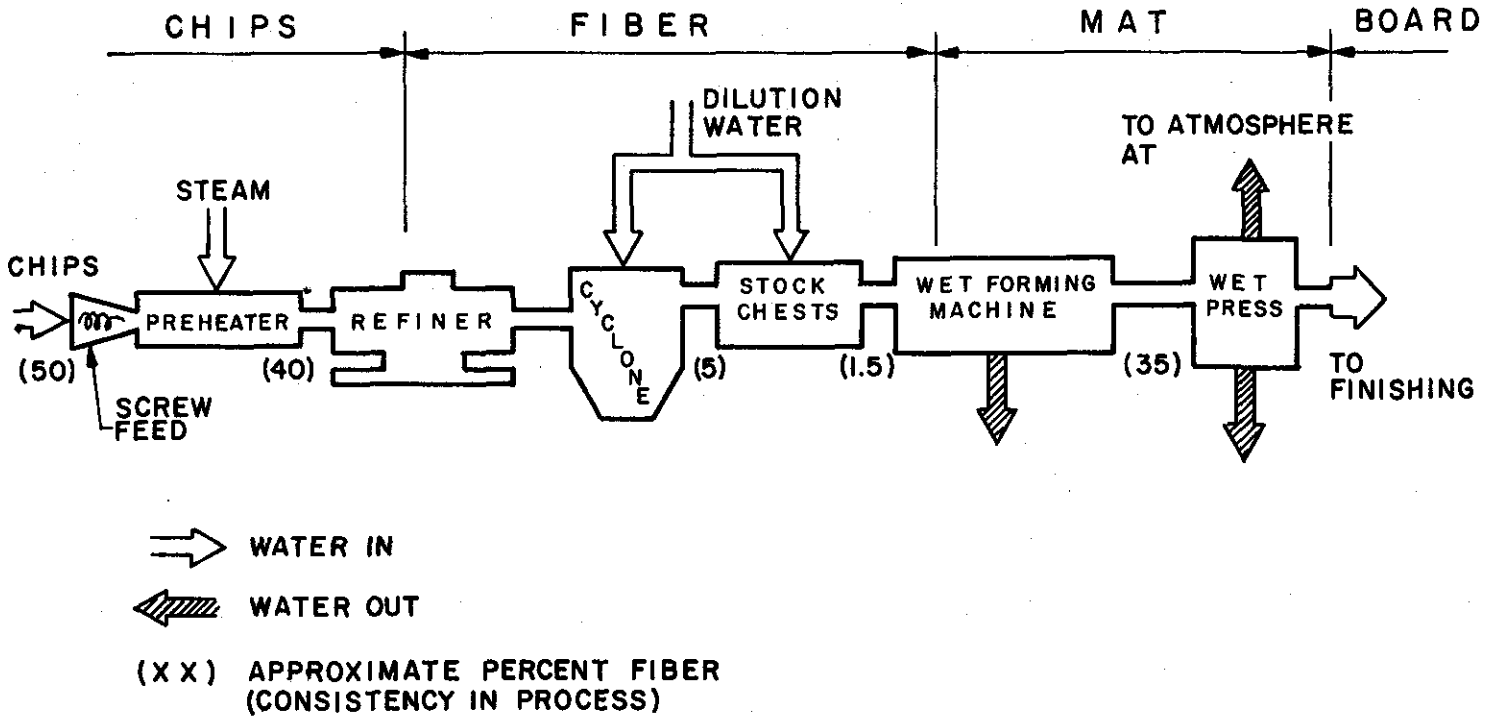


FIGURE 12 - TYPICAL WET PROCESS HARDBOARD MILL

TABLE 7

INVENTORY OF HARDBOARD MANUFACTURING FACILITIES

DRY PROCESS

Anacortes Veneer
Anacortes, Washington

Celotex Corporation
Deposit, New York

Celotex Corporation
Marion, South Carolina

Celotex Corporation
Paris, Tennessee

Evans Products
Doswell, Virginia

Evans Products
Moncure, North Carolina

Evans Products
Phillips, Wisconsin

Georgia-Pacific Corporation
Coos Bay, Oregon

Georgia Pacific Corporation
Conway, North Carolina

Masonite Corporation
Spring Hope, North Carolina

Masonite Corporation
Towanda, Pennsylvania

Pope and Talbot
Oakridge, Oregon

Superwood (Nu-Ply)
Bemidji, Minnesota

U.S. Plywood
Champion International
Catawba, South Carolina

U.S. Plywood
Champion International
Lebanon, Oregon

Weyerhaeuser Company
Broken Bow, 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

TABLE 7 CONTINUED

(INVENTORY OF HARDBOARD MANUFACTURING FACILITIES)

Masonite Corporation
Laurel, Mississippi

Masonite Corporation
Ukiah, California

Superior Fibre
Superior, Wisconsin

Superwood
Duluth, Minnesota

Superwood
North Little Rock, Arkansas

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

Temple Industries
Diboll, Texas

U.S. Gypsum
Danville, Virginia

U.S. Gypsum
Greenville, Mississippi

U.S. Gypsum
Pilot Rock, Oregon

Weyerhaeuser Company
Broken Bow, Oklahoma

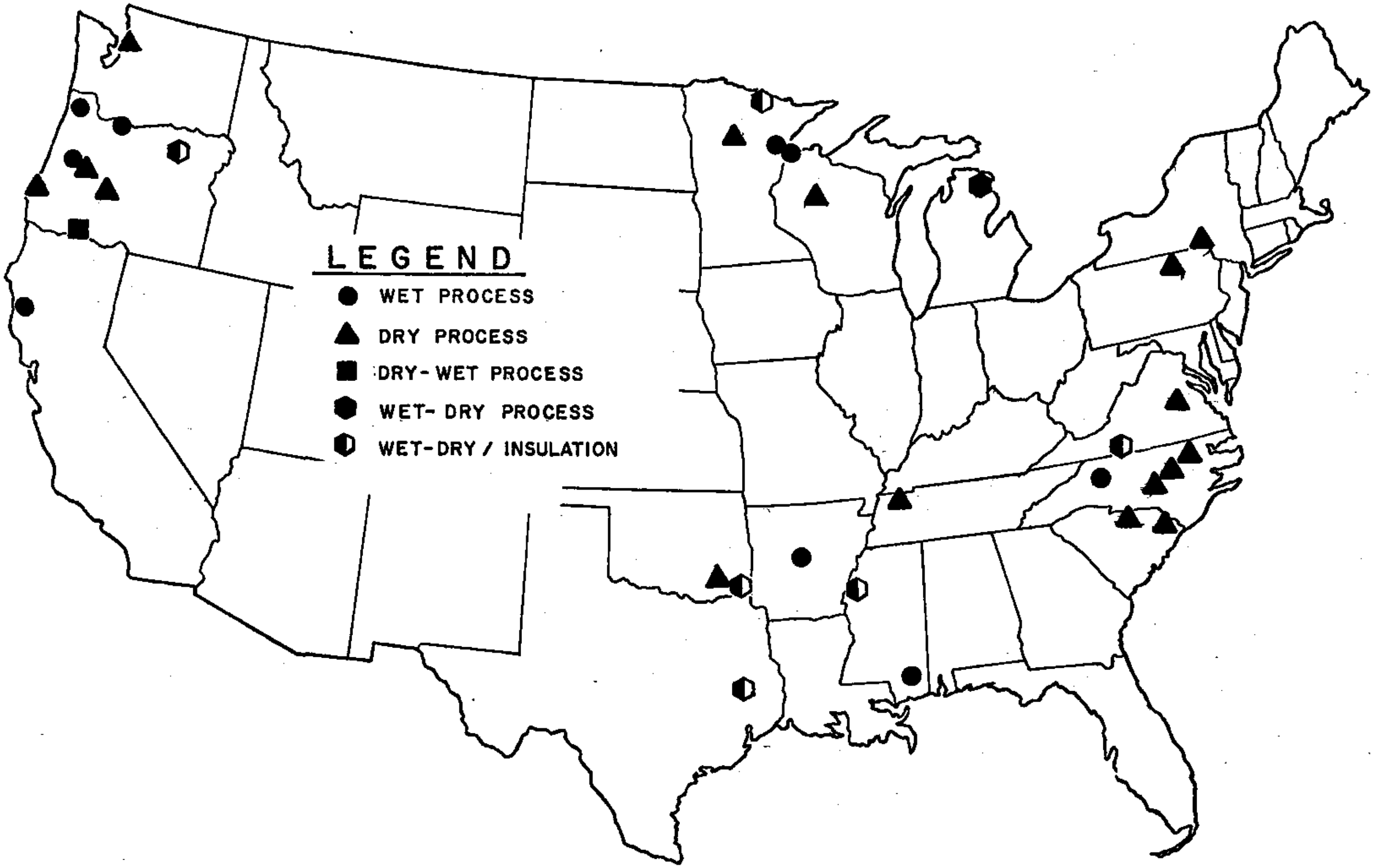


FIGURE 13 - GEOGRAPHICAL DISTRIBUTION OF HARDBOARD MANUFACTURING FACILITIES IN THE UNITED STATES

Somewhat akin to the saw mill part of the timber products processing industry, hardboard operations are spread nationally with some production of each kind in each forest region of the U.S.. The hardboard and particle board industries can use the residues from other wood working plants 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 involve pulp and paper, plywood, hardboard operations, and other 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, about one-third 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 three 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 sq m (50 to 100 million sq ft) may become economically marginal.

WOOD PRESERVING

The wood preserving process is one in which round and sawn wood products are treated by the injection of chemicals that have fungistatic and insecticidal properties or 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 U.S. use at least 2 of the 3 types of preservatives. Many treat with one or 2 preservatives plus a fire retardant .

Treatment is accomplished by either pressure or non-pressure processes. Pressure processes for treating wood with preservatives employ a combination of air and hydrostatic pressure and vacuum. Differences among the various pressure treating processes used are based mainly on the sequence of application of vacuum and pressure. Nonpressure 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. In the East, the process is used to treat lumber and posts. The conditioning method that must be employed to prepare stock for preservative treatment is partially dependent on the species of wood. 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. The purpose of this process, which is normally carried out in the same retort in which the actual injection of preservative is subsequently performed, is 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 by a process called Boultonizing, in which the wood is heated under vacuum in the retort 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.

Waste water generated in steam conditioning is composed of both steam condensate and water removed from the wood. Waste water 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.

Consumption data for the principle preservatives for the 5-year period between 1967 and 1971 are given in Table 8. 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.

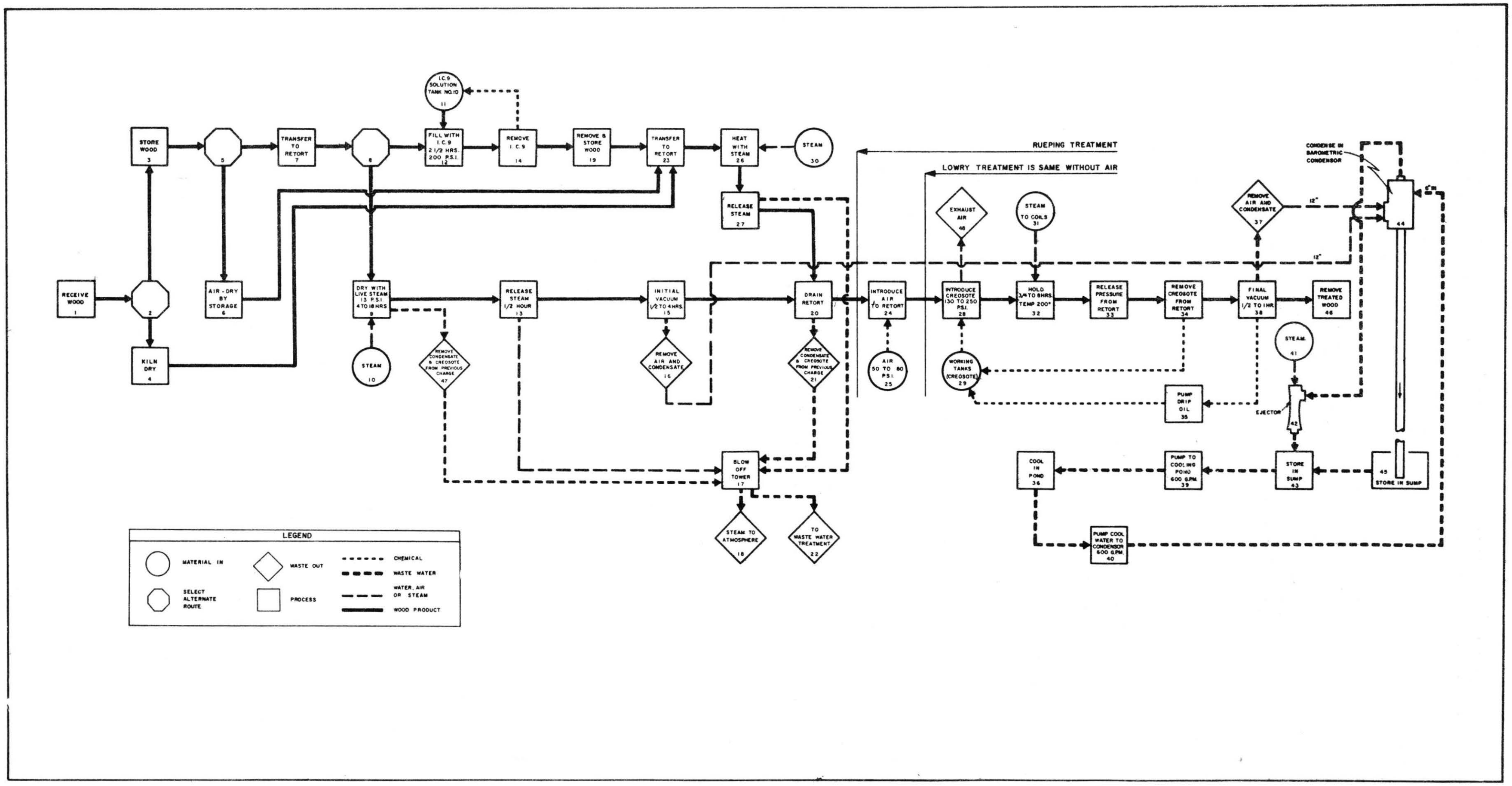


FIGURE 14 - PROCESS FLOW DIAGRAM FOR A TYPICAL WOOD-PRESERVING PLANT (COURTESY OF ALBERT H. HALFF ASSOCIATES, INC., DALLAS, TEXAS)

TABLE 8

CONSUMPTION OF PRINCIPAL PRESERVATIVES AND FIRE RETARDANTS OF REPORTING PLANTS IN THE UNITED STATES, 1967-1971

		Year				
Material	(Units)	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 the Wood Preserving Segments

The wood preserving industry in the U.S. 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 pine which is 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 plants in the U.S. are located outside these two regions. The distribution of plants by type and location is given in Table 9.

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 10), 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 9

WOOD PRESERVING PLANTS IN THE UNITED STATES BY STATE AND TYPE

(1971)

	Commercial			Railroad and Other		
	Pressure	Non-Pressure	Pressure and Non-Pressure	Pressure	Non-Pressure	Total Plants
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

TABLE 9 CONTINUED

	Commercial			Railroad and Other		
	Pressure	Non-Pressure	Pressure and Non-Pressure	Pressure	Non-Pressure	Total Plants
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 TOTAL	306	35	30	9	10	390

TABLE 10

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

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

		Thousand Cubic Meters					
Preservative	Year	Poles and Piling	Railroad Ties	Lumber and Timbers	Fence Posts	Other	Total
Creosote and Creosote-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

TABLE 10 CONTINUED

		Thousand Cubic Meters					
Preservative	Year	Poles and Piling	Railroad Ties	Lumber and Timbers	Fence Posts	Other	Total
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-Pentachlorophenol	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

TABLE 10 CONTINUED

Preservative	Year	Thousand Cubic Meters Poles and Piling	Railroad Ties	Lumber and Timbers	Fence Posts	Other	Total
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

INDUSTRY SUBCATEGORIZATION

INTRODUCTION

In developing effluent limitations guidelines and standards of performance for new sources for a given industry, a judgment must be made by EPA as to whether effluent limitations and standards are appropriate for different subcategories within the industry. The factors considered in determining whether such subcategories are needed for the segments of the timber products processing category of point sources are:

1. Products Produced
2. Manufacturing Process Employed
3. Raw Materials
4. Plant Age
5. Plant Size
6. Wastes Generated
7. Treatability of Waste Waters
8. Air Pollution Control Equipment

Based upon an intensive literature search, plant inspections, and communications with the industry, it is the judgment of the Agency that the timber products processing category should be subcategorized by product and by the type of manufacturing process employed. A discussion of these and other factors considered in this judgment follows.

FACTORS IN INDUSTRY SUBCATEGORIZATION

Type of Products Produced

As discussed in Section III, there are wide differences in the products manufactured by the segment of the timber products processing category being considered. Logs are barked to produce an intermediate product common to most of the timber products processing category. This intermediate product is further processed into veneer and plywood, hardboard, and treated or preserved wood. Because of the readily apparent disparity among these products it is initially concluded that the timber products processing category can be subcategorized on the basis of the type of product produced. Thus, the initial industry subcategorizations established are: (1) barking, (2) veneer and plywood manufacture, (3) hardboard manufacture, and (4) wood preserving. While barking does not produce a commercial product, it is a necessary initial operation throughout the industry, and for the purposes of this report is considered to produce an unfinished or intermediate product.

Manufacturing Process Employed

The manufacturing process used in the production of a given product have been found to be so different as to support the previous subcategorization and form a basis for further subcategorization in certain instances.

The process of barking or removing the bark layer from logs may be carried out either by mechanical abrasion or hydraulic removal as previously discussed. These processing operations are different from those used in any other segment of the category. Hence, this tends to reinforce the initial segregation of barking as a subcategory.

The principal processes employed in manufacturing veneer and plywood are unlike those employed in other segments of the category. The operations of log conditioning, veneer cutting, veneer drying, veneer preparation, gluing, pressing and finishing have been previously described and are unique to this segment of the category. This reinforces the previous preliminary conclusion that its veneer and plywood segment should be considered separately from the other segments of the timber products category. Also, since the veneer manufacturing process is a separate operation with waste water quality and quantity generation differences, and plywood manufacture is a process not always occurring in the same plant, they logically fall into distinct subcategories.

One method of log conditioning employs live steam to heat the logs directly and another uses steam to heat the conditioning vats resulting in significant discharges of process waste waters. Other log conditioning methods do not produce large discharges of process waste waters. Available data indicates that an allowance may be necessary in the veneer subcategory for those operations which use direct steam contact to condition wood prior to veneer cutting, and which are currently unable, or chose not to, implement other conditioning methods prior to 1983.

The manufacturing processes used to manufacture hardboard are unique within the timber products category. These processes, which include chipping, fiber preparation, forming (either wet- or air-felting), pressing, tempering and finishing, have been described in detail in Section III. This uniqueness of manufacturing operations tends to confirm that hardboard manufacturing should be considered separately within the timber products processing category.

There are two significantly different manufacturing processes in the hardboard industry which afford a basis for further subcategorization. These are the dry felting process and the wet felting process. In the dry-felting process the fibers are suspended in air as the mat is formed, while in the wet-felting process the fibers are suspended in water. There is little process waste water generation from the dry-felting process, while there is a continuous and substantial waste water generation from the wet-felting process.

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 and dry pressing, it does not warrant consideration as a separate category.

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 a future regulation and because the interrelationship between the manufacture of insulation board and hardboard, if any, is unknown at this time, these mills will be addressed by a future regulation.

In wet process hardboard mills, fiber preparation is a major factor affecting waste water characteristics. Two mills utilize the explosion process for fiber preparation, thus causing substantially more BOD to be released. However, both of these mills have installed evaporators to handle this high BOD process waste water and their overall waste discharge is as low or lower than other wet process mills. All other mills use a combination thermal-mechanical process for fiber preparation. 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 waste water flow and composition is not sufficient in itself to be used as grounds for subcategorizing the industry.

Wood preserving consists of treating round (barked) or sawn wood products by infusing them with chemicals to protect the wood from insects, microorganisms, fungi and fire. The chemicals used may be either oil type or salt (water soluble) type, and may be infused into the wood by soaking or pressure treatments, indirect steaming, prior to chemical infusions, the wood may be conditioned by direct heating, by a vacuum heating process called Boultonizing, or the wood may not be conditioned at all. The considerable differences between the processes employed in wood preserving and the other segments of the timber products category clearly confirm the preliminary conclusion that wood preserving should be considered separately from the remainder of the segment.

Water use and waste characterization, related to the process employed, and discussed in Section V, indicates that the wood preserving portion should be further divided for the purpose of establishing effluent guidelines and standards. The waste water volume generated during the conditioning step prior to infusing chemicals into the wood appears to offer a logical separation of the portion. The volume of process waste water generated in the direct steam conditioning process is relatively large so that treatment with discharge of the treated effluent appears necessary. The process waste water volumes generated by the Boulton conditioning process are relatively small and can be more readily managed. Opportunities for reuse of the small volume of waste water, generated in the treating of wood with water soluble preservatives, are available, unless the salts are used with steam conditioning. The nonpressure treatment methods produce almost no process waste water and can also be classified along with Boultonizing in this regard. Therefore, the wood preserving segment of the timber products category can be subcategorized into (1) processes using direct steam conditioning of stock to be treated, (2) processes using Boultonizing, and (3) other wood preserving processes, inclusively.

Raw Materials

Numerous species of wood are used in the industry and waste water characteristics may vary somewhat with raw material. Softwoods in contact with water (particularly hot water), release more wood sugars than do hardwoods. Within the broad categories of softwood and hardwood there are also many species with varying leaching characteristics. In addition, it is known that minor process variations are often dictated by the type of raw material. For example, hardwood logs may require a different type of conditioning than species of softwood do.

While it would be expected that different waste water characteristics result from different raw materials, it is observed that volumes of waste waters vary only with process variations. The control and treatment technology applied within these segments of the industry consist to a large degree of recycle and containment and is more a function of waste water volume than of pollutant concentration. Therefore, differences according to species do not significantly affect the degree to which waste waters can be treated or controlled.

Thus, while there are a number of distinctions related to raw material used within the industry, the data generated in this study indicates that these differences are insufficient to become a basis for further subcategorization.

Age of Facility

The age of the manufacturing facility has been considered as a factor for subcategorization of the industry. Barking is accomplished by a variety of processes and ages of equipment.

Within the group of processes which use mechanical abrasion to remove the bark, there appears to be no change in the water pollution vectors attributable to age of equipment. Similarily, the age of hydraulic barkers has no determinable impact on waste water pollutants.

The veneer and plywood subcategories include a number of older manufacturing facilities. The softwood plywood manufacturing subcategory, however, has been experiencing substantial growth for the past 20 years, and numerous new facilities have been constructed. The southeastern U.S., 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 within a plant are not necessarily reflected in installation age as equipment is constantly being modernized and replaced.

A review of information available and data from the plants in the hardboard subcategory indicates that plant age has no significant relationship to waste water generation, quality or quantity.

Within the hardboard subcategory, the major effects of plant age are higher equipment maintenance costs and possible difficulties involving the installation of recycle systems, but not in waste water flows or concentration.

In the wood preserving manufacturing subcategory, while plants of varying ages exist, there is no consistently defensible measure of the effect of plant age on waste water generation or control.

Plant Size

Plant size has been considered as a basis for subcategorization of the timber products processing category and this analysis indicates that no subcategorization should be made on this basis.

The relative quantity of process waste water pollutants from barking operations generally are not size-sensitive as the installation of additional duplicate units is required to handle larger capacities. The size of mills within the plywood subcategory can vary drastically from "backyard" operations producing 200,000 sq m/yr (2 million sq ft/yr) of plywood to a large plywood mill producing 56 million sq m (600 million sq ft/yr). Since the volume of waste water produced by a mill is largely proportional to the size of the mill, control and treatment are similarly proportional. Hence, plant size is rejected as a possible element for subcategorization.

Within the hardboard subcategory, it has been determined from existing data and from on-site inspections that, other than in volumes of process waste water, plant size has no effect upon the waste water characteristics and, therefore, does not present a rational base for subcategorization. Plant size will only affect costs of treatment as economies of scale for larger plants may show a generally a lower unit cost than for small plants.

Wastes Generated

While there are distinct differences in the quality and characteristics of the various waste waters generated in the timber products processing category, a careful examination of the information in Section V shows that the most significant differences are quantitative, and are directly related to product manufactured and manufacturing process employed. As an example, variation in waste generated in the hardboard portion of the industry is directly related to the two different manufacturing processes utilized in making hardboard. The waste water flow, excluding cooling water, from a typical dry process hardboard mill will consist of a discharge of less than 1,890 l/day (500 gal/day). This compares with a waste water flow of 1,500,000 l/day (378,000 gal/day) from a typical wet process hardboard mill. Since wastes generated are similarly related to products and processes in the remainder of the industry, a subcategorization on this basis is not indicated, because it is effectively accomplished by manufacturing process employed.

Treatability of Waste Waters

The waste waters generated by the barking, veneer, plywood, hardboard-dry process, and hardboard-wet process portions of this segment contain as major pollutants, BOD and suspended solids. These parameters are usually treated by biological methods. Waste waters generated by the wood preserving portion of the segment may include, in addition to the above listed parameters, pollutants such as COD, heavy metals, phenols, and high concentrations of oil and grease. This difference is considered in subcategorization.

Air Pollution Control Equipment

Air pollution is not a major problem in this manufacturing segment. Air pollution and its control is not a major problem in this segment of the timber products processing industry. In situations where air pollution problems exist, the type of control equipment required may be a venturi type scrubber. This system can be operated as a closed system with limited requirements for blowdown, and, therefore, the industry subcategorization should not be be affected by air pollution equipment.

SUMMARY OF SUBCATEGORIZATION

The segments of the timber industry considered in this document have been separated into the following subcategories for the purpose of establishing effluent guidelines and standards. These subcategories are defined as:

1. Barking. The barking subcategory includes the operations which result in the removal of bark from logs. Barking may be accomplished by several types of mechanical abrasion or by hydraulic force.

2. Veneer. The veneer subcategory includes the operations used to convert barked logs or heavy timber into thinner sections of wood known as veneer.

3. Plywood. The plywood subcategory includes the operations of laminating layers of veneer to form finished plywood.

4. Hardboard - Dry Process. The dry process hardboard subcategory includes all of the manufacturing operations attendant to the production of finished hardboard from chips, sawdust, logs, or other raw materials, using the dry matting process for forming the board mat.

5. Hardboard - Wet Process. The wet process hardboard subcategory includes all of the manufacturing operations attendant to the production of finished hardboard from chips, sawdust, logs, or other raw materials, using the wet matting process for forming the board mat.

6. Wood Preserving. The wood preserving subcategory includes all wood preserving processes in which steaming or boultonizing is not the predominant method of conditioning, all non-pressure preserving processes, and all pressure or non-pressure processes employing water borne salts, in which steaming or vapor drying is not the predominant method of conditioning.

7. Wood Preserving - Steam. The wood preserving-steam subcategory includes all processes that use direct steam impingement on the wood being conditioned as the predominant method of conditioning, discharges resulting from wood preserving processes that use vapor drying as a means of conditioning any portion of their stock, discharges that result from direct steam conditioning wood preserving processes that use fluor-chromium-arsenic-phenol treating solutions (FCAP), discharges resulting from direct steam conditioning processes and procedures where the same retort is used to treat with both salt-type and oil type preservatives, and discharges from plants which direct steam condition and apply both salt type and oil type treatments to the same stock.

8. Wood Preserving - Boultonizing. The wood preserving-boultonizing subcategory covers those wood preserving processes which use the Boulton process as the method of conditioning stock.

SECTION V

WATER USE AND WASTE CHARACTERIZATION

LOG BARKING

The water employed in hydraulic barking must be free of suspended solids to avoid clogging nozzles. Results of analyses of the effluent from a hydraulic barking installation are shown in Table 11. 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 11. 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 waters are often recycled, which accounts for part of the increase. The higher 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 may also be affected by the species of wood barked and by the time of the year in which the log is cut.

VENEER AND PLYWOOD MANUFACTURING

Water usage varies widely in the veneer and plywood portion of the 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 l/sec (50 gal/min) for a mill producing 9.3 million sq m/yr (100 million sq ft/yr). There are plants presently being designed to recycle all waste water, however, none are now in operation. Considerable effort can, in any case, be made to reduce the amount of waste water to be discharged or contained. The amount of information available on volumes and characteristics of waste waters from the industry is minimal. Data cited in waste water 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. Because the volumes that are involved are small, attention has been directed to finding methods for reducing the volumes and ways of handling process water in such a way as to eliminate discharges.

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

TABLE 11

ANALYSIS OF DEBARKING EFFLUENTS

Mill	Type of Debarking	Total Suspended Solids (mg/l)	Non-Set Solids (mg/l)	BOD5 (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	F200	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

(1) Log conditioning
(2) Cleaning of veneer dryers
(3) Washing of the glue lines
    and glue tanks
(4) Cooling

Figure 15 presents a detailed process flow diagram. The water use and waste characteristics for each operation are discussed below.

Log Conditioning

Veneer and plywood manufacturing operations use two distinct types of log conditioning systems. These systems are discussed in Section III, 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 plants use steam vats almost exclusively.

The only waste water from a steam vat is from condensed steam. This water carries leachates from the logs as well as wood particles. Table 12 presents the results of analyses of waste waters from steam vats. The magnitudes of these flows vary according to the size and number of vats. A plant producing 9.31 million sq m/yr (100 million sq ft/yr) of plywood on a 9.53 mm (3/8 in) basis has an effluent of about 1.58 to 3.15 l/sec (25 to 50 gal/min). A southern plywood mill (Plant A, Table 20) produces a BOD load of 2,500 kg/million sq m (515 lb/million sq ft) of production on a 9.53 mm (3/8 in) basis, and a total solids load of 29,200 kg/million sq m of production on a 9.53 mm (6,000 lb/million sq ft) (3/8 in) basis.

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. Hot water vats are usually emptied periodically, regardless of heating method, and the water and the solids that build up in the closed system is discharged and replaced with clean water. Some plants settle the spent waste water and pump it back into the vats. Chemical characteristics for hot water vats for a number of veneer and plywood plants are given in Table 13.

Dryer Washwater

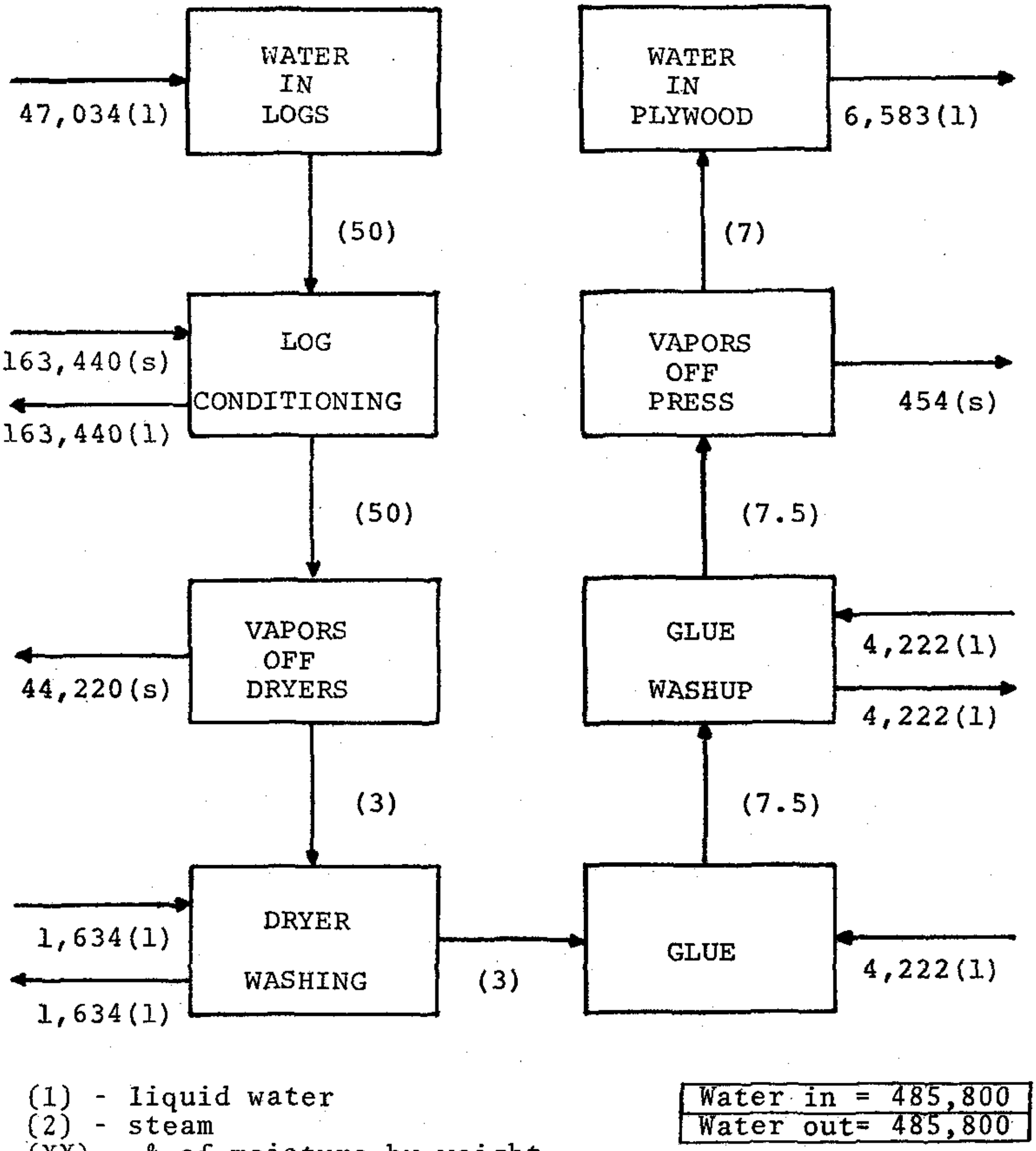
Veneer dryers accumulate wood particles. Volatile hydrocarbons will also condense on the surface of dryers to form an organic deposit called "pitch." In order to avoid excessive buildup of these substances, dryers must be cleaned periodically. Wood particles can be removed either by flushing with water 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.

TABLE 12

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.



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

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

TABLE 13

CHARACTERISTICS OF HOT WATER STEAM VAT DISCHARGES

	Concentrations									
Plant	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/1 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.

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 the 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 l (6,000 gal) of water per dryer over a period of 80 hours. At this plant there were six dryers which 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, caustic detergent was applied. Finally, the detergent was rinsed off with water for another 45 minutes. Samples of spent water were taken during both applications of water, and the analyses of these samples are shown in Table 14. The effluent from this washing operation was averaged over a 7-day period and expressed on a unit of production basis as shown in Table 15.

Various industry contacts emphasized that pitch build-up can be minimized by proper maintenance of the dryers. In addition, the volume of water necessary to wash the dryers can be greatly reduced. One Oregon plant of about one-half the size of the one described previously was observed to use 1/12 as much water per week to clean its dryers. Waste water characteristics from this plant are also given in Tables 14 and 15. 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 point of discharge.

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

In addition to the two waste water 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 waste water 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.

TABLE 14

ANALYSIS OF DRYER WASHWATER

Plant	BOD	COD	DS	SS	TS	Turb.	Phenols	Color	Kjld-N	T-PO4-P
A										
Part I	210	1,131	643	113	756	19	1.31	32	17.7	1.93
Part B	840	6,703	1,095	5,372	6,467	50	0.20	43	211	11.0
B	60	1,586	1,346	80	1,426	6	4.68	51	2.91	0.495

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

TABLE 15

WASTE LOADS FROM VENEER DRYERS

Plant	BOD	COD	DS	SS	TS	Phenols	Kjld-N	T-PO4-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.

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 waste water from a glue system results from the washing of the glue spreaders and mixing tanks. Table 16 shows a list of the typical ingredients of the 3 categories of glues already established. The specific quantities of these ingredients may vary slightly. Table 17 lists the results of chemical analyses of typical mixtures of the different glues. The waste waters from the washing operations are diluted at a ratio of about 20:1 with water to yield the concentrations shown in Table 18-B. Samples of two phenolic and one urea formaldehyde waste water were collected and are shown in Table 17. These are in the same range as those in Table 18, so it is reasonable to assume a 20:1 dilution with water. This ratio varies considerably, however, according to frequency of cleaning and amount of water used.

Waste waters 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 waste water flow and reuse in gluing operations to determine the possibility of complete waste water 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 20 shows a list of southern plywood mills along with the waste water generated and the water needed in glue makeup. Table 21 shows measurement of waste waters 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, a significant reduction must be made in the wash water generated. These reductions, however, are feasible and many plants currently operate with complete recycle.

Cooling Requirements

A typical combined veneer and plywood mill requires a certain amount of cooling water to dissipate heat from the air compressor as well as from from machines such as the press and the lathe. A mill producing 9.3 million sq m/yr (100 million sq ft/yr) of plywood on a 9.53 mm (3/8 in) basis needs to dissipate about 55,000 kcal/hr (217,000 BTU) from the compressor and 101,000 kcal/hr (400,000 BTU) from the rest of the plant, for a total of 156,000 kcal/hr (617,000 BTU).

TABLE 16

INGREDIENTS OF TYPICAL PROTEIN, PHENOLIC AND UREA GLUE MIXES

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

TABLE 17

AVERAGE CHEMICAL ANALYSIS OF PLYWOOD GLUE

Analysis and Units	Phenolic Glue	Protein Glue	Urea Glue
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
Suspended Solids, mg/kg	92,000	59,000	346,000
Dissolved Solids, mg/kg	305,000	118,000	304,000
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

TABLE 18

AVERAGE CHEMICAL ANALYSIS OF PLYWOOD GLUE WASHWATER (ASSUMING A 20:1 DILUTION WITH WATER)

Analysis And Units	Phenolic Glue	Protein Glue	Urea Glue
COD, mg/kg	32,650	8,850	21,050
BOD, mg/kg	--	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, mg/kg	25.7	90.5	
Suspended Solids, mg/kg	15,250	5,900	10,200
Dissolved Solids, mg/kg	15,250	5,900	10,200
Total Solids, mg/kg	19,850	8,850	27,500
Total Volatile Suspended Solids, mg/kg	4,200	1,700	17,300
Total Volatile Solids, mg/kg	8,600	6,850	27,500

TABLE 19

CHARACTERISTICS OF GLUE WASHWATER

(mg/l)

Plant	BOD	COD	TS	DS	SS	Kjld-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 20

AMOUNT OF ADHESIVE WASHWATER GENERATED IN SOUTHERN PINE PLYWOOD PLANTS

Plywood Plant Production (million sq. meters/Year) 9.53mm basis	Weekly Adhesive Use (kg)	Amount of Washwater Produced (Liters)				Amount of Adhesive per week (kg)
		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 21

GLUE WASTE DISCHARGE MEASUREMENTS

Plant	Days Measured	Average Discharge for Days Measured (1/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

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 combination veneer and plywood mill with an annual production of 9.3 million sq m (100 million sq ft) of plywood on a 9.53 mm (3/8 in) basis is used as a basis for the development of the water balance. Such a mill would be producing plywood equivalent to 93,980 kg/day (207,000 lb/day) or 95 kkg/day (104 ton/day) on a dry wood basis.

Water Inflows

Water inflows from a typical mill include water from the logs, glue, and 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 kg/day or 500 kg/kkg (1,000 lb/ton). The amount of water that is applied to plywood glue is estimated to be 4,200 kg/day or 43 kg/kkg (86 lb/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 kg/day (360,000 lb/day) or 1,750 kg/kkg (3,500 lb/ton) of steam is used in log conditioning; about 1,620 kg/day (3,570 lb/day) or 17.5 kg/kkg (35 lb/ton) of water is used to wash veneer dryers; and about 4,200 kg/day (9,300 lb/day) or 45 kg/kkg (90 lb/ton) of water is used to wash the glue system.

Water Outflows

Water outflows from a typical mill include the water in the finished plywood, vapor losses from 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 kg/day (14,500 lb/ day or 140 lb/ton) based on a 7 percent moisture content.

Vapor losses occur in the dryers and in the press. Based on 3 percent moisture content in dried veneer, approximately 44,000 kg/day (97,400 lb/day or 940 lb/ ton) of steam must be released. Similar calculations indicate a steam discharge of 450 kg/day (1,000 lb/day or 10 lb/ton) from the press. Waste water 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 kg/day (360,000 lb/day or 3,500 lb/ton).

Waste water discharges from the washing operations are equal to the respective water usage. Dryer wash water is approximately 1,635 kg/day (3,600 lb/day or 35 lb/ ton), and glue wash water is approximately 4,200 kg/day (9,300 lb/day or 90 lb/ton).

HARDBOARD - DRY PROCESS

Specific Water Uses In A Typical Mill

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:

(1) Log Washing
(2) Chip Washing
(3) Resin System
(4) Caul Washing
(5) Housekeeping
(6) Humidification
(7) Fire Fighting

The quantity of water utilized in any dry process hardboard mill depends upon water uses in raw materials handling and inplant processes, the recycle system utilized, housekeeping practices, and many other factors. Table 22 shows waste water flows from 11 dry process hardboard mills. The quantity of process water utilized in a typical mill would be approximately 18,900 l/day (5,000 gal/day). This water is either evaporated in the press or becomes a part of the final product. A typical waste water flow from a dry process mill should be less than 1,900 l/day (500 gal/day). Cooling water usage varies widely from mill to mill but rarely exceeds 280,000 l/day (975,000 gal/day). The water usage in a dry process hardboard mill is low and waste water discharges are 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 total amount of dirt varying 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. Mills may store both whole logs and chips on-site and the ratio of logs purchased as compared with chips vary; the quantity of water utilized will vary accordingly. Both fresh water and cooling water from the inplant processes may be used for log washing. Quantities of water used for log washing can be expected to range from 400 l/kkg (105 gal/ton) to 1,250

TABLE 22

DRY PROCESS HARDBOARD WASTEWATER FLOW AND SOURCE

Mill	Log Wash	Chip Wash	Resin* Wash	Caul* Wash	House-keeping*	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

l/kkg (330 gal/ton). Typical chemical analyses would include a BOD of 200 mg/l and 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 can result in excessive equipment wear. Chip washing serves not only to remove this unwanted matter, but also gives the chips a more uniform moisture content and, in northern climates, helps thaw frozen chips. No dry process hardboard mills reported the use of chip washing, but the trend is toward mills having to wash chips. As prime sources of fiber become increasingly scarce, the trend will be toward whole tree utilization. This means that whole trees, or just limbs and branches, might be chipped in the forest and shipped to the mill. Because 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. Because there are, at the most, only one known chip washing systems in use, there are no reliable 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 becomes part of the hardboard and it is evaporated in the press. Some mills claim it is necessary to clean the resin system, and available data, as shown in Table 22, 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, phenol formaldehyde and urea formaldehyde. These resins are essentially the same as those utilized in the plywood industry where many mills have already gone to a completely closed resin system. Table 23 shows typical chemical analysis of plywood glue.

The chemical analysis of resin washwater will be those concentrations shown in Table 23 diluted by a factor depending upon the quantity of water used for wash-up. Several hardboard mills presently recycle this wash water as resin make-up water or simply do not wash at all, therefore having no discharge.

Caul and Press Plate Wash Water

Another minor water usage and waste water source in some mills is 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

TABLE 23

AVERAGE CHEMICAL ANALYSIS OF PLYWOOD RESIN

Analysis and Units	Phenolic Resin	Urea Resin
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, mg/kg	514,000	
Suspended Solids, mg/kg	92,000	246,000
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

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 may also be cleaned with a caustic solution inplace. After soaking, cauls are removed, rinsed with fresh water, and 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 l/day (100 to 250 gal/day) or approximately 4 l/kkg (1.0 gal/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 l/day (400 gal/day) in a typical mill. This source of waste water results in such a minor volume that it can easily be disposed of on-site. Several mills utilize no water at all for cleaning as all of their house cleaning is done by sweeping and vacuum cleaning.

Humidification

All dry process hardboard mills humidify board after pressing. This procedure consists of passing the boards through a room with a high humidity and temperature to bring the moisture content to an air dry level. Most mills report no waste water discharge from this operation.

Fire Water

A major problem with the dry process for manufacturing hardboard is the fire hazard. The inside of a dry process hardboard mill may 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 obviously not scheduled and their frequency varies from mill to mill. The water used to control a fire will vary according to the duration and extent of the fire.

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. 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 l/day (5,000 to 75,000 gal/day) with a typical mill utilizing 190,000 l/day (50,000 gal/day). Cooling water may 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 appears to be toward the use of wet scrubbers in 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 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

For the purpose of illustrating the water requirements in a dry process hardboard manufacturing plant, presented below is a water balance. This presentation is not intended to suggest that the average (or typical) plant in the industry produces 225 kkg/day. The water intakes and outflows are presented also on a volume of water per unit of production basis, also, to illustrate the water requirements and outflows related to the operations involved in the manufacture of hardboard.

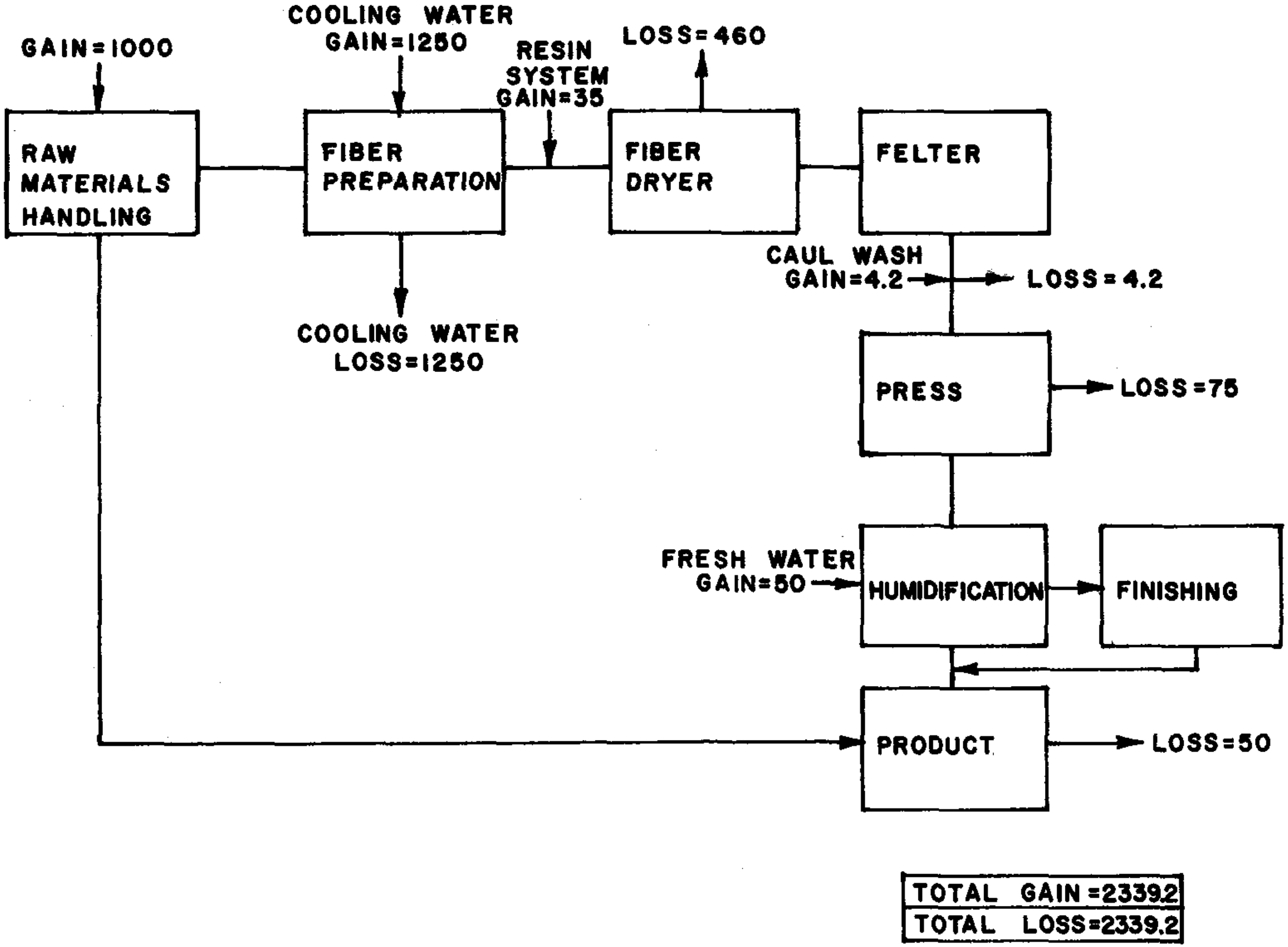
A schematic diagram of the water balance (net inflows and outflows) for a typical dry process hardboard mill is shown in Figure 16. Water gains or outflows are shown as l/kkg of dry product produced in a typical 225 kkg/day mill.

Water Inflows: Water inflows 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 l/kkg (50 percent moisture) (240 gal/ton)

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

Water in glue = 35 l/kkg of (3.5 percent of product) product (8.4 gal/ton)



*GAINS AND LOSSES SHOWN IN LITERS/TON DRY PRODUCT

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

Caul wash 950 l/day = 4.2 l/kkg of (250 gal/day)
product (1 gal/ton)

Humidification = 50 l/kkg of (5.0 percent of product)
product (12 gal/ton)

Cooling water-284,000 = 1,250 l/kkg of l/day (75,000 gal/day)
product (300 gal/ton)

Total Water Inflows = 2339 l/kkg of product (561 gal/ton)

Water Outflows: Water outflows in a dry process hardboard mill result from:

Fiber drying to 7.5 percent moisture = 960 l/kkg of product (230.4 gal/ton)

Press evaporation (0.0 percent moisture) = 75 l/kkg of product (18 gal/ton)

Water in product (5.0 percent moisture) = 50 l/kkg of product (12 gal/ton)

Caul wash (950 l/day) (250 gal/day) = 4.2 l/kkg of product (1.0 gal/ton)

Cooling water (284,000 l/day) = 1,250 l/kkg of product (300 gal/ton)

Total Water Outflows =2339 l/kkg of Product (561 gal/ton)

HARDBOARD - WET PROCESS

Specific Water Uses

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

1. Raw materials handling
2. Fiber preparation
3. Mat formation and pressing
4. Miscellaneous

Raw Materials Handling

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

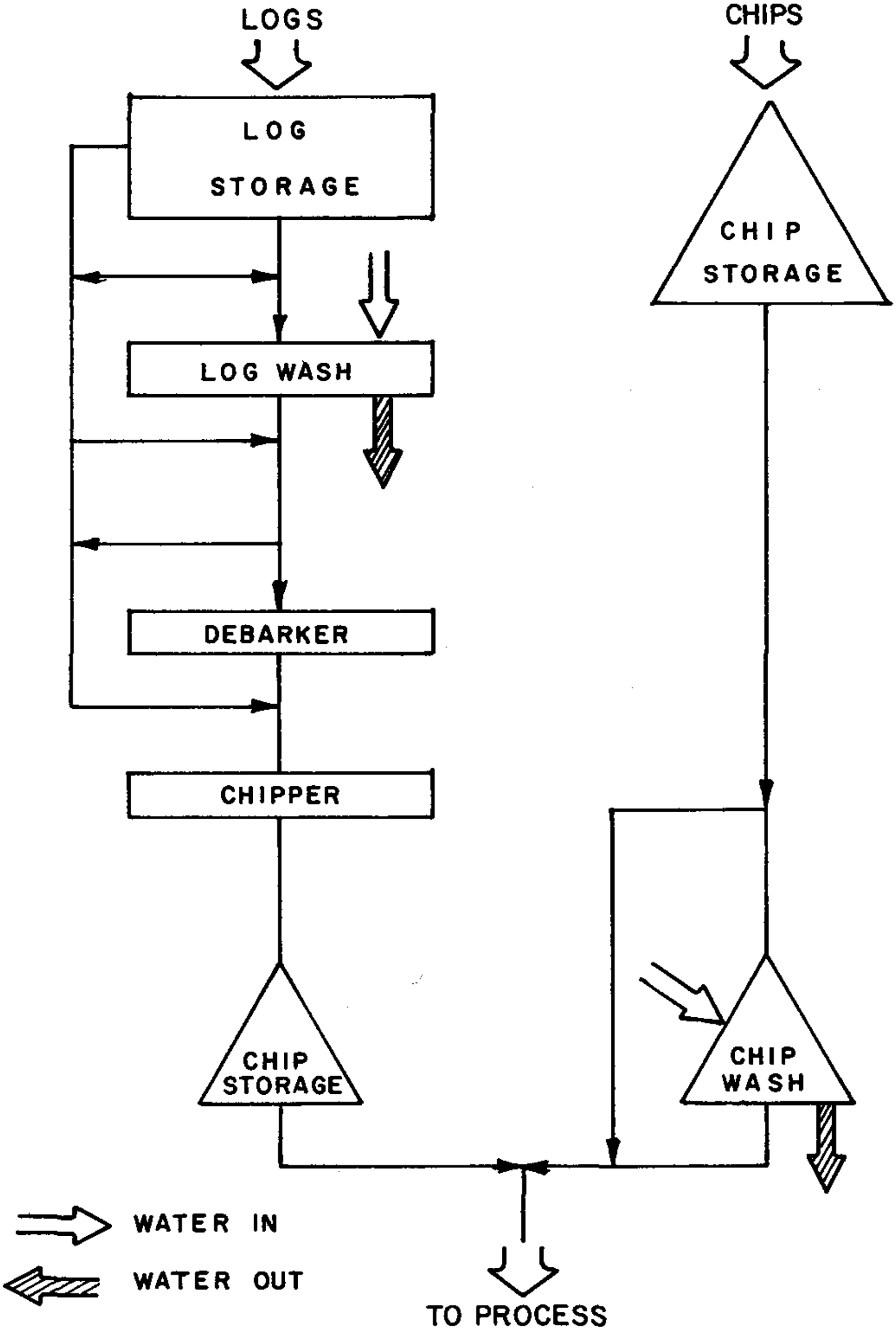


FIGURE 17 - WATER USAGE IN RAW MATERIALS HANDLING IN THE HARDBOARD INDUSTRY

hardboard discusses raw materials handling, and the figures and discussion there also apply to the wet process hardboard segment of the timber products processing industry.

Fiber Preparation

As previously discussed, there are two principal fiber preparation processes: (1) thermal plus mechanical refining process and, (2) the explosion process. Figure 11 showed 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 utilize the explosion process as shown in Figure 18.

The amount of 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 is approximately equal to one-half the weight of dry chips processed or approximately 0.5 cu m/kkg (120 gal/ton).

The principal reason for significant waste water flows and concentrations from the wet process as compared with the dry process is the fact that the fiber is diluted from approximately 40 percent consistency to 1.5 percent consistency prior to forming on a wet felting machine. There are limitations on the concentrations of organics in the process water. This means that most of the soluble organics released into solution during fiber preparation must be disposed of in some manner as only a portion of the solubles may be retained in the hardboard.

The interrelation between fiber preparation processes, variations of cooking time, and temperature and wood chemistry on waste water discharge is extremely important. Wood is difficult to define chemically because it is a complex heterogeneous product of nature made up of interrelated 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. Variations in the chemical composition of wood influences the quantities and kinds of chemicals released during fiber preparation.

At normal temperatures wood resists 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

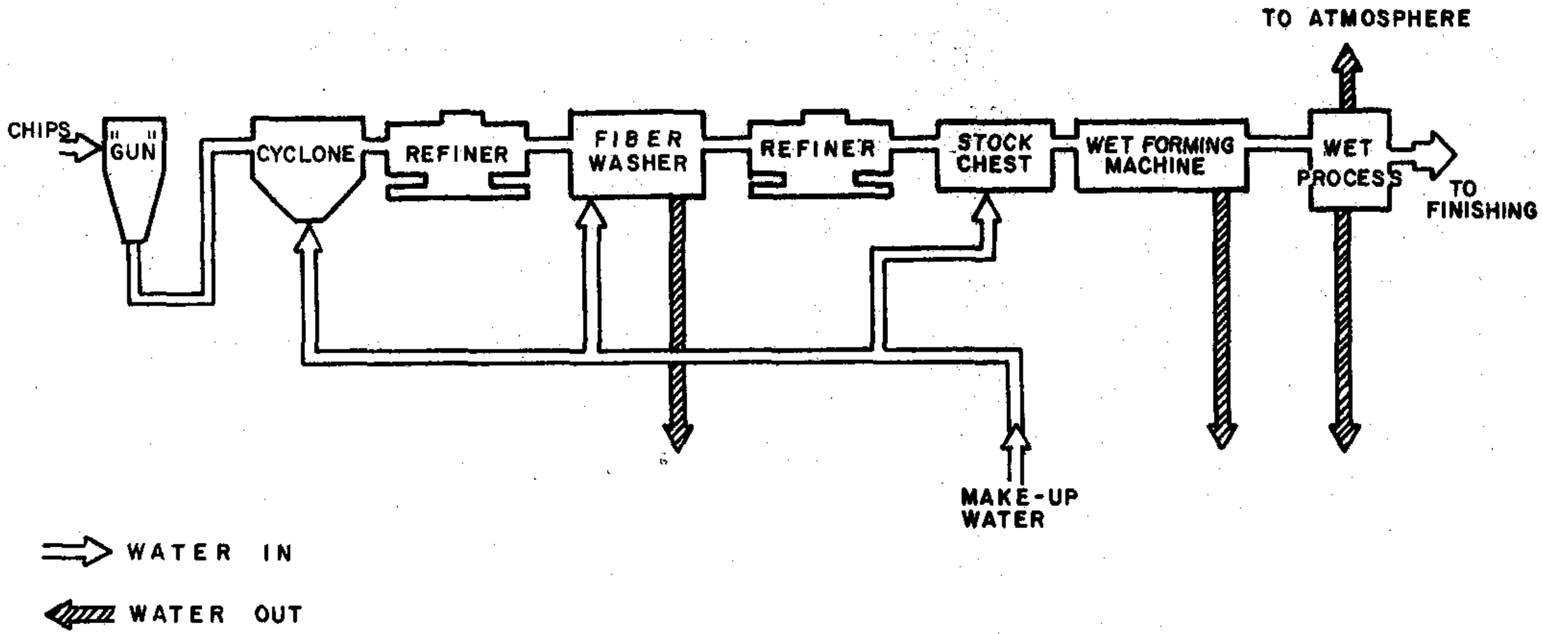


FIGURE 18 - WATER USE IN THE EXPLOSION PROCESS

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. Cellulose resists hydrolysis better than the hemicellulose fractions.

The thermal and explosion pulping processes make use of the effect of water on wood at high temperatures to prepare fiber for mechanical refining prior to being formed 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, and therefore potential waste water problems increase significantly.

In the 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 these 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 common process makes use of a screw press to force compressed chips into one end of a horizontal stainless-steel tube, typically 3 m (10 ft) long and one m (3 ft) 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 disc 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. Because of the lower temperatures and pressures, the quantity of released organics is considerably less than in the explosion process, resulting in potentially less waste.

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

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:

1. pH of liquor (water solution)
2. Temperature and pressure of digestion
3. Time of digestion
4. Method of defibration

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 difficult to make determinations of the yield of pulp from wood as a function of the pre-heating conditions. Some attempts have been made, however, and in Figure 19 a graph for beechwood is shown, where the preheating 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.

During the pre-heating two primary reactions take place. One 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 reaction for the dissolution of wood substances during the pre-heating stage. The rate of reaction seems to roughly double with an increase in temperature of about 8°C (14°F), which is normal for most chemical reactions. 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

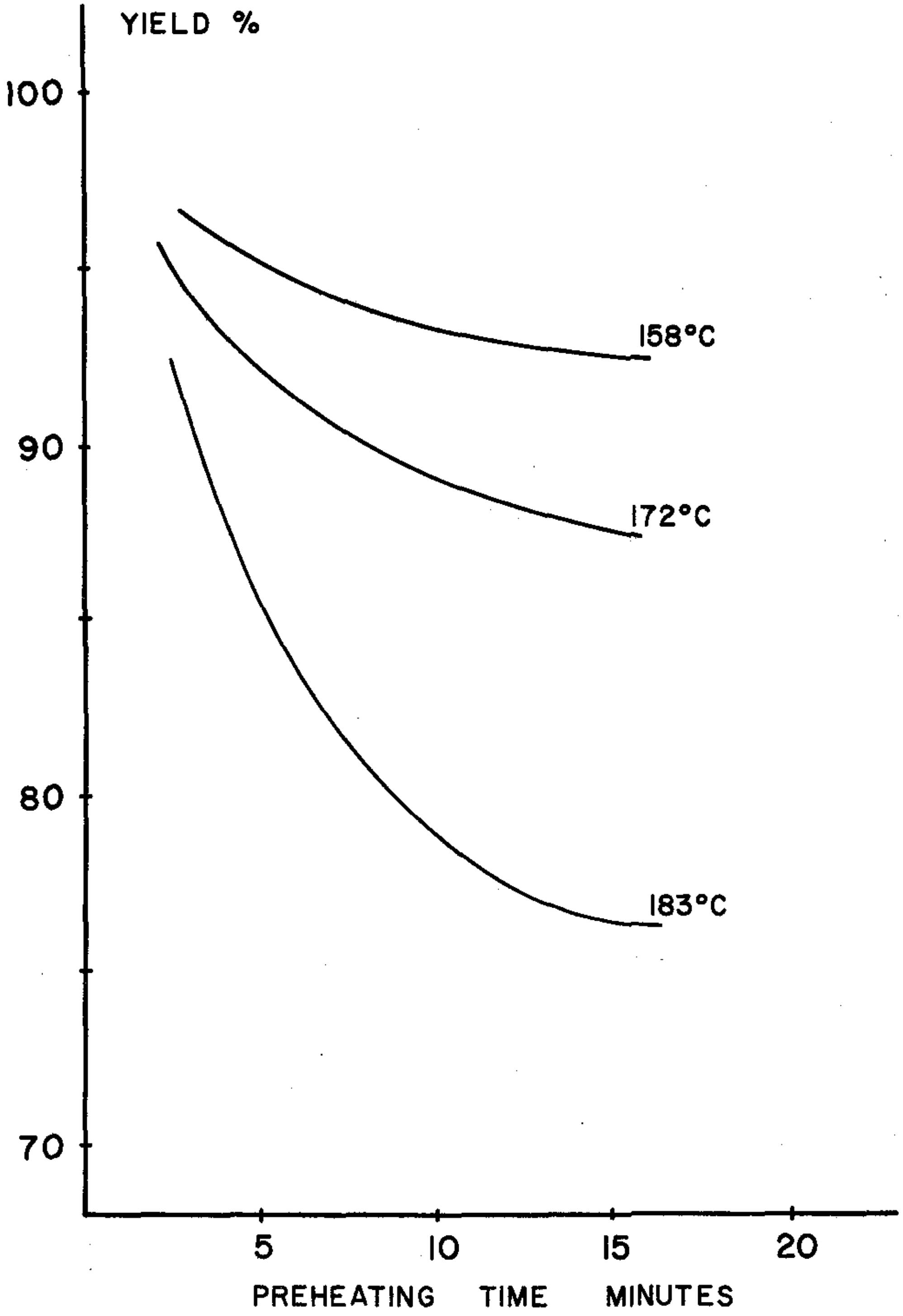


FIGURE 19 - EFFECT OF PREHEATING TIME AND TEMPERATURE ON YIELD

dissolved in the thermal-mechanical process was made by Edhborg in 1958. 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.

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.

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 24 and 25 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.

Mat Formation and Pressing

Figure 11 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 waste water. Process water may be recycled until the temperature, or the concentration of soluble organics or suspended solids becomes too high. Normally, fresh makeup water

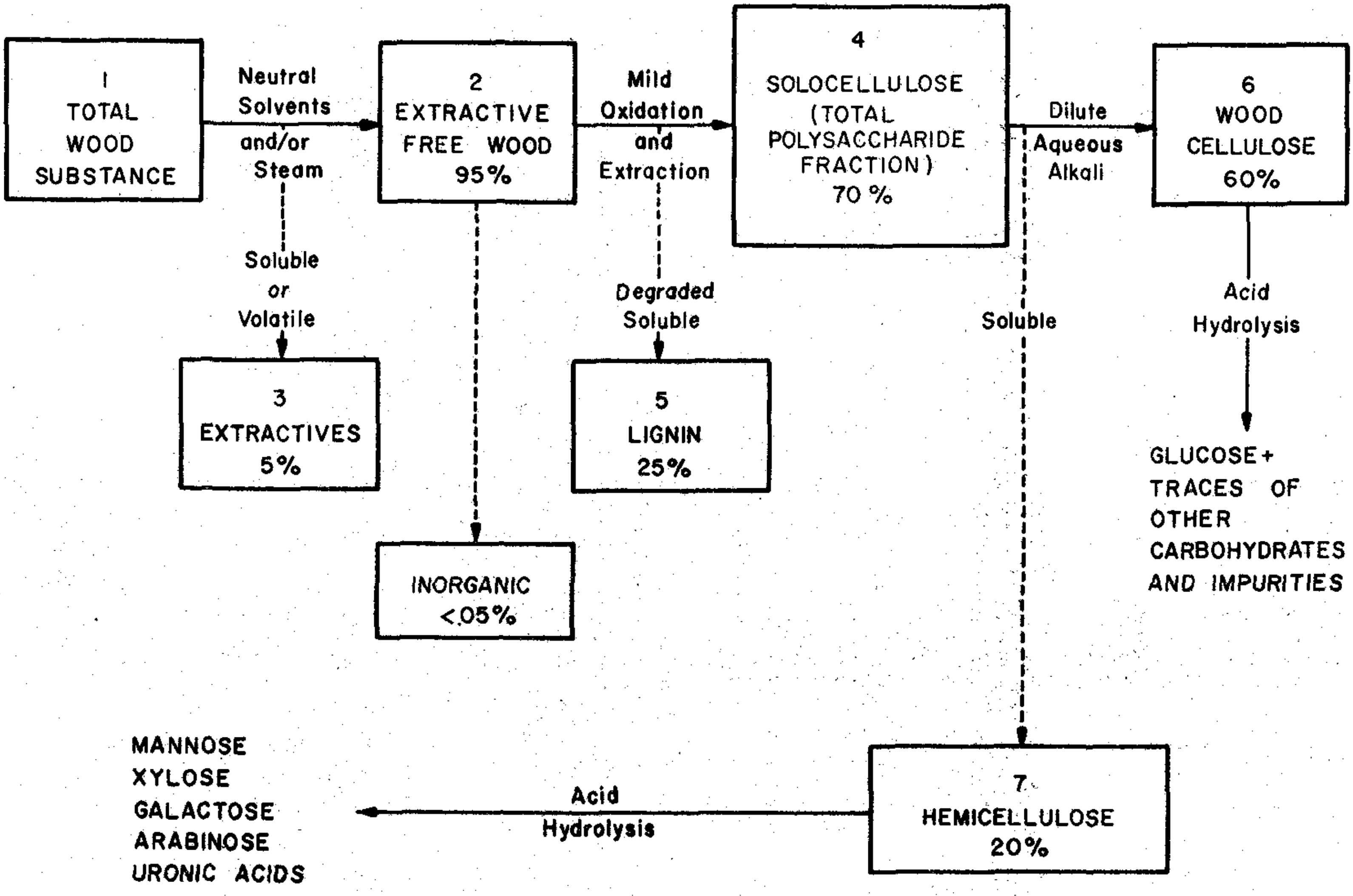


FIGURE 20 - THE CHEMICAL COMPONENTS OF WOOD

TABLE 24

SOME PROPERTIES OF CERTAIN UNITED STATES WOODS

	Specific gravity	*Shrinkage, %*	*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	14.1	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[c]	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[g]	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	—	780	810	61.3	—	4.0[h]	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	0.4
Sweet	0.44	15.0	—	520	630	59.6	20.5	2.8	0.8
Maple									
Red	0.49	13.1	—	700	780				
Silver	0.44	12.0	—	590	670				
Sugar	0.56	14.9	13.7	970	1,070	60.8	23.2	4.4	0.3
Poplar									
Quaking aspen	0.35	11.5	18.4	300	280	65.5	23.4	3.0	1.1
Balsam	0.30	10.5	—	230	240				
Eastern cottonwood	0.37	14.1	14.7	340	380	63.2	23.6	2.0	0.4
Large-tooth aspen	0.35	11.8	—	370	400				
Sycamore	0.46	14.2	—	610	700				
Yellow poplar	0.38	12.3	—	340	390	61.7	20.0	2.0	0.2

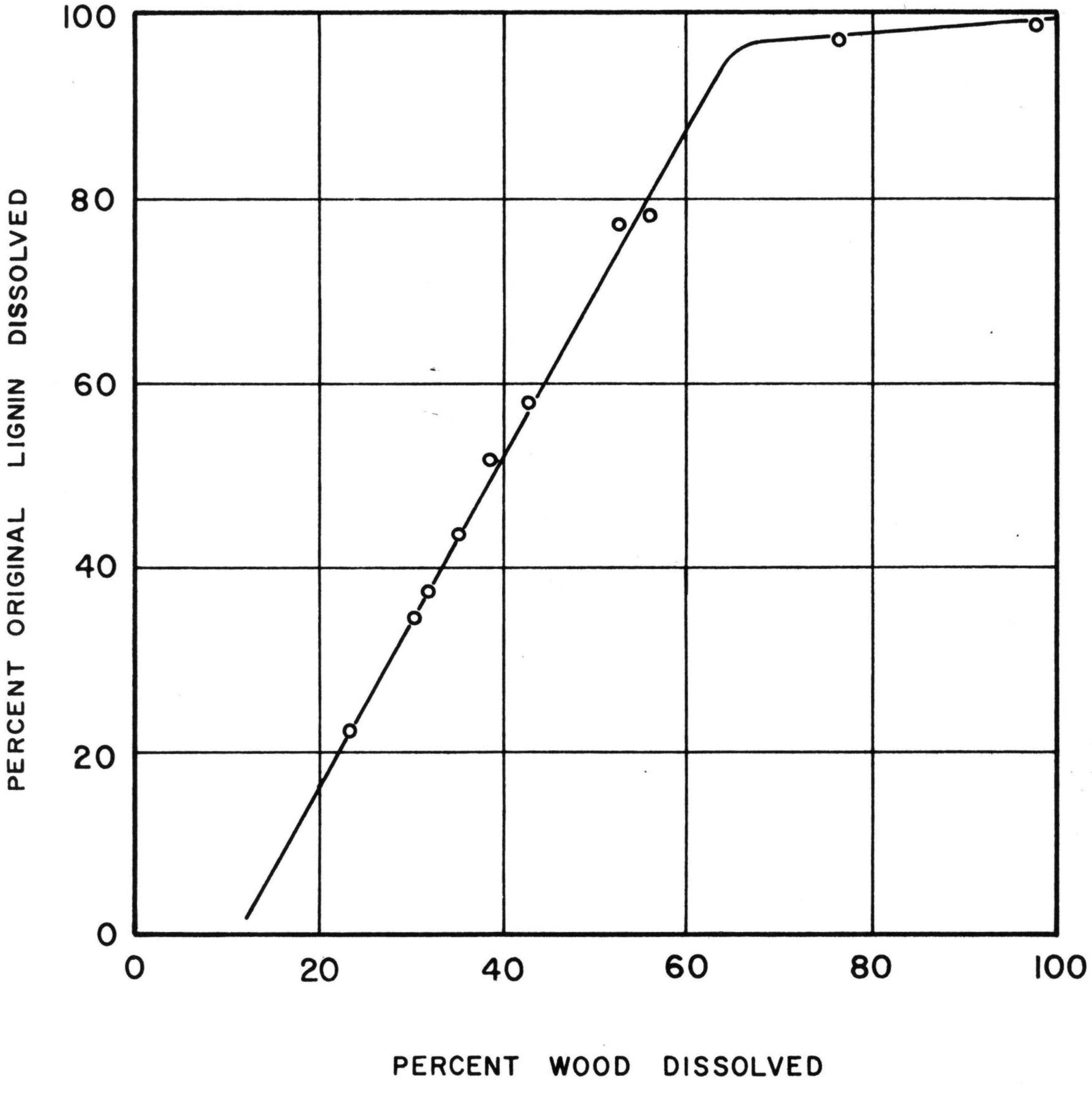


FIGURE 21 - RELATION BETWEEN DISSOLVED LIGNINS AND WOOD

TABLE 25

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				
a-Cellulose	57.2	55.0	51.5	45.7
Hemicellulose	14.1	15.3	17.4	23.3
Total (a	100.6	101.2	98.4	97.7
Summation B				
a-Cellulose (b	48.3	46.6	45.6	43.7
Mannac (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	0.2	0.2	0.6
Total (a	92.0	96.3	97.9	97.5

a) Including ash, acetyl, and lignin.
b) Corrected for mannan, xylan, and uronic anhydride.
c) By the phenylhydrazine method; the figures are probably low.
d) Calculated from methoxyl not in lignin.

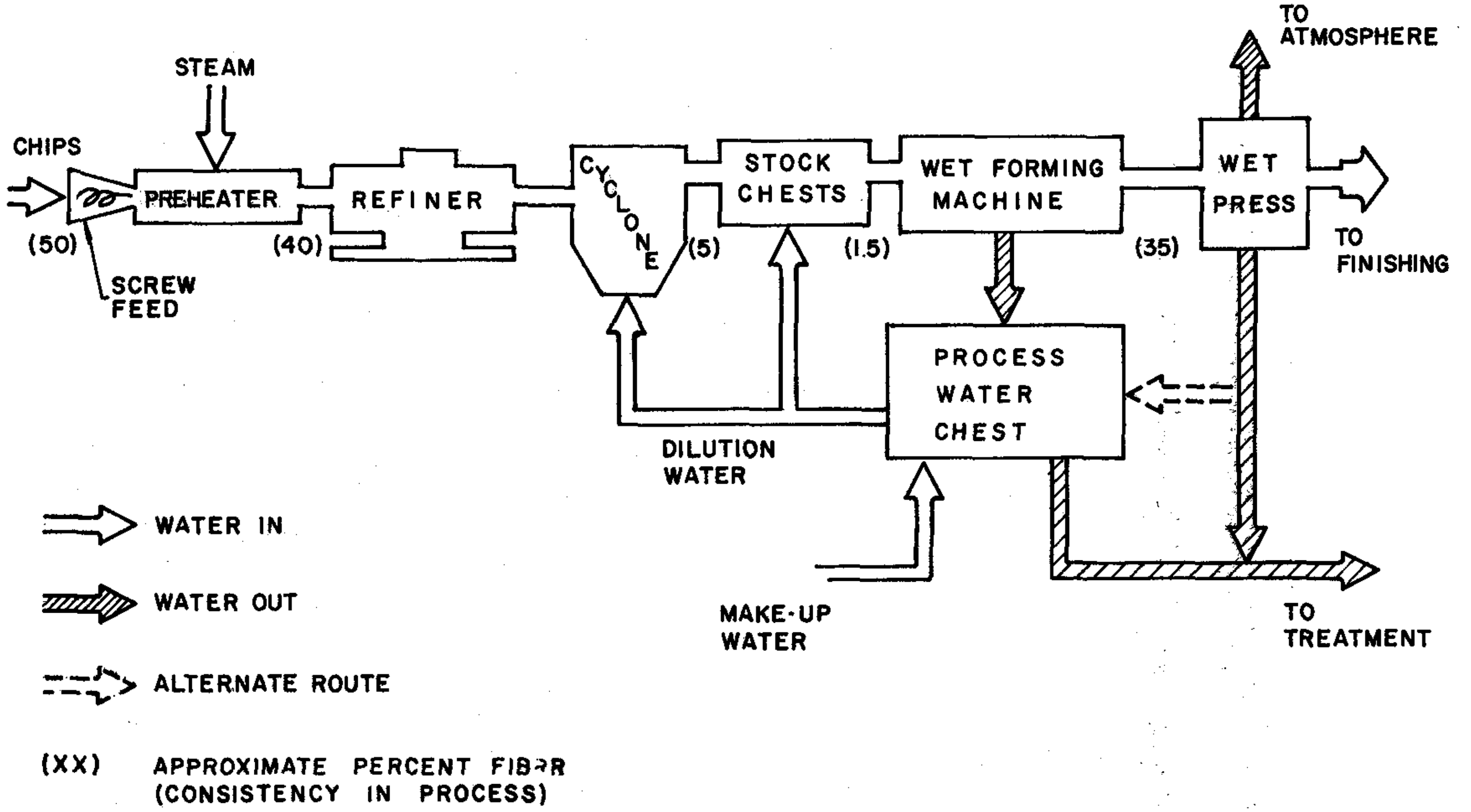


FIGURE 22 - PROCESS WATER RECYCLE IN A TYPICAL WET PROCESS HARDBOARD MILL

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. Two plants use process water for fiber washing. Fiber wash water from the explosion process is a major source of pollutants. A waste load from this process alone of 40 kg/kkg (80 lb/ton) into a flow of 2.5 cu m/kkg (600 gal/ton) is reported. Typical waste water concentrations of this fiber wash are:

BOD = 22,620 mg/l
COD = 51,100 mg/l
TSS = 32,000 mg/l
Volume = 2.5 cu m/kkg (600 gal/ton)

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

Two other wet process mills which use the thermal-mechanical cooking process wash fiber prior to mat formation. These mills do not evaporate this washwater separately as is done by the explosion process mills, but discharge it directly to waste.

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, that the board coming from the press has a zero percent moisture, and that there is no recycle, approximately 66.8 cu m/kkg (16,000 gal/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 (86°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, certain corrosion problems are experienced. Machines become very humid, making working conditions unpleasant. A critical temperature seems to exist after which spots will appear on the board, thereby lowering the

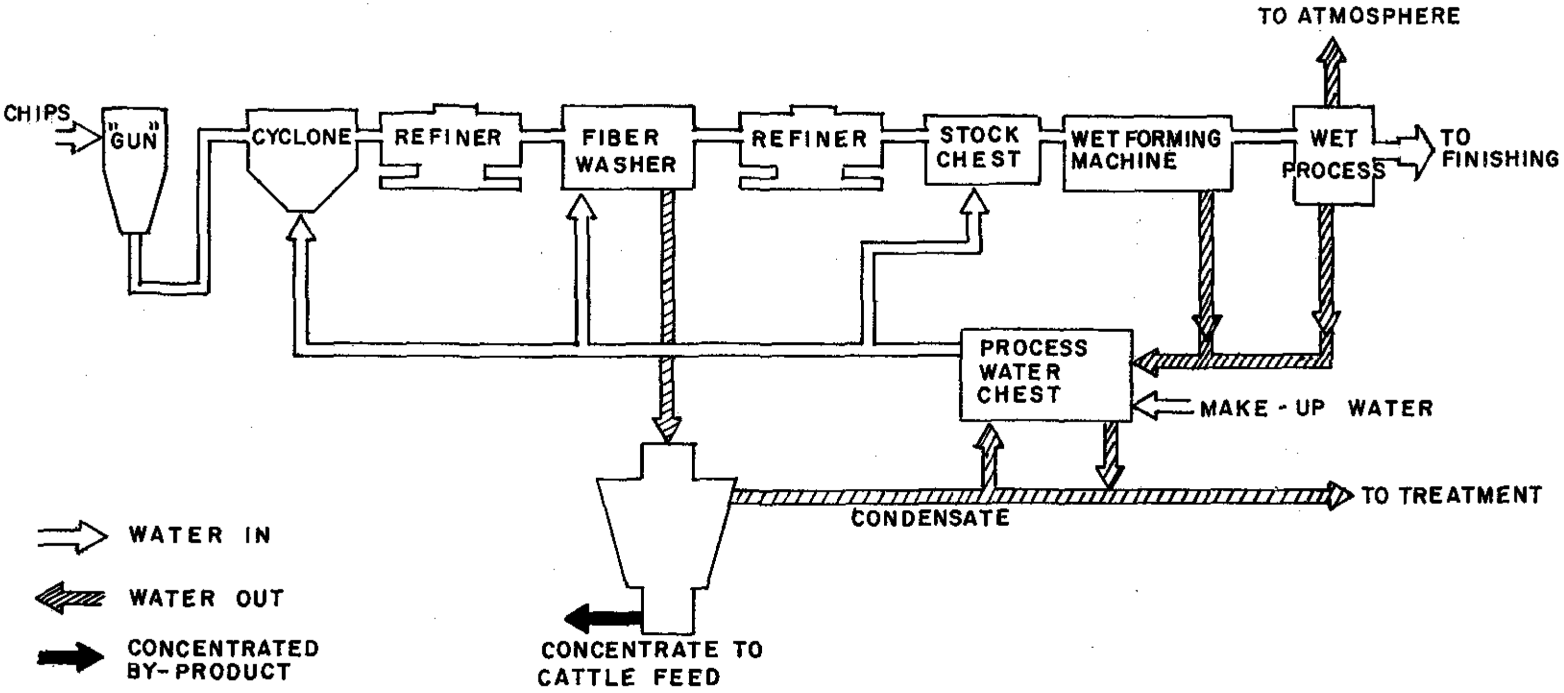


FIGURE 23 - PROCESS WATER RECYCLE IN A HARDBOARD MILL USING THE EXPLOSION PROCESS

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 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 related to concentration and type of soluble materials in the process water.

The effect of suspended solids concentrations relates to the dewatering characteristics of the board. 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. This can be attributed to a buildup of fines which cause the mat to dewater slowly. As the suspended solids level becomes too high in the process water they must be removed either by blowing down this concentrated water and diluting it with fresh water, or by removing the solids from the process water by some other means.

Miscellaneous Waste Water Sources

By far the major waste water discharges from a wet process hardboard mill are process water from mat formation, pressing, and fiber washing. Other waste water sources which may be classified as miscellaneous streams include resin system wash water, caul wash water, housekeeping water, and cooling water. A discussion of these sources can be found in the earlier part of this section relating to dry process hardboard.

Total Waste water Flow

Table 26 is a summary of the total waste water flow from seven wet process hardboard mills. Table 27 gives a summary of the average waste water concentrations from these same mills.

Waste water flows vary from about 4.6 to 45.9 cu m/kkg (1,000 to 11,000 gal/ton), BOD concentrations vary from 700 mg/l to 4,000 mg/l and suspended solids from 220 to 1,650 mg/l. A comparison of data reported as raw waste water concentrations from mill to mill should be made with caution. Several mills report raw waste water 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 BOD_5 in the raw waste water ranges from 28 to 50 kg/kkg (56 to 100 lb/ton), while average discharge of suspended solids ranges from 3.2 to 19 kg/kkg (6.4 to 38 lb/ton).

TABLE 26

WASTEWATER DISCHARGES FROM WET PROCESS HARDBOARD

Plant	Production (metric tons)	Wastewater (cubic meters/day)	Wastewater (cubic meters/kkg
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 27

RAW WASTEWATER CHARACTERISTICS FROM WET PROCESS HARDBOARD

	Discharge Flow		BOD		S.S.		
Plant	cu m/D	cu m/metric ton	mg/l	kg/kkg	mg/l	kg/kkg	pH
1	4,164	45.9	720	33	220	10	--
2	2,945	38.2	1,130	50	--	--	--
3+*	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
\+ Masonite Explosion Process

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

Parameter	Concentration (mg/l)
BOD	1,300 - 4,000
COD	2,600 - 12,000
Suspended Solids	400 - 1,100
Total Dissolved Solids	500 - 4,000
Kjeldahl Nitrogen	017 4.0
Phosphates, as P	0.3 - 3.0
Turbidity	80 - 700
Phenols	0.7 - 1.0
pH Range	4.0 - 5.0

Water Balance for a Typical Wet Process Hardboard Mill For the purpose of illustrating the water requirments in a wet hardboard manufacturing plant, presented below is a water balance. This presentation is not intended to suggest that the average (or typical,) plant in the industry produces 127 kkg/day. The water intakes and outflows are presented also on a volume of water per unit of production basis, also, to illustrate the water requirement and outflows related to the operations involved in the manufacture of hardboard.

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

Water Inflows. Water inflows 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.

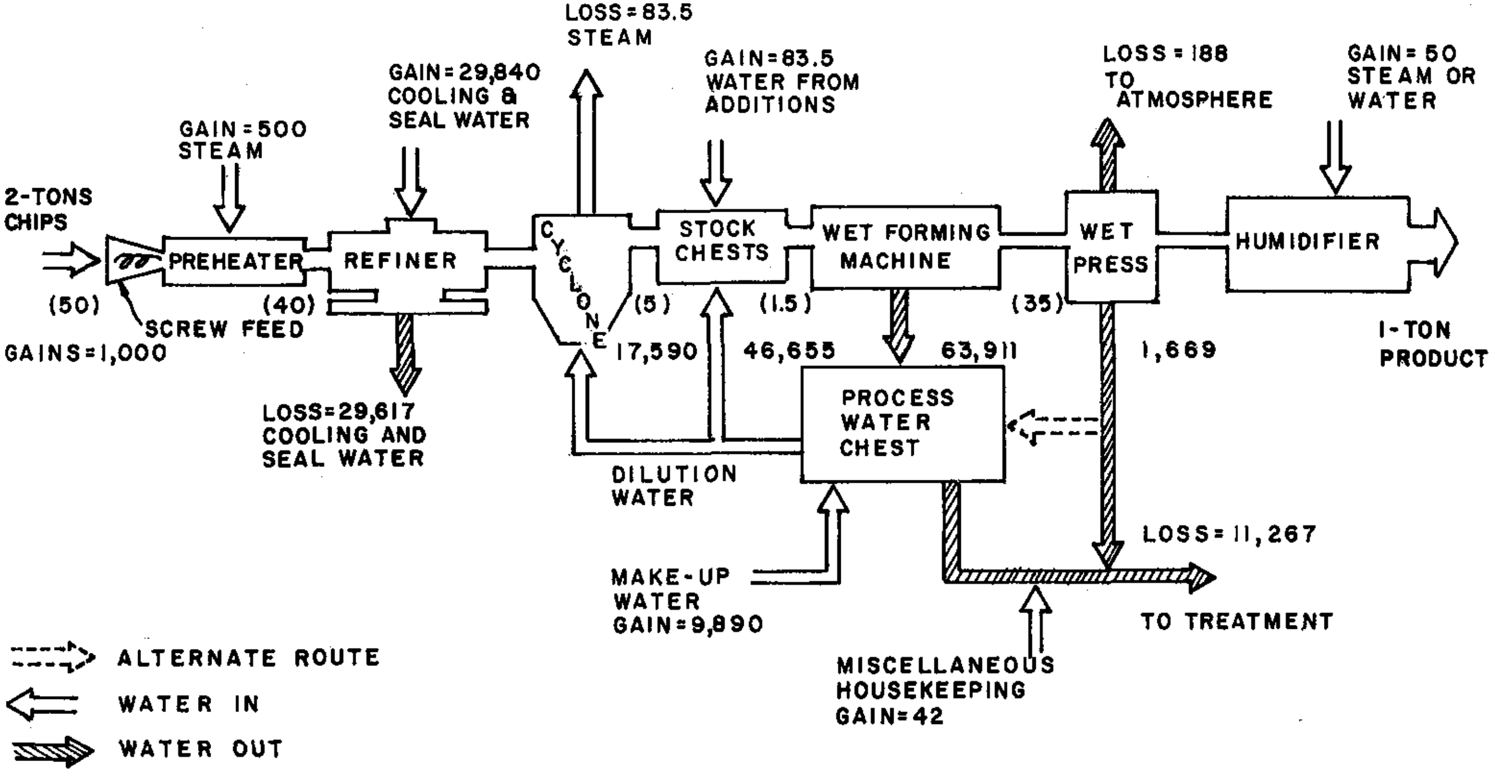
The volume of miscellaneous housekeeping water, used for such things as floor and caul washing, is highly variable. There is little data as this stream is normally discharged to the treatment system with the process water without monitoring.

Water from incoming chips = 1,000 l/kkg
(50 percent moisture) (240 gal/ton)

Steam to preheater = 500 l/kkg
(120 gal/ton)

Cooling and seal water = 29,840 l/kkg
(7,150 gal/ton)

Additive dilution water = 83.5 l/kkg
(20 gal/ton)



(XX) PERCENT FIBER (CONSISTENCY IN PROCESS)

ALL NUMBERS = LITERS / METRIC TON

TOTAL GAIN	41,405
TOTAL LOSS	41,405

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

Process water makeup = 9,890 l/kkg (2,370 gal/ton)

Humidifier = 50 l/kkg (12 gal/ton)

Miscellaneous housekeeping = 42 l/kkg (10 gal/ton)

Total Water Inflows =41,405 l/kkg of product (9,922 gal/ton)

Water Outflows: Water outflows in a wet process mill result from:

Press Evaporation = 188 l/kkg (45 gal/ton)

Cooling and Seal Water discharge) = 29,817 l/kkg (7,145 gal/ton)

Steam from cyclone = 83.5 l/kkg (20 gal/ton)

Discharge of excess process water (includes miscellaneous housekeeping water discharge = 11,267 l/kkg (2,700 gal/ton)

Water in product = 50 l/kkg (12 gal/ton)

Total Water Outflows = 41,405 l/kkg of product (9,922 gal/ton)

WOOD PRESERVING SUBCATEGORIES

Waste water 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 retorts are diluted with water from other sources. Typically, waste waters 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/l, most of which is attributable to entrained oils and to wood extractives, principally simple sugars, that are removed from wood during conditioning.

Closed Steam Conditioning

The characteristics of wood preserving waste water 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, in addition to 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 waste water; and as a result of the reduction of the oily content, the oxygen demand and the solids content of the waste water are reduced significantly, relative to the effluent from plants using open steaming. Typical oil and COD values from a single plant before and after the plant commenced modified-closed steaming are shown in Figures 25 and 26, respectively. The COD of the waste water 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 reuse of the water. Because practically all of the solids content of this waste are dissolved solids, only insignificant reductions in oxygen demand and 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 28. 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 waste water and total weight of pollutants released can be achieved by using closed steaming.

Effect of Time

Because many plants use the same preservatives and follow essentially the same treating practices, the waste waters 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.

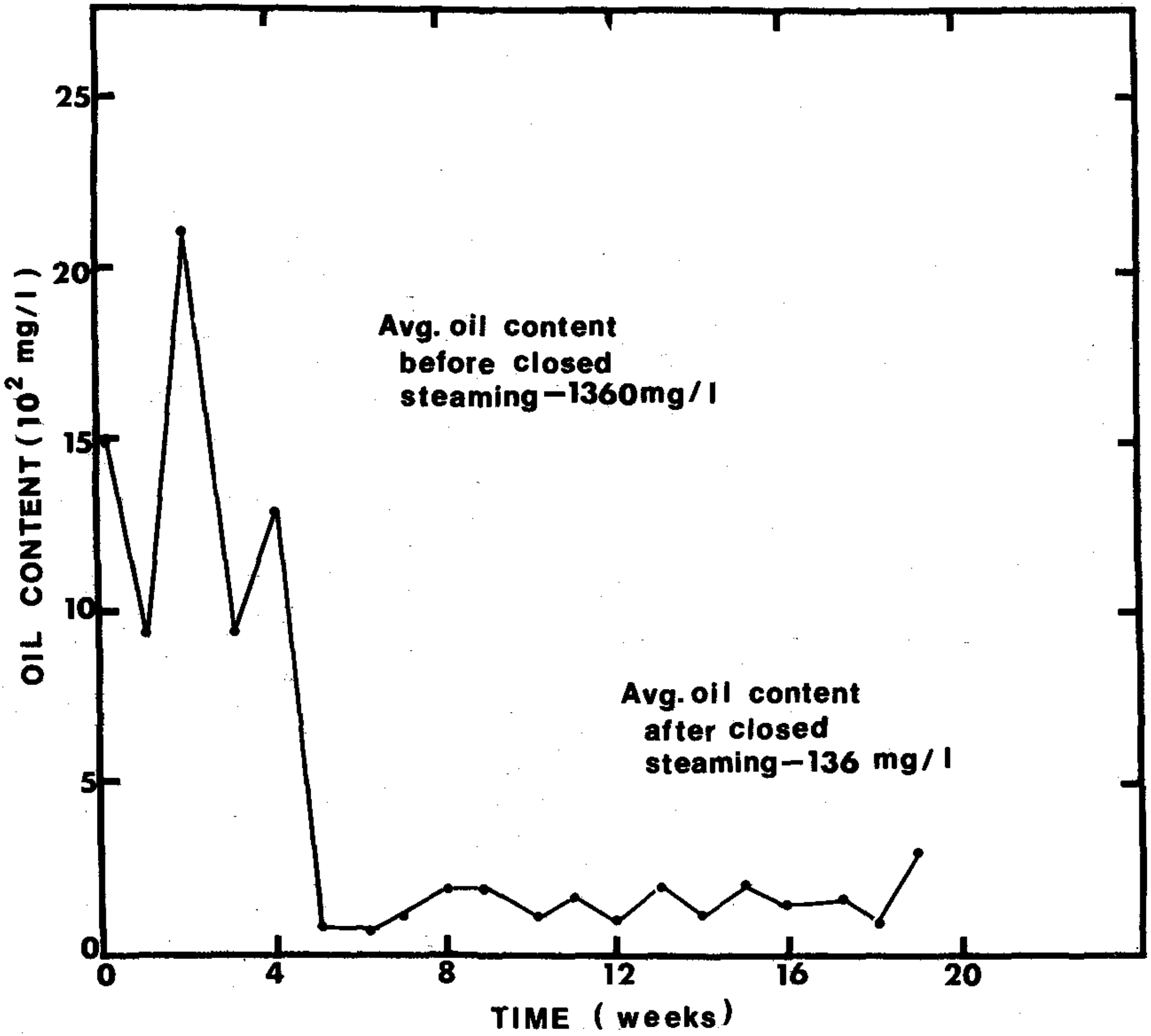


FIGURE 25 - VARIATION IN OIL CONTENT OF EFFLUENT WITH TIME BEFORE AND AFTER INITIATING CLOSED STEAMING

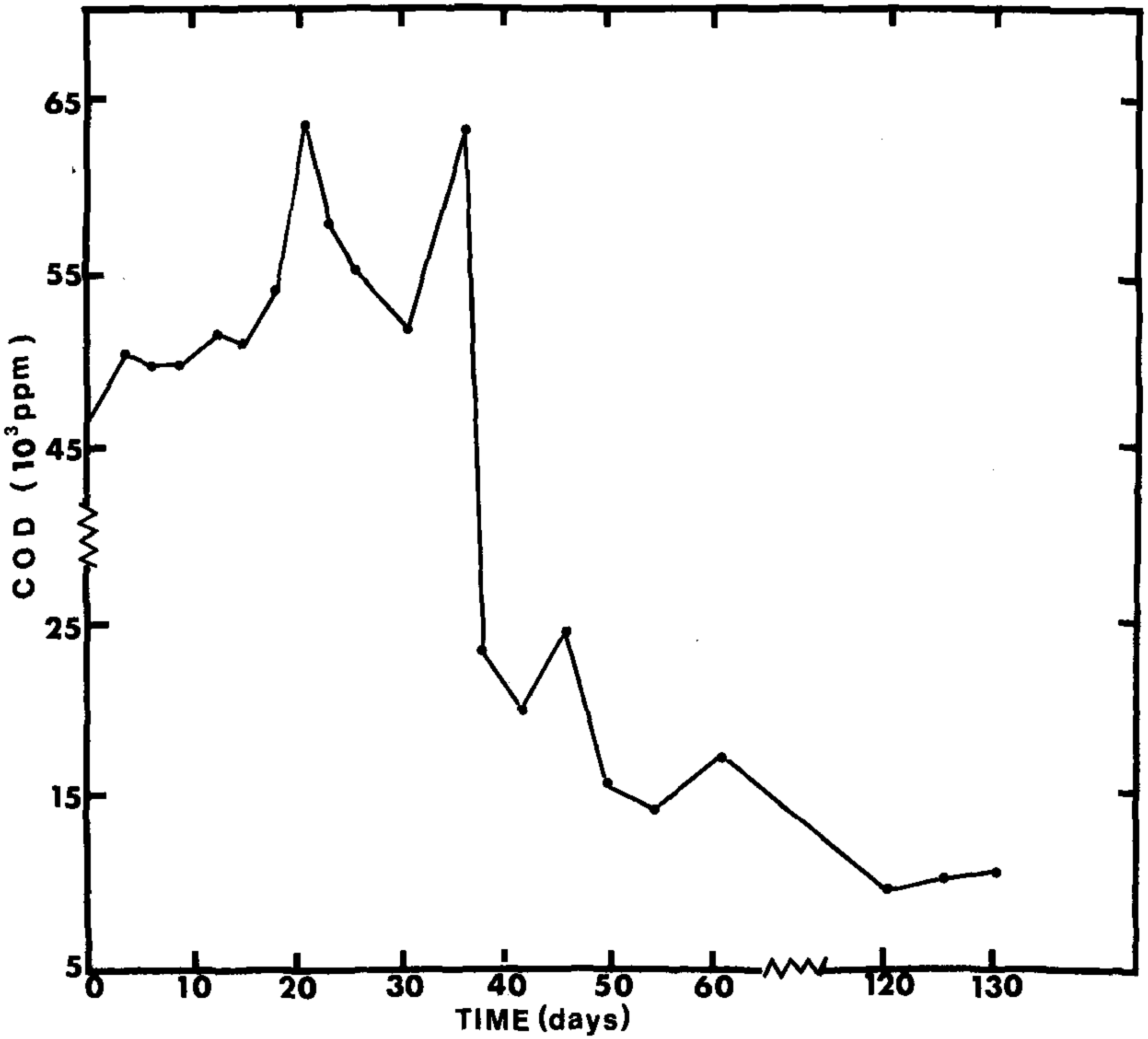


FIGURE 26 - VARIATION IN COD OF EFFLUENT WITH TIME BEFORE AND AFTER CLOSED STEAMING: DAYS 0-35 OPEN STEAMING; DAYS 35-130 CLOSED STEAMING

TABLE 28

PROGRESSIVE CHANGES IN SELECTED CHARACTERISTICS OF WATER RECYCLED IN CLOSED STEAMING OPERATIONS

Charge Number	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/l

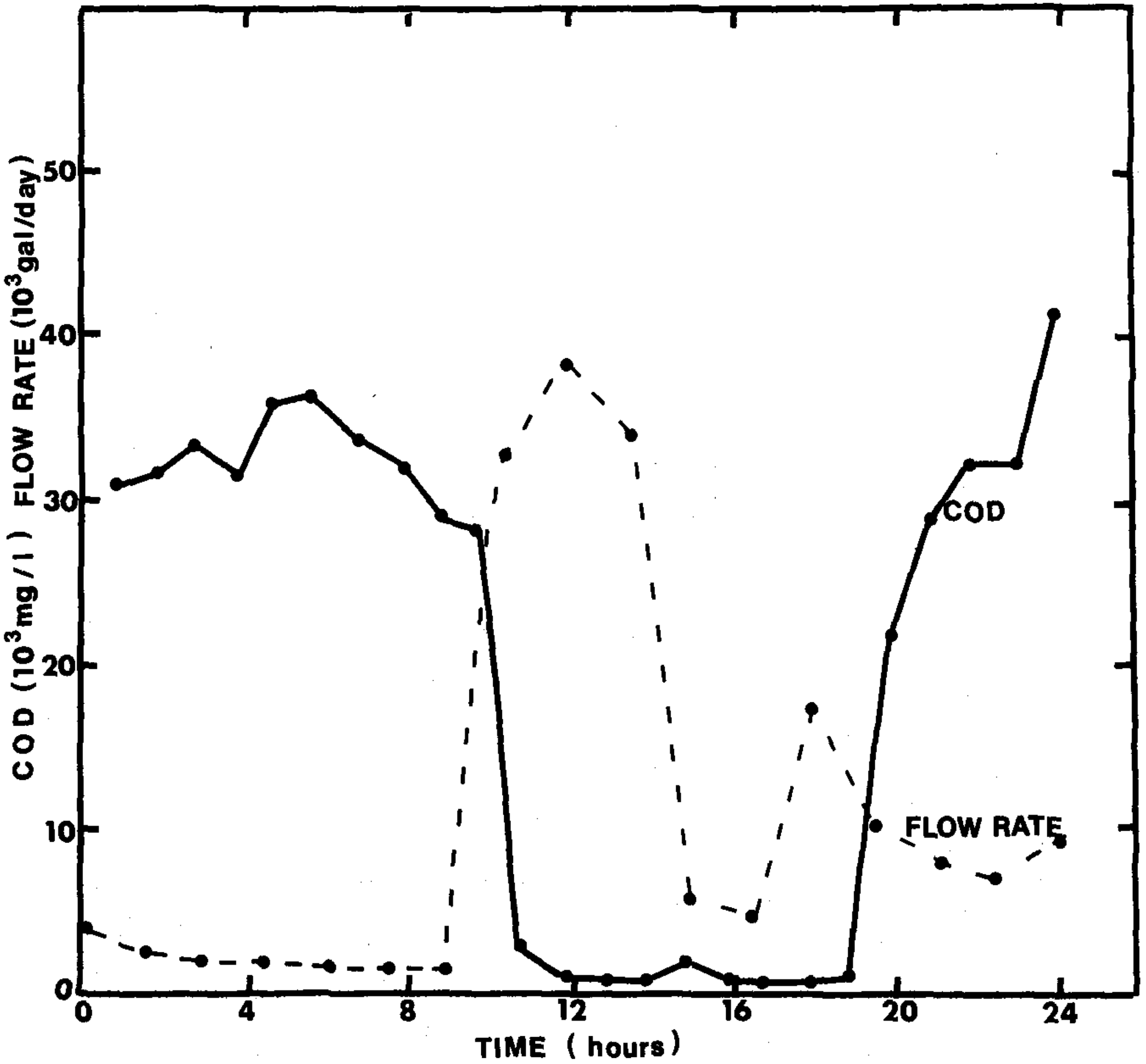


FIGURE 27 - VARIATION IN COD CONTENT AND WASTEWATER FLOW RATE WITH TIME

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/l to 43,000 mg/l during the 24 hour sampling period, a 100-fold variation. Flow rate varied from 7570 l/day to 151,400 l/day (2,000 gal/day to 40,000 gal/day). 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 29, which show the phenol and COD values of raw waste for 13 plants. Also shown in the same 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 after flocculation.

Biological Characteristics

Waste water 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/l 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 the result of the characteristics of the waste samples or differences in the bacterial cultures employed and their degree of acclimation to the waste. Dust and Thompson obtained differences in BOD values for creosote waste water of 200 percent among several acclimated cultures of bacteria.

The correlation between BOD and COD for wood preserving waste water is high. Using creosote waste water with BOD values larger than 150 mg/l, the above authors found that the equation $BOD=0.497\ COD + 60$, for which $r=0.985$, accounted for practically all of the variation between the two parameters (Figure 28). The general applicability of this equation was indicated by spot

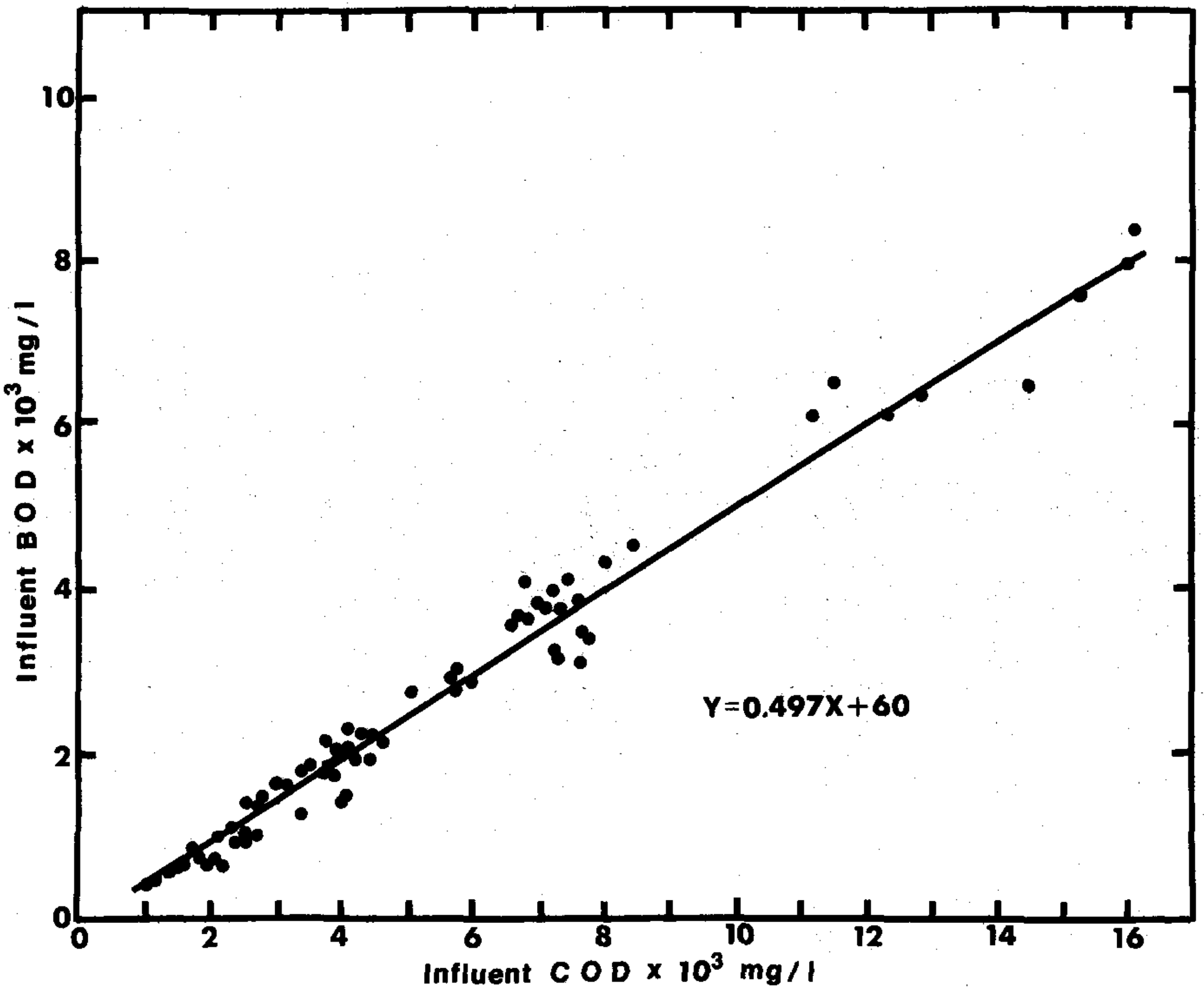


FIGURE 28 - RELATIONSHIP BETWEEN BOD AND COD FOR WASTEWATER FROM A CREOSOTE TREATING OPERATION

TABLE 29

PHENOL AND COD VALUES FOR EFFLUENTS FROM THIRTEEN WOOD PRESERVING PLANTS

Plant Location	Phenol (mg/1)	COD (mg/1) Raw	COD (mg/1) After Flocculation	COD (mg/1) Percent Reduction
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

TABLE 30 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 31 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
PO4	15 - 150
NH_3-N	80 - 200
pH	5.0 - 6.8

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/l (Table 30), and averages 6.2 for values in the range of 20 to 40 mg/l. 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

Waste waters 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 31. The presence and concentration of a specific ion in waste water for 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 5 typical wood preserving plants treating with pentachlorophenol-petroleum solutions and/or creosote are given in Tables 32 through 36. Data for plants 1 through 4 (Tables 32-35) 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 (Table 36) 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 blowdown 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/l) and kg/1000 cu m of product treated for each of the 5 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 32-36 is shown in Table 37. 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 is 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.

TABLE 32

RAW WASTE LOADINGS FOR PLANT NO. 1

	Raw Waste Loadings Parenthetical values = Pounds/1000 Cubic Feet		Raw Waste Loadings/Day(Kg) Parenthetical values are in pounds		
Parameter	(mg/l)	Kg/1000 Cubic Meters 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 (.2)	5.6 (12.4)
Oils 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			

Avg. flow = 42,494 lpd (11,227 gpd)
Void vol. of cylinders = 293 cubic meters (10,337 cubic feet)
1971 production (est.) = 26,760 cubic meters (945,000 cubic feet)
Avg. work days/yr. = 225
Avg. daily production = 119 cubic meters (4,200 cubic feet)
Preservatives = Creosote

TABLE 33

RAW WASTE LOADINGS FOR PLANT NO. 2

	Raw Waste Loadings Parenthetical values = Pounds/1000 Cubic Feet		Raw Waste Loadings/Day(Kg) Parenthetical values are in pounds		
Parameter	(mg/l)	Kg/1000 Cubic Meters 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)
Oils and Grease	55	19.3 (1.2)	4.6 (10.2)	2.0 (4.4)	3.7 (8.2)
Total Solids	3,504	1,190.0 (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			

Avg. flow = 68,471 lpd (18,090 gpd)
Void Vol. of cylinders = 427 cubic meters (15,068 cubic feet)
Est. 1971 production = 60,163 cubic meters (2,124,588 cubic feet)
Avg. work days/yr. = 300
Avg. daily production = 201 cubic meters (7,082 cubic feet)
Preservatives - Creosote, Pentachlorophenol

TABLE 34

RAW WASTE LOADINGS FOR PLANT NO. 3

	Raw Waste Loadings Parenthetical values = Pounds/1000 Cubic Feet		Raw Waste Loadings/Day(Kg) Parenthetical values are in pounds		
Parameter	(mg/l)	Kg/1000 Cubic Meters 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 Solids	196	51.4 (3.2)	14.8 (32.6)	7.9 (17.4)	11.1 (24.5)
pH		4.5			

Avg. flow (est.) = 56,775 lpd (15,000 gpd)
Void vol. of cylinders = 457 cubic meters (16,152 cubic feet)
Est. 1971 production = 64,491 cubic meters (2,277,432 cubic feet)
Avg. work days/yr. = 300
Avg. daily production = 215 cubic meters (7,591 cubic feet)
Preservatives - Creosote, Pentachlorophenol

TABLE 35

RAW WASTE LOADINGS FOR PLANT NO. 4

	Raw Waste Loadings Parenthetical values = Pounds/1000 Cubic Feet		Raw Waste Loadings/Day(kg) Parenthetical values are in pounds		
Parameter	(mg/l)	Kg/1000 Cubic Meters 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	2,748	675.7 (42.1)	383.1 (842.4)	93.8 (206.4)	166.1 (365.5)
Suspended Solids	684	168.5 (42.1)	147.4 (324.2)	6.0 (13.3)	41.3 (90.9)
pH		5.8			

Avg. flow (est.) = 60,560 lpd (16,000 gpd)
Void vol. of cylinders = 523 cubic meters (18,470 cubic feet)
Est 1971 production = 73,746 cubic meters (2,604,270 cubic feet)
Avg. work days/yr. = 300
Avg. daily production = 246 cubic meters (8,681 cubic feet)
Preservatives - Creosote, Pentachlorophenol

TABLE 36

RAW WASTE LOADINGS FOR PLANT NO. 5

	Raw Waste Loadings Parenthetical values = Pounds/1000 Cubic Feet		Raw Waste Loadings/Day(kg) Parenthetical values are in pounds		
Parameter	(mg/l)	Kg/1000 Cubic Meters 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)
Phenols	126	28.9 (1.8)	5.1 (11.2)	3.4 (7.4)	4.3 (9.4)
Oils 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			

Void vol. of cylinders = 356 cubic meters (12,557 cubic feet)
Est. 1971 production = 44,175 cubic meters (1,560,000 cubic feet)
Avg. work days/yr. = 300
Avg. daily production = 147 cubic meters (5,200 cubic feet)
Preservatives - Creosote, Pentachlorophenol

TABLE 37

AVERAGE RAW WASTE LOADINGS FOR FIVE WOOD-PRESERVING PLANTS

	Raw Waste Loadings Parenthetical values = Pounds/1000 Cubic Feet		Raw Waste Loadings/Day(kg) Parenthetical values are in pounds		
Parameter	(mg/l)	Kg/1000 Cubic Meters 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)
Oils 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			

Avg. flow = 52,990 lpd (14,000 gpd)
Void vol. of cylinders = 411 cubic meters (14,517 cubic feet)
Est. 1971 Production = 53,867 cubic meters (1,902,258 cubic feet)
Avg. work days/yr. = 285
Avg. daily production = 189 cubic meters (6,674 cubic feet)
Preservatives - Creosote, Pentachlorophenol

Sources of Waste Water

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

a. Condensate from conditioning by steaming: This is the most heavily contaminated waste water, 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, 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 blowdown water: This 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 waste water 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 waste water discharged by a hypothetical wood preserving plant (Table 37) that employs steam conditioning are shown in Figure 29. A more complete breakdown of these data is given in Table 38. A representative plant has an intake of approximately 121,120 l/day (32,000 gal/day), gross water usage

TABLE 38

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

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
a) Water extracted from wood and recycled as cooling water.
b) Approximately 15 percent loss due to flash evaporation.
c) Loss of cooling water by drift and evaporation.

Note: Based on hypothetical plant, data for which are given in TABLE 3 .

of 567,750 l/day (150,000 gal/day), and a discharge of 104,100 l/day (27,500 gal/day). An estimated 13,250 l/day (3,500 gal/day) of cooling water are lost by evaporation. Roughly 446,650 l/day (118,000 gal/day) are recycled as cooling water, including 6,400 l/day (1,700 gal/day) of water extracted during the conditioning process (vacuum water). The amount of vacuum water recovered averages about 1.9 kg/cu m (4.3 lb/cu ft) of green wood that is steam conditioned. Approximately two times this amount of vacuum water is removed from Boultonized stock.

The actual volume of water used at a plant of this size and type is not static, but 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 38 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 waste water. 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 l/day (1 million gal/day).

Assuming recycling of cooling and coil condensate water, the most important source of waste water in terms of volume and level of contamination is cylinder condensate. The amount of waste water 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

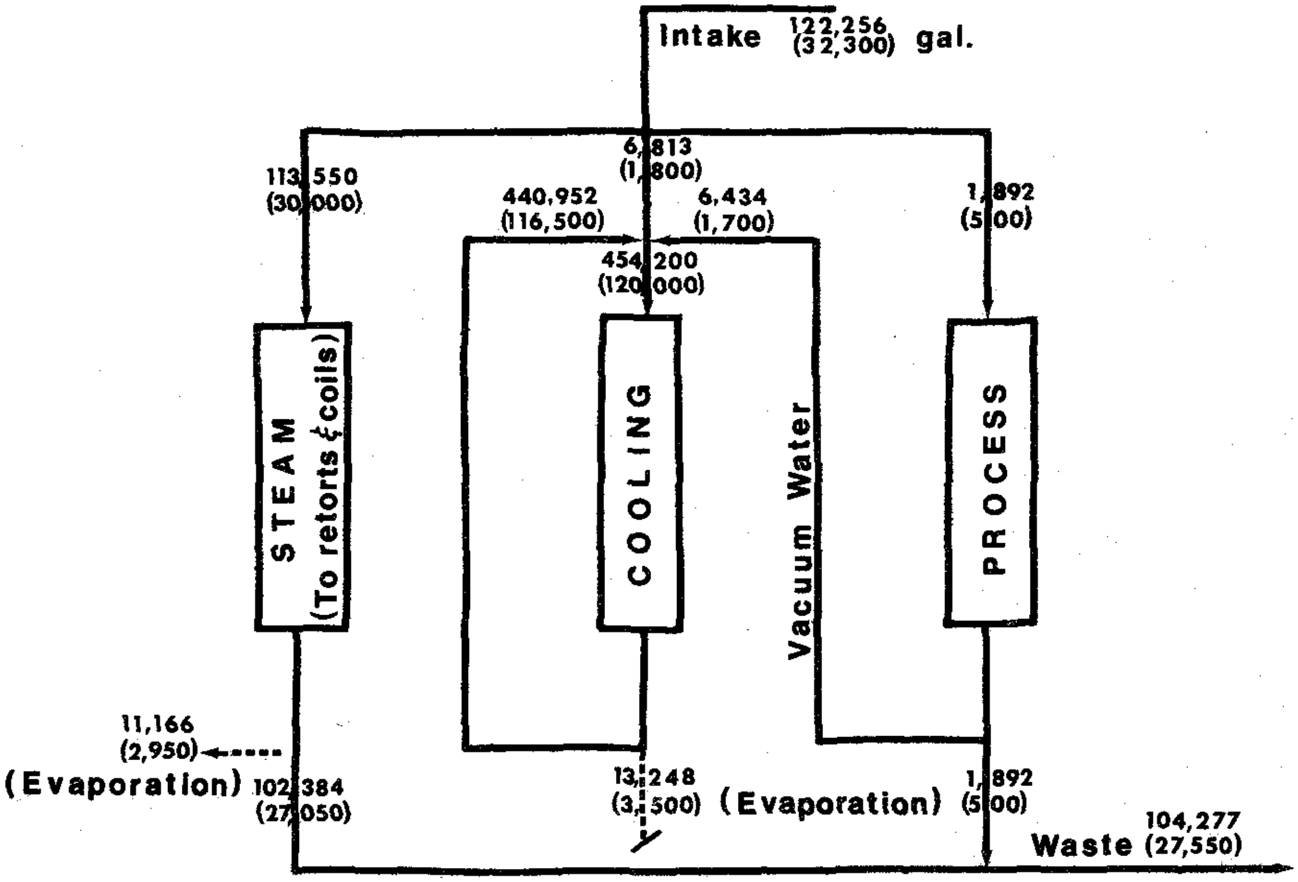


FIGURE 29 - SOURCE AND VOLUME OF DAILY WATER USE AND RECYCLING AND WASTEWATER SOURCE AT A TYPICAL WOOD-PRESERVING PLANT

the volume of waste does not vary widely among plants of comparable size and generally is less than 75,500 l/day (20,000 gal/day).

SECTION VI

POLLUTANT PARAMETERS

Presented below is a discussion of pollutants and pollutant parameters that may be present in process waters in the portion of the timber products processing industry that is the subject of this effluent guidelines and standards development document.

Certain of these parameters are common to all the subcategories covered by this document, although the concentrations in the process water and the absolute amounts generated per unit of production vary considerably among the subcategories.

Review of published information, Refuse Act Permit applications, industry data, and information generated during the survey and analysis phase of this effluent guidelines development program determined that the following pollutants or pollutant parameters are common to all of the subcategories:

Biochemical Oxygen Demand (BOD_5)
Chemical Oxygen Demand
Phenols
Oil and Grease
pH
Temperature
Dissolved Solids
Total Suspended Solids
Phosphorus
Ammonia

The wood preserving subcategories may have the following pollutants or pollutant parameters present in process water flows:

Copper
Chromium
Arsenic
Zinc
Flourides

The above listed pollutants or pollutant parameters are, of course, not present in process water from all the subcategories for which effluent guidelines and standards are presented in this document. Their presence depends on a number of factors, such as processing method, raw materials used, and chemicals added to the process.

Following is a discussion of the significant pollutants and pollutant parameters.

Biochemical Oxygen Demand (BOD5)

Biochemical oxygen demand (BOD) is a measure of the oxygen consuming capabilities of organic matter. The Biochemical Oxygen Demand does not in itself cause direct harm to a water system, but it does exert an indirect effect by depressing the oxygen content of the water. Sewage and other organic effluents during their processes of decomposition exert a Biochemical Oxygen Demand, which can have a catastrophic effect on the ecosystem by depleting the oxygen supply. Conditions are reached frequently where all of the oxygen is used and the continuing decay process causes the production of noxious gases such as hydrogen sulfide and methane. Water with a high Biochemical Oxygen Demand indicates the presence of decomposing organic matter and subsequent high bacterial counts that degrade its quality and potential uses.

Dissolved oxygen (DO) is a water quality constituent that, in appropriate concentrations, is essential not only to keep organisms living but also to sustain species reproduction, vigor, and the development of populations. Organisms undergo stress at reduced DO concentrations that make them less competitive and able to sustain their species within the aquatic environment. For example, reduced DO concentrations have been shown to interfere with fish population through delayed hatching of eggs, reduced size and vigor of embryos, production of deformities in young, interference with food digestion, acceleration of blood clotting, decreased tolerance to certain toxicants, reduced food efficiency and growth rate, and reduced maximum sustained swimming speed. Fish food organisms are likewise affected adversely in conditions with suppressed DO. Since all aerobic aquatic organisms need a certain amount of oxygen, the consequences of total lack of dissolved oxygen as a result or a high BOD can kill all inhabitants of the affected area.

If a high BOD is present, the quality of the water is usually visually degraded by the presence of decomposing materials and algae blooms due to the uptake of degraded materials that form the foodstuffs of the algal populations.

Chemical Oxygen Demand (COD)

Chemical oxygen demand (COD) provides a measure of the equivalent oxygen required to oxidize the organic material present in a waste water sample, under acid conditions with the aid of a strong chemical oxidant, such as potassium dichromate, and a catalyst (silver sulfate). One major advantage of the COD test is that the results are available normally in less than three hours. However, one major disadvantage is that the COD test does not differentiate between biodegradable and nonbiodegradable organic material. In addition, the presence of inorganic reducing chemicals (sulfides, etc.) and chlorides may interfere with the COD test. In certain cases where a definite ratio between BOD5 and COD can often serve as an indicator of organics that are not readily biodegradable.

Phenols

Phenols and phenolic wastes are derived from petroleum, coke, and chemical industries; wood distillation; and domestic and animal wastes. Many phenolic compounds are more toxic than pure phenol; their toxicity varies with the combinations and general nature of total wastes. The effect of combinations of different phenolic compounds is cumulative.

Phenols and phenolic compounds are both acutely and chronically toxic to fish and other aquatic animals. Also, chlorophenols produce an unpleasant taste in fish flesh that destroys their commercial value.

It is necessary to limit phenolic compounds in raw water used for drinking water supplies, as conventional treatment methods used by water supply facilities do not remove phenols. The ingestion of concentrated solutions of phenols will result in severe pain, renal irritation, shock and possibly death.

Phenols also reduce the utility of water for certain industrial uses, notably food and beverage processing, where it creates unpleasant tastes and odors in the product.

Oil and Grease

Oil and grease exhibit an oxygen demand. Oil emulsions may adhere to the gills of fish or coat and destroy algae or other plankton. Deposition of oil in the bottom sediments can serve to exhibit normal benthic growths, thus interrupting the aquatic food chain. Soluble and emulsified material ingested by fish may taint the flavor of the fish flesh. Water soluble components may exert toxic action on fish. Floating oil may reduce the re-aeration of the water surface and in conjunction with emulsified oil may interfere with photosynthesis. Water insoluble components damage the plumage and coats of water animals and fowls. Oil and grease in a water can result in the formation of objectionable surface slicks preventing the full aesthetic enjoyment of the water.

Oil spills can damage the surface of boats and can destroy the aesthetic characteristics of beaches and shorelines.

Temperature

Temperature is one of the most important and influential water quality characteristics. Temperature determines those species that may be present; it activates the hatching of young, regulates their activity, and stimulates or suppresses their growth and development; it attracts, and may kill when the water becomes too hot or becomes chilled too suddenly. Colder water generally suppresses development. Warmer water generally accelerates activity and may be a primary cause of aquatic plant nuisances when other environmental factors are suitable.

Temperature is a prime regulator of natural processes within the water environment. It governs physiological functions in organisms and, acting directly or indirectly in combination with other water quality constituents, it affects aquatic life with each change. These effects include chemical reaction rates, enzymatic functions, molecular movements, and molecular exchanges between membranes within and between the physiological systems and the organs of an animal.

Chemical reaction rates vary with temperature and generally increase as the temperature is increased. The solubility of gases in water varies with temperature. Dissolved oxygen is consumed by the decay or decomposition of dissolved organic substances and the decay rate increases as the temperature of the water increases reaching a maximum at about 30°C (86°F). The temperature of stream water, even during summer, is below the optimum for pollution-associated bacteria. Increasing the water temperature increases the bacterial multiplication rate when the environment is favorable and the food supply is abundant.

Reproduction cycles may be changed significantly by increased temperature because this function takes place under restricted temperature ranges. Spawning may not occur at all because temperatures are too high. Thus, a fish population may exist in a heated area only by continued immigration. Disregarding the decreased reproductive potential, water temperatures need not reach lethal levels to decimate a species. Temperatures that favor competitors, predators, parasites, and disease can destroy a species at levels far below those that are lethal.

Fish food organisms are altered severely when temperatures approach or exceed 90°F. Predominant algal species change, primary production is decreased, and bottom associated organisms may be depleted or altered drastically in numbers and distribution. Increased water temperatures may cause aquatic plant nuisances when other environmental factors are favorable.

Synergistic actions of pollutants are more severe at higher water temperatures. Given amounts of domestic sewage, refinery wastes, oils, tars, insecticides, detergents, and fertilizers more rapidly deplete oxygen in water at higher temperatures, and the respective toxicities are likewise increased.

When water temperatures increase, the predominant algal species may change from diatoms to green algae, and finally at high temperatures to blue-green algae, because of species temperature preferentials. Blue-green algae can cause serious odor problems. The number and distribution of benthic organisms decreases as water temperatures increase above 90°F, which is close to the tolerance limit for the population. This could seriously affect fish that depend on benthic organisms as a food source.

The cost of fish being attracted to heated water in winter months may be considerable, due to fish mortalities that may result when the fish return to the cooler water.

Rising temperatures stimulate the decomposition of sludge, formation of sludge gas, multiplication of saprophytic bacteria and fungi (particularly in the presence of organic wastes), and the consumption of oxygen by putrefactive processes, thus affecting the esthetic value of a water course.

In general, marine water temperatures do not change as rapidly or range as widely as those of freshwaters. Marine and estuarine fishes, therefore, are less tolerant of temperature variation. Although this limited tolerance is greater in estuarine than in open water marine species, temperature changes are more important to those fishes in estuaries and bays than to those in open marine areas, because of the nursery and replenishment functions of the estuary that can be adversely affected by extreme temperature changes.

pH, Acidity and Alkalinity

Acidity and alkalinity are reciprocal terms. Acidity is produced by substances that yield hydrogen ions upon hydrolysis and alkalinity is produced by substances that yield hydroxyl ions. The terms "total acidity" and "total alkalinity" are often used to express the buffering capacity of a solution. Acidity in natural waters is caused by carbon dioxide, mineral acids, weakly dissociated acids, and the salts of strong acids and weak bases. Alkalinity is caused by strong bases and the salts of strong alkalies and weak acids.

The term pH is a logarithmic expression of the concentration of hydrogen ions. At a pH of 7, the hydrogen and hydroxyl ion concentrations are essentially equal and the water is neutral. Lower pH values indicate acidity while higher values indicate alkalinity. The relationship between pH and acidity or alkalinity is not necessarily linear or direct.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add such constituents to drinking water as iron, copper, zinc, cadmium and lead. The hydrogen ion concentration can affect the "taste" of the water. At a low pH water tastes "sour". The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7. This is very significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Dead fish, associated algal blooms, and foul stenches are aesthetic liabilities to any waterway.

Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. Metalocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units. The availability of many nutrient substances varies with the alkalinity and acidity. Ammonia is more lethal with a higher pH.

The lacrimal fluid of the human eye has a pH of approximately 7.0 and a deviation of 0.1 pH unit from the norm may result in eye irritation for the swimmer. Appreciable irritation will cause severe pain.

Dissolved Solids

In natural waters the dissolved solids consist mainly of carbonates, chlorides, sulfates, phosphates, and possibly nitrates of calcium, magnesium, sodium, and potassium, with traces of iron, manganese and other substances.

Many communities in the U.S. and in other countries use water supplies containing 2000 to 4000 mg/l of dissolved salts, when no better water is available. Such waters are not palatable, may not quench thirst, and may have a laxative action on new users. Waters containing more than 4000 mg/l of total salts are generally considered unfit for human use, although in hot climates such higher salt concentrations can be tolerated whereas they could not be in temperate climates. Waters containing 5000 mg/l or more are reported to be bitter and act as bladder and intestinal irritants. It is generally agreed that the salt concentration of good, palatable water should not exceed 500 mg/l.

Limiting concentrations of dissolved solids for fresh-water fish may range from 5,000 to 10,000 mg/l, according to species and prior acclimatization. Some fish are adapted to living in more saline waters, and a few species of fresh-water forms have been found in natural waters with a salt concentration of 15,000 to 20,000 mg/l. Fish can slowly become acclimatized to higher salinities, but fish in waters of low salinity cannot survive sudden exposure to high salinities, such as those resulting from discharges of oil-well brines. Dissolved solids may influence the toxicity of heavy metals and organic compounds to fish and other aquatic life, primarily because of the antagonistic effect of hardness on metals.

Waters with total dissolved solids over 500 mg/l have decreasing utility as irrigation water. Dissolved solids in industrial waters can cause foaming in boilers and cause interference with cleaness, color, or taste of many finished products. High contents of dissolved solids also tend to accelerate corrosion.

Specific conductance is a measure of the capacity of water to convey an electric current. This property is related to the total concentration of ionized substances in water and water temperature. This property is frequently used as a substitute method of quickly estimating the dissolved solids concentration.

Total Suspended Solids

Suspended solids include both organic and inorganic materials. The inorganic components include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, animal and vegetable fats, various fibers, sawdust, hair, and various materials from sewers. These solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. They adversely affect fish by covering the bottom of the stream or lake with a blanket of material that destroys the fish-food bottom fauna or the spawning ground of fish. Deposits containing organic materials may deplete bottom oxygen supplies and produce hydrogen sulfide, carbon dioxide, methane, and other noxious gases.

In raw water sources for domestic use, state and regional agencies generally specify that suspended solids in streams shall not be present in sufficient concentration to be objectionable or to interfere with normal treatment processes. Suspended solids in water may interfere with many industrial processes, and cause foaming in boilers, or encrustations on equipment exposed to water, especially as the temperature rises. Suspended solids are undesirable in water for textile industries; paper and pulp; beverages; dairy products; laundries; dyeing; photography; cooling systems, and power plants. Suspended particles also serve as a transport mechanism for pesticides and other substances which are readily sorbed into or onto clay particles.

Solids may be suspended in water for a time, and then settle to the bed of the stream or lake. These settleable solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration and impair the photosynthetic activity of aquatic plants.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, they are often much more damaging to the life in water, and they retain the capacity to displease the senses. Solids, when transformed to sludge deposits, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. When of an organic and decomposable nature, solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a seemingly inexhaustible food source for sludge worms and associated organisms.

Turbidity is principally a measure of the light absorbing properties of suspended solids. It may be used as a substitute method of quickly estimating the total suspended solids when the concentration is relatively low and a correlation factor is available.

Phosphorus

During the past 30 years, a formidable case has developed for the belief that increasing standing crops of aquatic plant growths, which often interfere with water uses and are nuisances to man, frequently are caused by increasing supplies of phosphorus. Such phenomena are associated with a condition of accelerated eutrophication or aging of waters. It is generally recognized that phosphorus is not the sole cause of eutrophication, but there is evidence to substantiate that it is frequently the key element in all of the elements required by fresh water plants and is generally present in the least amount relative to need. Therefore, an increase in phosphorus allows use of other, already present, nutrients for plant growths. Phosphorus is usually described, for this reasons, as a "limiting factor."

When a plant population is stimulated in production and attains a nuisance status, a large number of associated liabilities are immediately apparent. Dense populations of pond weeds make swimming dangerous. Boating and water skiing and sometimes fishing may be eliminated because of the mass of vegetation that serves as an physical impediment to such activities. Plant populations have been associated with stunted fish populations and with poor fishing. Plant nuisances emit vile stenches, impart tastes and odors to water supplies, reduce the efficiency of industrial and municipal water treatment, impair aesthetic beauty, reduce or restrict resort trade, lower waterfront property values, cause skin rashes to man during water contact, and serve as a substrate and breeding ground for flies.

Phosphorus in the elemental form is particularly toxic, and subject to bioaccumulation in much the same way as mercury. Colloidal elemental phosphorus will poison marine fish (causing skin tissue breakdown and discoloration). Also, phosphorus is capable of being concentrated and will accumulate in organs and soft tissues. Experiments have shown that marine fish will concentrate phosphorus from water containing as little as 1 microgram/l (ug/l).

Ammonia

Ammonia is a common product of the decomposition of organic matter. Dead and decaying animals and plants along with human and animal body wastes account for much of the ammonia entering the aquatic ecosystem. Ammonia exists in its non-ionized form only at higher pH levels and is the most toxic in this state. The lower the pH, the more ionized ammonia is formed and its toxicity decreases. Ammonia, in the presence of dissolved oxygen, is converted to nitrate (NO_3) by nitrifying bacteria. Nitrite (NO_2), which is an intermediate product between ammonia and nitrate, sometimes occurs in quantity when depressed oxygen conditions permit. Ammonia can exist in several other chemical combinations including ammonium chloride and other salts.

Nitrates are considered to be among the poisonous ingredients of mineralized waters, with potassium nitrate being more poisonous than sodium nitrate. Excess nitrates cause irritation of the mucous linings of the gastrointestinal tract and the bladder; the symptoms are diarrhea and diuresis, and drinking one liter of water containing 500 mg/l of nitrate can cause such symptoms.

Infant methemoglobinemia, a disease characterized by certain specific blood changes and cyanosis, may be caused by high nitrate concentrations in the water used for preparing feeding formulae. While it is still impossible to state precise concentration limits, it has been widely recommended that water containing more than 10 mg/l of nitrate nitrogen (NO_3-N) should not be used for infants. Nitrates are also harmful in fermentation processes and can cause disagreeable tastes in beer. In most natural water the pH range is such that ammonium ions (NH_4^+) predominate. In alkaline waters, however, high concentrations of un-ionized ammonia in undissociated ammonium hydroxide increase the toxicity of ammonia solutions. In streams polluted with sewage, up to one half of the nitrogen in the sewage may be in the form of free ammonia, and sewage may carry up to 35 mg/l of total nitrogen. It has been shown that at a level of 1.0 mg/l un-ionized ammonia, the ability of hemoglobin to combine with oxygen is impaired and fish may suffocate. Evidence indicates that ammonia exerts a considerable toxic effect on all aquatic life within a range of less than 1.0 mg/l to 25 mg/l, depending on the pH and dissolved oxygen level present.

Ammonia can add to the problem of eutrophication by supplying nitrogen through its breakdown products. Some lakes in warmer climates, and others that are aging quickly are sometimes limited by the nitrogen available. Any increase will speed up the plant growth and decay process.

Copper

Copper salts occur in natural surface waters only in trace amounts, up to about 0.05 mg/l, so that their presence generally is the result of pollution. This is attributable to the corrosive action of the water on copper and brass tubing, to industrial effluents, and frequently to the use of copper compounds for the control of undesirable plankton organisms.

Copper is not considered to be a cumulative systemic poison for humans, but it can cause symptoms of gastroenteritis, with nausea and intestinal irritations, at relatively low dosages. The limiting factor in domestic water supplies is taste. Threshold concentrations for taste have been generally reported in the range of 1.0-2.0 mg/l of copper, while as 5mg/l makes the water completely unpalatable.

The toxicity of copper to aquatic organisms varies significantly, not only with the species, but also with the physical and chemical characteristics of the water, including temperature, hardness, turbidity, and carbon dioxide content. In hard water, the toxicity of copper salts is reduced by the precipitation of copper carbonate or other insoluble compounds. The sulfates of copper and zinc, and of copper and cadmium are synergistic in their toxic effect on fish.

Copper concentrations less than 1 mg/l have been reported to be toxic, particularly in soft water, to many kinds of fish, crustaceans, mollusks, insects, phytoplankton and zooplankton. Concentrations of copper, for example, are detrimental to some oysters above 0.1 mg/l. Oysters cultured in sea water containing 0.13-0.5 mg/l of copper deposited the metal in their bodies and became unfit as a food substance.

Chromium

Chromium, in its various valence states, is hazardous to man. It can produce lung tumors when inhaled and induces skin sensitizations. Large doses of chromates have corrosive effects on the intestinal tract and can cause inflammation of the kidneys. Levels of chromate ions that have no effect on man appear to be so low that they are below detectable limits.

The toxicity of chromium salts toward aquatic life varies widely with the species, temperature, pH, valence of the chromium, and synergistic or antagonistic effects, especially that of hardness. Fish are relatively tolerant of chromium salts, but fish food organisms and other lower forms of aquatic life are extremely sensitive. Chromium also inhibits the growth of algae.

In some agricultural crops, chromium can cause reduced growth or death of the crop. Adverse effects of low concentrations of chromium on corn, tobacco and sugar beets have been documented.

Arsenic

Arsenic is found to a small extent in nature in the elemental form. It occurs mostly in the form of arsenites of metals or as pyrites.

Arsenic is normally present in sea water at concentrations of 2 to 3 ug/l and tends to be accumulated by oysters and other shellfish. Concentrations of 100 mg/kg have been reported in certain shellfish. Arsenic is a cumulative poison with long-term chronic effects on both aquatic organisms and on mammalian species and a succession of small doses may add up to a final lethal dose. It is moderately toxic to plants and highly toxic to animals especially as AsH_3.

Arsenic trioxide, which also is exceedingly toxic, was studied in concentrations of 1.96 to 40 mg/l and found to be harmful in that range to fish and other aquatic life. Work by the Washington Department of Fisheries on pink salmon has shown that at a level of 5.3 mg/l of As_2O_3 for 8 days was extremely harmful to this species; on mussels, a level of 16 mg/l was lethal in 3 to 16 days.

Severe human poisoning can result from 100 mg concentrations, and 130 mg has proved fatal. Arsenic can accumulate in the body faster than it is excreted and can build to toxic levels, from small amounts taken periodically through lung and intestinal walls from the air, water and food.

Arsenic is a normal constituent of most soils, with concentrations ranging up to 500 mg/kg. Although very low concentrations of arsenates may actually stimulate plant growth, the presence of excessive soluble arsenic in irrigation waters will reduce the yield of crops, the main effect appearing to be the destruction of chlorophyll in the foliage. Plants grown in water containing 1 mg/l of arsenic trioxides showed a blackening of the vascular bundles in the leaves. Beans and cucumbers are very sensitive, while turnips, cereals, and grasses are relatively resistant. Old orchard soils in Washington that contained 4 to 12 mg/kg of arsenic trioxide in the top soil were found to have become unproductive.

Zinc

Occurring abundantly in rocks and ores, zinc is readily refined into a stable pure metal and is used extensively for galvanizing, in alloys, for electrical purposes, in printing plates, for dye-manufacture and for dyeing processes, and for many other industrial purposes. Zinc salts are used in paint pigments, cosmetics, pharmaceuticals, dyes, insecticides, and other products too numerous to list herein. Many of these salts (e.g., zinc chloride and zinc sulfate) are highly soluble in water; hence it is to be expected that zinc might occur in many industrial wastes. On the other hand, some zinc salts (zinc carbonate, zinc oxide, zinc sulfide) are insoluble in water and consequently it is to be expected that some zinc will precipitate and be removed readily in most natural waters.

In zinc-mining areas, zinc has been found in waters in concentrations as high as 50 mg/1 and in effluents from metal-plating works and small-arms ammunition plants it may occur in significant concentrations. In most surface and ground waters, it is present only in trace amounts. There is some evidence that zinc ions are adsorbed strongly and permanently on silt, resulting in inactivation of the zinc.

Concentrations of zinc in excess of 5 mg/1 in raw water used for drinking water supplies cause an undesirable taste which persists through conventional treatment. Zinc can have an adverse effect on man and animals at high concentrations.

In soft water, concentrations of zinc ranging from 0.1 to 1.0 mg/1 have been reported to be lethal to fish. Zinc is thought to exert its toxic action by forming insoluble compounds with the mucous that covers the gills, by damage to the gill epithelium, or possibly by acting as an internal poison. The sensitivity of fish to zinc varies with species, age and condition, as well as with the physical and chemical characteristics of the water. Some acclimatization to the presence of zinc is possible. It has also been observed that the effects of zinc poisoning may not become apparent immediately, so that fish removed from zinc-contaminated to zinc-free water (after 4-6 hours of exposure to zinc) may die 48 hours later. The presence of copper in water may increase the toxicity of zinc to aquatic organisms, but the presence of calcium or hardness may decrease the relative toxicity.

Observed values for the distribution of zinc in ocean waters vary widely. The major concern with zinc compounds in marine waters is not one of acute toxicity, but rather of the long-term sub-lethal effects of the metallic compounds and complexes. From an acute toxicity point of view, invertebrate marine animals seem to be the most sensitive organisms tested. The growth of the sea urchin, for example, has been retarded by as little as 30 ug/l of zinc.

Zinc sulfate has also been found to be lethal to many plants, and it could impair agricultural uses.

Fluorides

As the most reactive non-metal, fluorine is never found free in nature but as a constituent of fluorite or fluorspar, calcium fluoride, in sedimentary rocks and also of cryolite, sodium aluminum fluoride, in igneous rocks. Owing to their origin only in certain types of rocks and only in a few regions, fluorides in high concentrations are not a common constituent of natural surface waters, but they may occur in detrimental concentrations in ground waters.

Fluorides are used as insecticides, for disinfecting brewery apparatus, as a flux in the manufacture of steel, for preserving wood and mucilages, for the manufacture of glass and enamels, in chemical industries, for water treatment, and for other uses.

Fluorides in sufficient quantity are toxic to humans, with doses of 250 to 450 mg giving severe symptoms or causing death.

There are numerous articles describing the effects of fluoride-bearing waters on dental enamel of children; these studies lead to the generalization that water containing less than 0.9 to 1.0 mg/l of fluoride will seldom cause mottled enamel in children, and for adults, concentrations less than 3 or 4 mg/l are not likely to cause endemic cumulative fluorosis and skeletal effects. Abundant literature is also available describing the advantages of maintaining 0.8 to 1.5 mg/l of fluoride ion in drinking water to aid in the reduction of dental decay, especially among children.

Chronic fluoride poisoning of livestock has been observed in areas where water contained 10 to 15 mg/l fluoride. Concentrations of 30 - 50 mg/l of fluoride in the total ration of dairy cows is considered the upper safe limit. Fluoride from waters apparently does not accumulate in soft tissue to a significant degree and it is transferred to a very small extent into the milk and to a somewhat greater degree into eggs. Data for fresh water indicate that fluorides are toxic to fish at concentrations higher than 1.5 mg/l.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

BARKING

Logs are barked by a variety of abrasion and pressure processes as described in detail in Section III. Ring and cutterhead barkers produce a solid waste composed of chipped dry bark, which may be sent to the hog to be shredded and then to the bark boiler ("hog boiler") for use as fuel. Wet drum barkers, bag (pocket) barkers, and hydraulic barkers, require steps to separate the abraded bark from the water. The bark is usually pressed to remove water, and sent to the boiler, again for use as fuel. The water can be recycled. The volume requirements, in addition to the quality requirments of supply water to the hydraulic barking operation, result in a significant difference in procedures and practices for handling the process contact water generated by this operation.

Hydraulic Barking

The volume of water used in this method of barking range between 50,000 and 120,000 l/cu m (370 to 890 gal/cu ft) of wood. Raw effluent from hydraulic barkers ranges between 56 and 250 mg/l BOD and 500 to 2400 mg/l suspended solids. Primary settling can reduce suspended solids to less than 250 mg/l.

Opportunity for disposal of these volumes of waste water are limited in many segments of the timber products processing category. With the exception of the pulp and paper, the volumes generated by hydraulic barking are in excess of the amount that could be utilized in other unit operations of the manufacturing process.

Because little information was available on the separate treatment of hydraulic barker effluent, treatment and control technology will be applied from another industry, the pulp and paper industry. It is noted, however, that water from a hydraulic barker is being sucessfully recycled by at least one timber products processing plant.

In the pulp industry, modern practice is the use of circular, heavy-duty type clarifiers or thickeners. These are designed for a rise rate of 40,700 to 48,900 l/sq m/day (1000 to 1200 gal/sq ft/day) of surface area and to provide a retention period of about two hours. They are equipped and piped to handle dense sludge as well as having a skimmer to collect the floating materials. The under flow is removed by means of diaphragm, plunger, or screw pumps and transferred to drying beds or to a vacuum filter for dewatering. Filter media frequently consists of 120-mesh stainless steel wire cloth. Filter cake produced contains about 30 percent solids and loadings range from 235 to 284 kg/sq m of dry solids. Such cakes are either disposed of on the land or sold as mulch.

Effluents from clarifiers are usually not treated further separately but combined with pulp mill and other wastes for biological treatment, which can be 85% to 95% effective.

VENEER

Treatment and control technology in the veneer manufacturing industry is not extensive. The major effort made by this segment of the industry to reduce waste water discharge has been to reduce the amount of waste water by reuse and conservation of water and to contain waste waters that cannot be reused. Each source of potential waste water and methods of treatment is discussed below.

Log Conditioning

Waste water from log conditioning may be the largest and most difficult source to handle in a veneer mill.

Although seldom used, biological treatment of the effluent from hot water vats and steam vats used in log conditioning is practicable and effective. It has been reported that 85 to 90 percent reduction of BOD is attainable by using lagoons or aerated lagoons. 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 or from periodic cleaning. Plants operating in this manner need only to settle the water in 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 indirect 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 control corrosive activity. The resulting sludge may be trucked to landfill.

Waste water discharge from steam vats is more difficult to eliminate. Condensate from the vats must be discharged because of the difficulty of reusing the contaminated condensate. Various modifications have been made to steam vats which allow them to be converted to totally closed systems. Several plants have converted steam vats to hot water spray tunnels which would have conditioning effects similar to hot water vats. 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 because of the fact that some species of logs do not sink, hot water sprays can be used as an alternative and 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 reused after settling and screening.

The other possible modification is a technology from the wood preserving industry called "modified steaming." 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 small volumes of waste water 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 wash water can be significantly reduced.

Veneer and plywood mills producing 9.3 million sq m per year (100 million sq ft) on a 9.53 mm (3/8 in) basis may use as much as 57,000 l/week (15,000 gal) of water 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 l/week (2,000 gal/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 l/week (3,000 gal), and this small volume can be handled without discharge by containment, or land irrigation.

For a plant producing 0.465 million sq m/year of hardwood plywood the veneer dryer wash water will be considerably less than the flows discussed under veneer dryers serving a 9.3 million sq m/year softwood plant. Control technology is the same i.e., containment, land irrigation, or evaporation.

PLYWOOD

Similar to the veneer manufacturing subcategory, treatment and control technology is not extensive in the plywood subcategory. This is true partly because water requirements for the manufacture of plywood are minimal. In fact water is generated only in the glue makeup and glue wash-up operations, and in the veneer drying operations where they occur at the plywood manufacturing site.

Glue Lines

Current technology in the handling of glue wash water indicates 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 during the course of the guidelines development study and are practicable with all three major types of glue. In 1968, only one plywood mill had a glue wash water recycle system. Currently the system is accepted technology in the industry. Nevertheless, there are still a number of plywood mills that discharge waste water from their glue operations.

A plywood mill using phenolic glue can reduce the waste water flow from its glue operation to about 7,570 l/day (about 2,000 gal/day), without altering the process, by conserving water. 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 pot life of the glue. In order to reduce the flows from a mill that uses protein glue, in-plant modifications in addition to water conservation are necessary.

Phenolic glues usually require about 227 kg (500 lbs) of water per batch, or 4.5 cu m/day (1200 gal/day). Further reduction of waste water is then necessary for all of the waste water to be used in the makeup of glue. Table 26 indicates that most southern plywood mills generate about twice as much waste water 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 waste water 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.

These modifications can be used in combination 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. An economic benefit has been established by using glue waste water, because of the fact that it contains glue and other chemicals such as sodium hydroxide, as shown in Table 39.

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/or evaporate glue washwater, spray the glue water on the bark that goes into the boiler, or use a combination of these techniques.

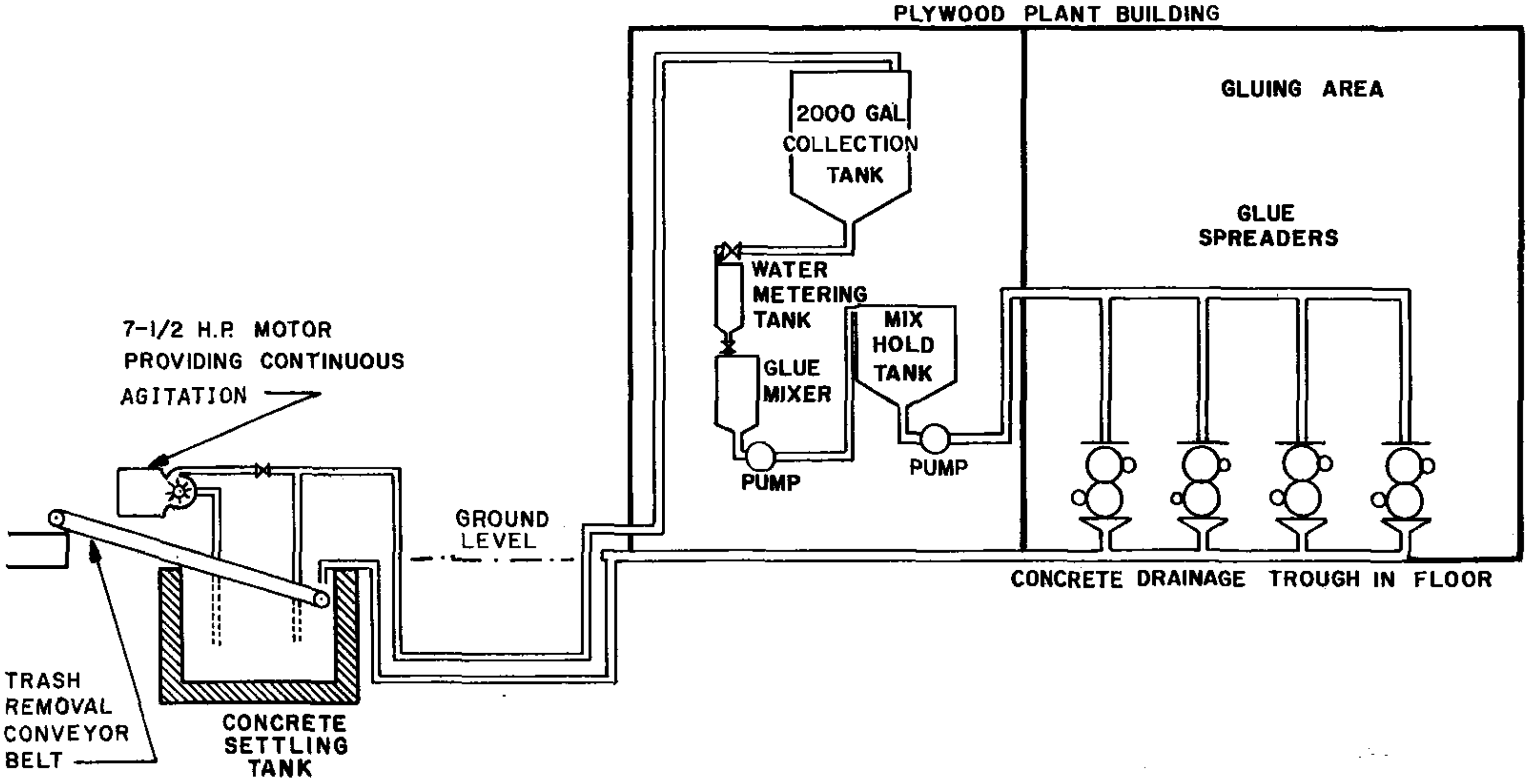


FIGURE 30 - PLYWOOD PLANT WASH WATER REUSE SYSTEM

TABLE 39

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%

a) Control mix - clean water used for mix.
b) 20:1 dilution of Mix 1 used for mix water - pH 11.5
c) 30:1 dilution of Mix 1 used for mix water - pH 11.4

HARDBOARD - DRY PROCESS

The small volumes of cprocess waste 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, because the small volumes of waste water generated, the major treatment processes have been limited to oil-water separation, waste retention ponds, or perhaps spray irrigation.

The major waste water source in one particular mill may be non-existent in another mill. Inplant modifications to reduce, eliminate, or reuse waste water can greatly affect total waste water discharge from any mill. By inplant modifications and containment on site, the elimination of discharge can be achieved throughout the dry process hardboard industry.

Log Wash: At the time of this study, only two mills reported washing logs. One mill which washes logs has zero discharge of all its waste through impoundment and land irrigation. The second mill uses approximately 82 cu m/day (21,600 gal/day) for log washing with the wash water being discharged directly to a stream without treatment. Log washwater can be successfully recycled by settling with only a small percentage of blowdown to remove accumulated solids. The blowdown from log wash water recycle systems can be disposed of by impounding or land spreading.

Chip Wash: At the time of this study, there were no dry process hardboard mills which reported washing chips, however several have indicated plans to install chip washing in the future. Until such time as chip washers are installed and experience gained, no demonstrated technology is available in the dry process hardboard industry for treatment of this waste stream. Predicted waste water discharges from a chip wash system are 18.9 to 37.8 cu m/day (5,000 to 10,000 gal/day) for a 227 kkg/day plant.

Resin System

Six mills out of the total of 16 dry process hardboard mills report no discharge from their resin systems. Several other mills report a waste discharge of less than 750 l/day (200 gal/day). All hardboard mills use essentially the same types of resin (phenolic or urea formaldehyde). Taking into consideration that several mills already have no discharge of waste water pollutants and that many plywood mills using the same resin have no discharge of waste water pollutants from the resin (glue) system, dry process hardboard mills can employ similar practices and procedures to to achieve no discharge of process waste water pollutnts from their resin systems.

Caul Wash: Five (5) mills report no caul wash water discharge. Those mills reporting discharges of caul washwater average 750 l/day (200 gal/day). This low quality of water can either be eliminated or neutralized, as necessary, then disposed of by impounding, land spreading, or disposal of by alternative methods.

Housekeeping: Housekeeping wash water is a miscellaneous waste water 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 waste water can be eliminated by preventing condensate water from entering the press pit and by reducing hydraulic fluid leaks. Housekeeping waste water can be either totally eliminated or, if water is used, held on site by impounding and spray irrigation, evaporation, discharge to a municipal system, or discharge to a treatment system serving a timber processing complex.

Cooling Water: Cooling water is by far the major waste water flow from dry process hardboard mills. Cooling water is used in such unit processes as refiner seal water cooling systems, and air compressor cooling systems. erator cooling systems. Use of cooling water varies widely but is usually less than 380 cu m/day (100,000 gal/day) Cooling water can be recycled through cooling towers or cooling ponds.

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 cu m/day (3,000 gal/day). It has been determined that humidifiers can be operated with no discharge of waste water pollutants.

Finishing: All dry process hardboard mills report no discharge from finishing operations. Concern was indicated by industry with the potential of new technology causing waste water 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 waste water source could exist. At the present time there is no discharge from finishing operations.

Summary

The water pollution resulting from dry process hardboard manufacture is directly related to waste water flow and concentration, which, in turn, is influenced by operation and maintenance practices and situations in each mill. The decision to wash logs or chips by a mill is a result of the effect of dirt and grit on inplant machinery. High maintenance costs resulting from abrasion of refiner plates, and other equipment, may make it desirable to wash logs and chips. Quantities of extraneous material on logs depend upon harvesting transportation and storage operations, and therefore, directly affect waste water flow and composition.

The operation and maintenance of the resin system affects waste water flow. Most hardboard mills and numerous plywood mills using similar resins are able to operate with no discharge from their resin systems. Modification of inplant equipment or maintenance procedures should eliminate the resin system as a source of waste water flow.

Caul washing, a minor waste water 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 disposed of. The resulting low volumes of water (less than 750 l/day or 200 gal/day) can be easily disposed of on-site.

Housekeeping practices vary widely from mill to mill with resulting effects on waste water discharge. Several mills are able to perform clean up operations without having waste water 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 minimize water usage with resulting elimination of 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.

HARDBOARD - WET PROCESS

As discussed in Section V, the volumes of waste water generated in wet process hardboard manufacture is sufficient in volume that the waste water cannot be contained on site. There is no single scheme currently being used to treat waste water 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, individual company approach to waste water control, and other factors.

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 settleable 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 waste water source in a similar manner.

Process Water: The major source of waste water flow and concentration comes from discharging the process water. This includes water from fiber preparation, mat formation, and pressing operations. 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, pressure, temperature, and degree and nature of refining.

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 has been done in this area, however, 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 kkg of dry fiber processed, 60.5 cu m (16,000 gal) of water is needed for dilution. The obvious procedure to obtain this quantity of water and reduce or eliminate the discharge of organic material is to recycle a portion or all of the process water.

There are several limiting factors preventing total recycle of process water, including temperature, soluble organics, and build up of suspended solids (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 mills produces greater quantities of soluble organics (pollutants) than other processes because of the higher temperature and pressure. Because of the large quantities of organic material released from the wood, these plants installed evaporation systems to reduce the quantities of organics discharged in their waste water. Figure 31 shows a schematic diagram of one of these systems. In this system countercurrent 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 is then 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

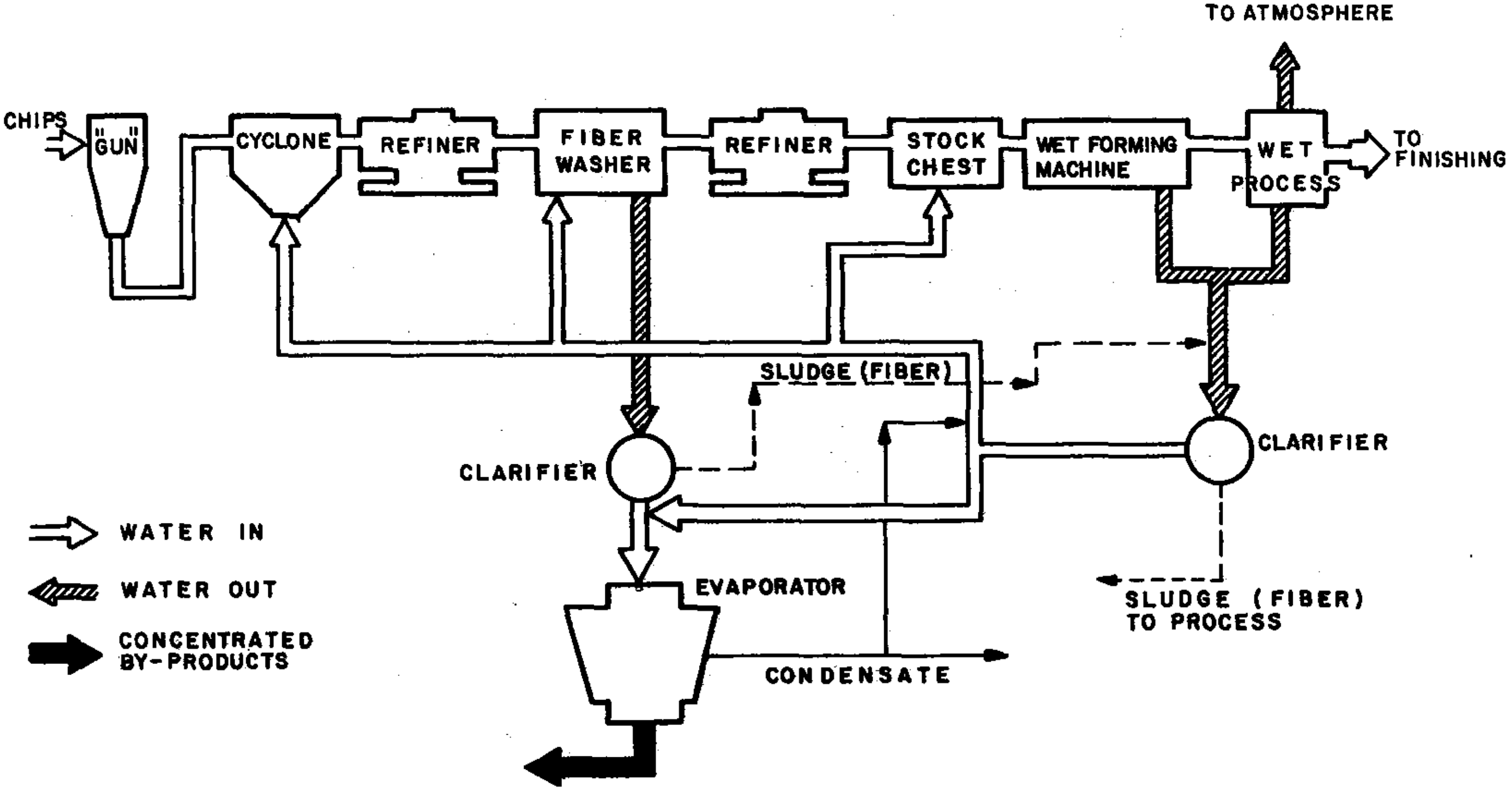


FIGURE 31 - INPLANT TREATMENT AND CONTROL TECHNIQUES AT MILL NO. 7

as a waste water stream. Process water from the felter and the press pass 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 BOD5 discharge from this mill without biological treatment is only 3.25 kg/kkg (6.5 lb/ton).

The thermal-mechanical pulping process releases 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. One possibility to decrease the volume of waste water without increasing the concentration of soluble substances in the process water system at the same time is to arrange some kind of prepressing of the pulp to remove the concentrated organics before they enter the refining and formation process water stream. An arrangement of this type is shown in Figure 32, where a pre-press has been inserted 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 waste water leaving the pre-press. The concentration of soluble substances in this waste water depends on the amount of substances dissolved during the pre-heating, on the volume of waste water 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 must 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 waste water. If treatment methods such as evaporation are used, the suspended solids concentrations entering these processes must be controlled. Suspended solids removal systems are usually of gravity settling, screening, filtration, or flotation.

Only 2 mills utilize sedimentation tanks for removal of suspended solids in process water prior to recycle, and both use 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 waste water treatment scheme, but do not recycle back to process. In one of the mills utilizing gravity separators 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 because of differences related to raw material.

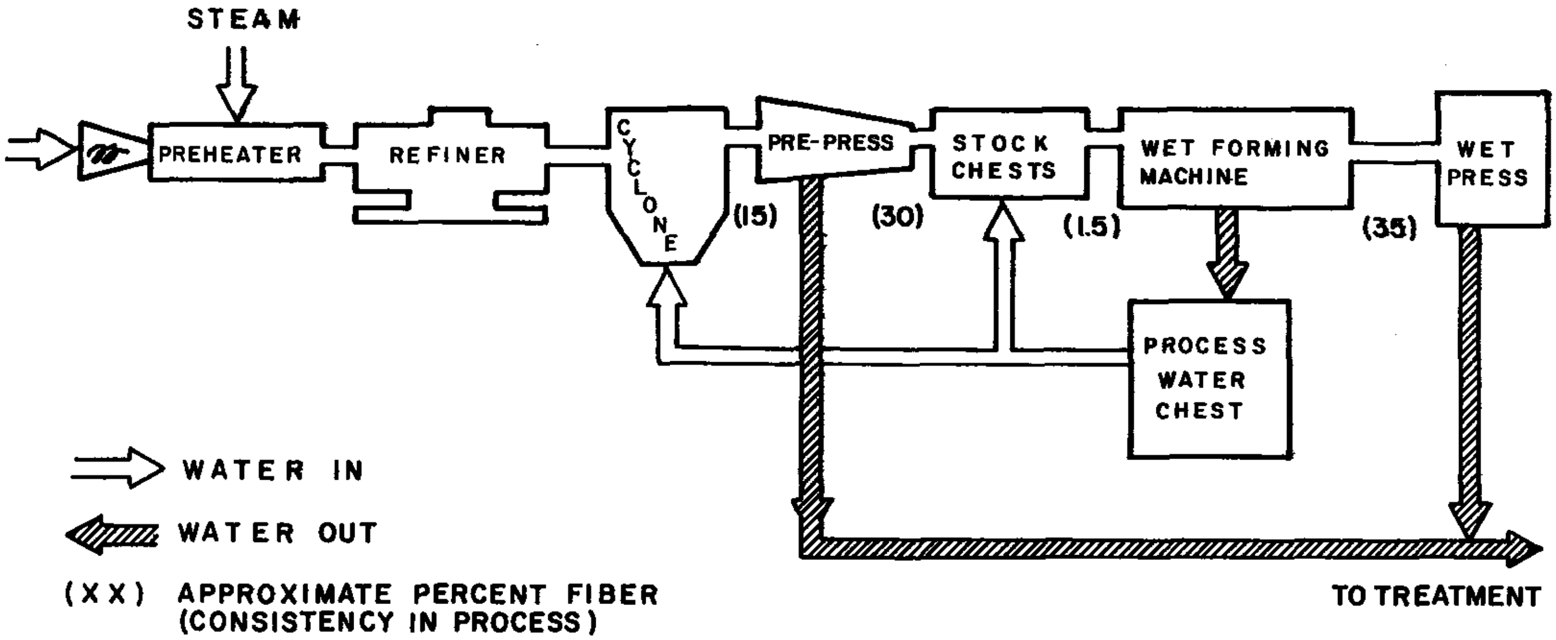


FIGURE 32 - TYPICAL WET-PROCESS HARDBOARD MILL WITH PRE-PRESS

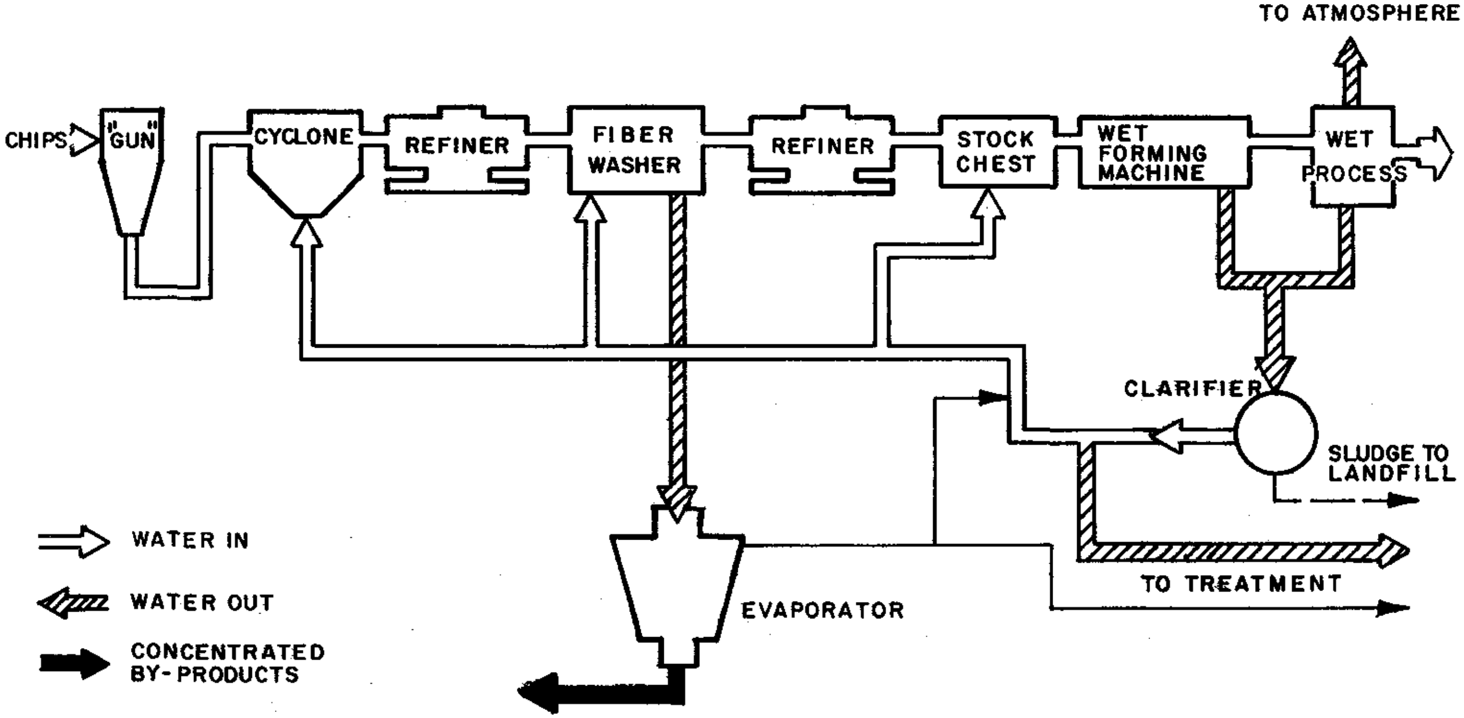


FIGURE 33 - INPLANT TREATMENT AND CONTROL TECHNIQUES AT MILL NO. 3

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 40.

One system 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, addition of chemicals for coagulation, followed by removal of suspended solids and some dissolved and colloidal solids.

There are 2 mills in the U.S. presently using this system to some degree. Typical data from the Savo system from one of these mills is shown below:

	Influent (mg/l)	Effluent (mg/l)	Percent Reduction
COD	7775	4745	39
Total suspended solids	750	48	94
Total dissolved solids	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 waste water flow to 2.3 cu m/ton (611 gal) and BOD discharge to 8.5 kg/kkg (17 lb/ton). This rate and concentration is the result of inplant modifications and does not include end of line treatment. Figure 34 shows a schematic diagram of this process.

End Of Line Waste water Treatment

The existing end of line waste treatment facilities consist primarily of screening followed by primary and biological treatments. All of the 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 nine wet process mills were either sampled or the mill reported treatment efficiencies across their primary clarifiers. This data is shown in Table 41. Although this data 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

TABLE 40

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

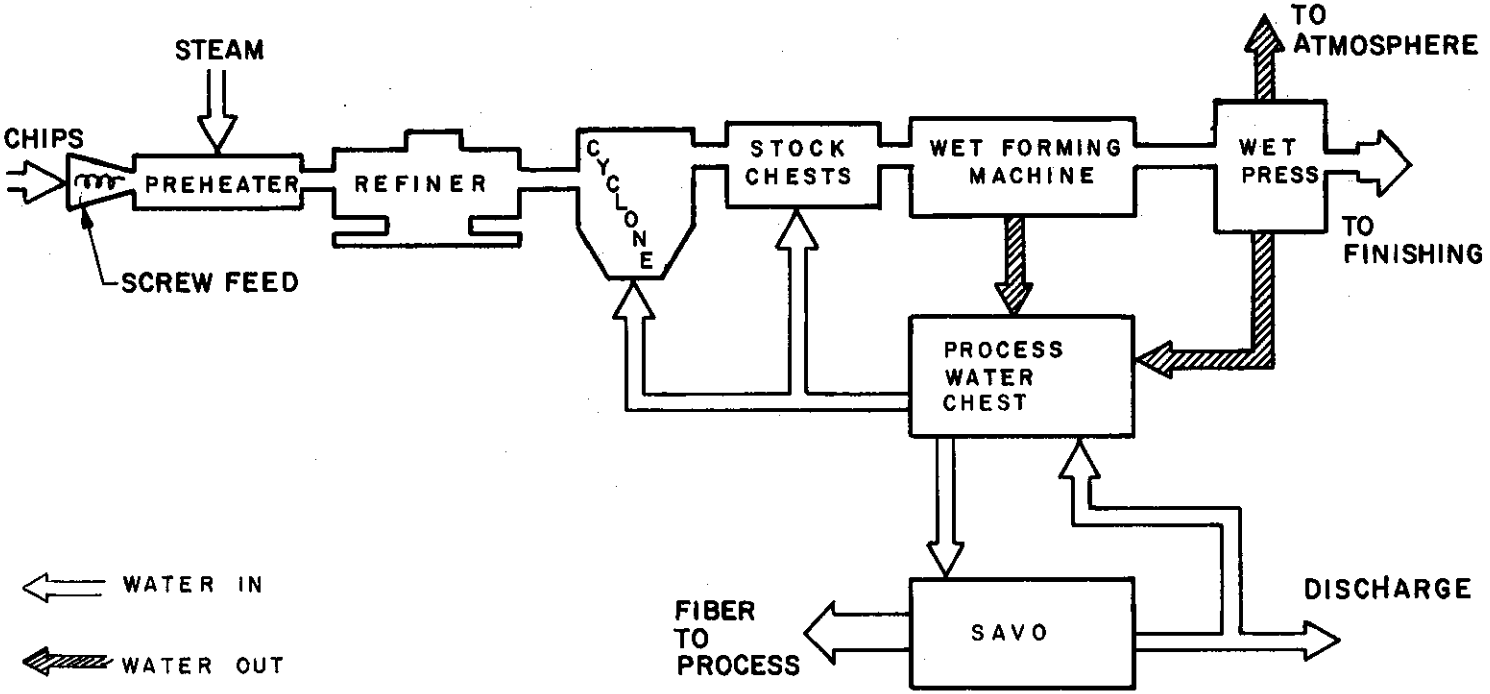


FIGURE 34 - TYPICAL WET-PROCESS HARDBOARD MILL WITH SAVO SYSTEM

TABLE 41

PRIMARY SETTLING TANK EFFICIENCY

	BOD IN		BOD Out		Percent	SS In		SS Out		Percent
Mill	mg/1	k/kkg	mg/1	k/kkg	Removal	mg/1	k/kkg	mg/1	k/kkg	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

listed in Table 41 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 BOD5 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 BOD5 removal.

The pH of wet process waste water 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 the addition of lime or sodium hydroxide.

Wet process hardboard mill waste water is deficient in nitrogen and phosphorus. These nutrients 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:

Mill No.	End Of Line Treatment System
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.

Table 42 shows the treatment efficiency of the five mills which presently have bioligical 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.

TABLE 42

TREATMENT EFFICIENCY OF BIOLOGICAL SYSTEMS

	BOD, kg/kkg			SS, kg/kkg		
Mill No.	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
	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

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 wastes 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 waste water 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 U.S. and Europe have put excess sludge back into the process water to become part of the board. 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.

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 sludge from the activated sludge treatment of wet process hardboard waste water leads to a build up of solids within the system with a resulting discharge of solids in the effluent. Weather conditions (temperature) are also reported to have an effect on the settling rate of biological solids in both aerated lagoon systems and the activated sludge system.

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 seasonal temperature variations. 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 mg/l.

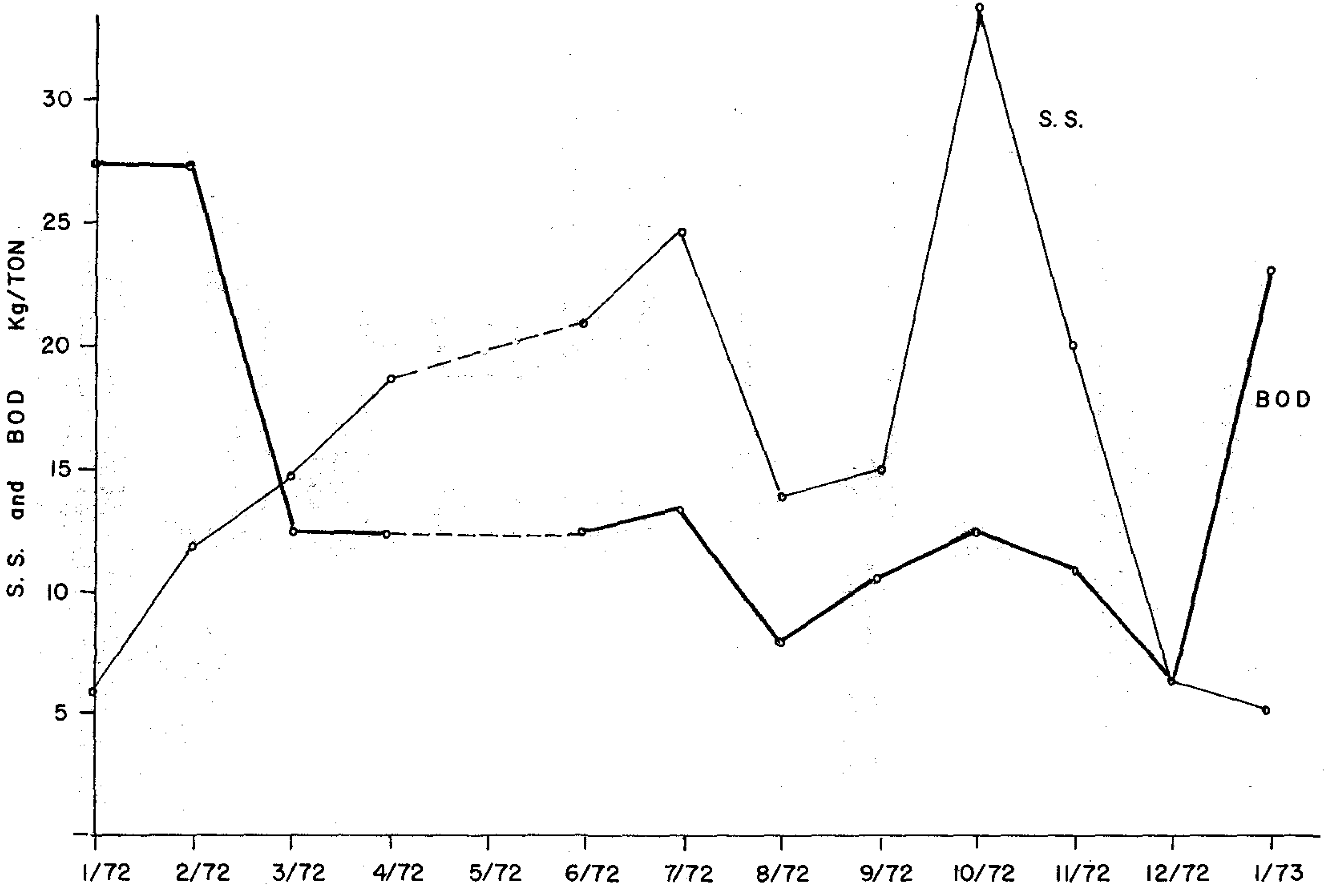


FIGURE 35 - VARIATION OF EFFLUENT BOD AND SUSPENDED SOLIDS AS A FUNCTION OF TIME FOR MILL NO. 2

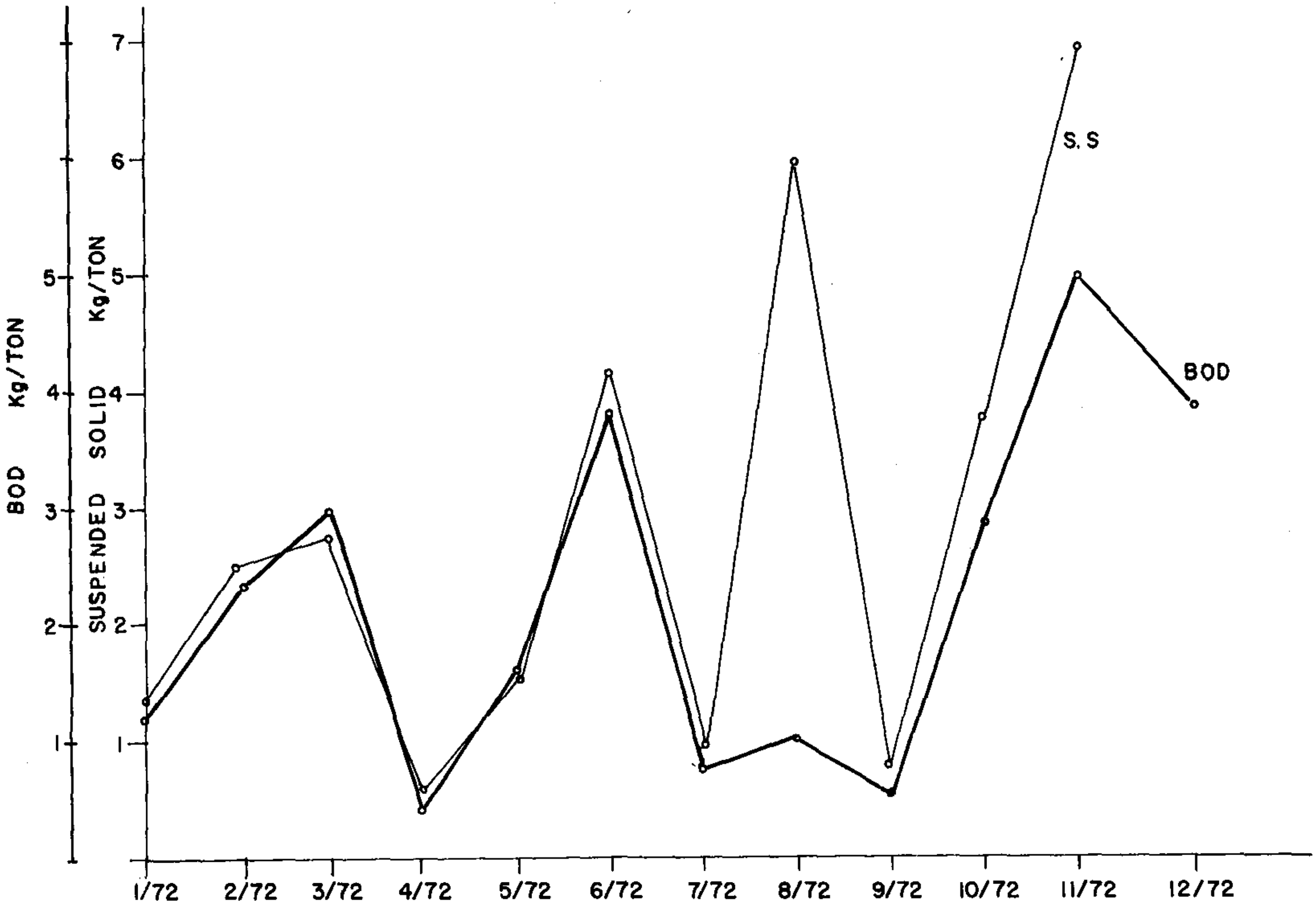


FIGURE 36 - VARIATION OF EFFLUENT BOD AND SUSPENDED SOLIDS AS A FUNCTION OF TIME FOR MILL NO. 3

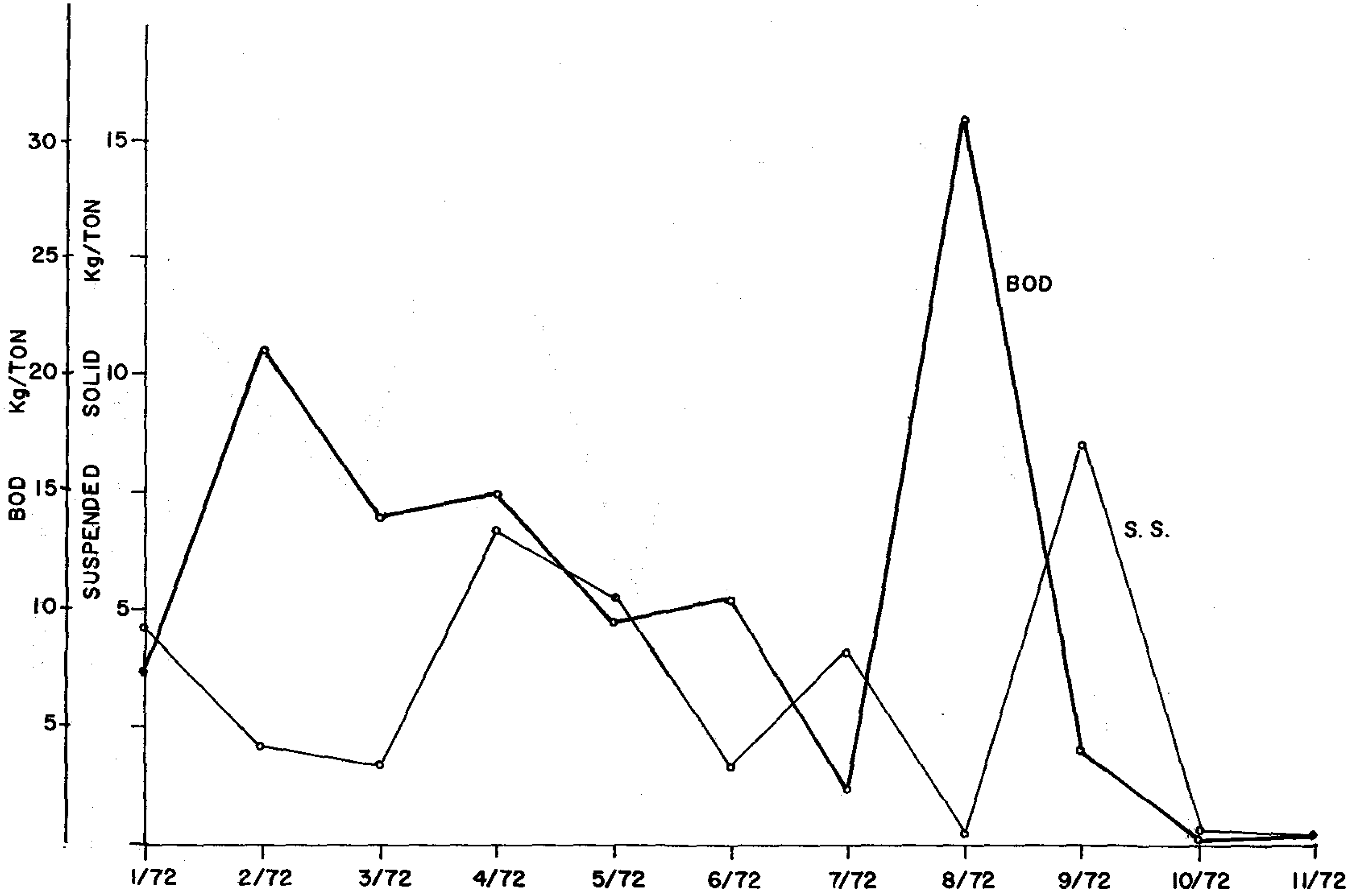


FIGURE 37 - VARIATION OF EFFLUENT BOD AND SUSPENDED SOLIDS AS A FUNCTION OF TIME FOR MILL NO. 4

Table 43 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. 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

Water Reuse: The 9 wet process hardboard mills presently practice considerable recycle of waste water. These systems include:

(1) Process water recycle with blowdown to control suspended solids 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 makeup. In the explosion process all fiber washwater is discharged through a primary clarifier prior to evaporation. (4) Process water recycle with blowdown passing through chemical coagulation system. Part of coagulated waste recycled back to process and all sludge returned to stock chest.

Waste water Treatment: End of pipe treatment technology presently consists of one or more of the following practices:

(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

TABLE 43

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

WOOD PRESERVING

The technological base for waste control in the wood preserving industry is generally quite weak by comparison with most other industrial subcategories. 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.

The comments and data which follow summarize the status of pollution control activities in the wood preserving industry, as revealed by a recent (1973) survey by Thompson of 377 plants. The data are based on the results on a questionaire survey from 207 plants.

Disposition of Waste water

The approach to the pollution problem taken by many treating plants is to store their waste water on company property (Table 44). This is by far the most popular method of handling waste water, accounting for 42 percent of the plants reporting. Seventeen percent are still releasing their waste water 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 secondary treatment before releasing it. Eighteen percent either have no waste water or are disposing of it by special methods such as evaporation or incineration.

There are no unusual trends when the data on methods of disposal of waste water were broken down by region (Table 45). 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 in 1973 indicated that they currently meet state and federal water pollution standards (Table 46). 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 and Southwest currently meet

TABLE 44 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 45 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

TABLE 46. 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 47. 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	12
TOTAL	81

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.

Table 47 gives a breakdown of what the plants that did not meet the 1973 standards plan to do with the their waste water. Nationally, roughly onethird of the plants have made no plans. Most of the remainder plan either to construct on-site treatment facilities for their waste water (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.

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 48). Only 14 plants (about 15 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 49).

Plant Sanitation

Plant sanitation covers 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 48 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)	10
TOTAL	89

TABLE 49 TYPE OF SECONDARY WASTEWATER TREATING FACILITIES INSTALLED OR PLANNED BY WOOD PRESERVING PLANTS BY REGION

Treatment	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

SE - Southeast
SW - Southwest
AC - Atlantic Coast
W - Western
L - Lake and Northeast

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.

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

Waste water treating facilities have been installed and are in operation at only about 9 percent of the estimated 390 plants in the U.S. (Table 44). 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 waste water 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. Review 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 waste waters 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 oxygendemanding substances preparatory to secondary treatment, and (2) to render waste water 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 waste water is the reduction of the oil content of the waste water to a level compatible with the secondary treating process that is employed. This is particularly important with those waste waters 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 waste water 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 waste water.

Primary treatments of waste waters containing salt-type preservatives and fire retardants serve to precipitate heavy metals and thus make the waste amenable to biological treatment.

Waste Waters 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 waste water pollution in the industry. Oils account for most of the oxygen demand of the waste water, serve as carriers for concentrations of pentachlorophenol far in excess of those attainable in oil-free water, and create emulsion problems.

Recovery Of Free Oils - Most wood preserving plants have oil-recovery systems for reclaiming a high percentage of the oil that may become 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 waste water has become an important consideration. Within the past 5 years many plants have added new oil-recovery systems or revamped existing ones.

Free oils are recovered from waste water by gravity-type separators. Various designs are used. The most common ones are patterned after the separator developed by the American Petroleum Institute. 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. Good practice dictates the installation of separate oil removal systems 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 waste water 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 50. These data are based upon the treatment of petroleum refinery waste water, but are 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.

Only free oils are removed in conventional oil-water separators. However, emulsions are broken by rotary vacuum filters and by

TABLE 50 EFFICIENCIES OF OIL SEPARATION PROCESSES

	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

TABLE 51 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

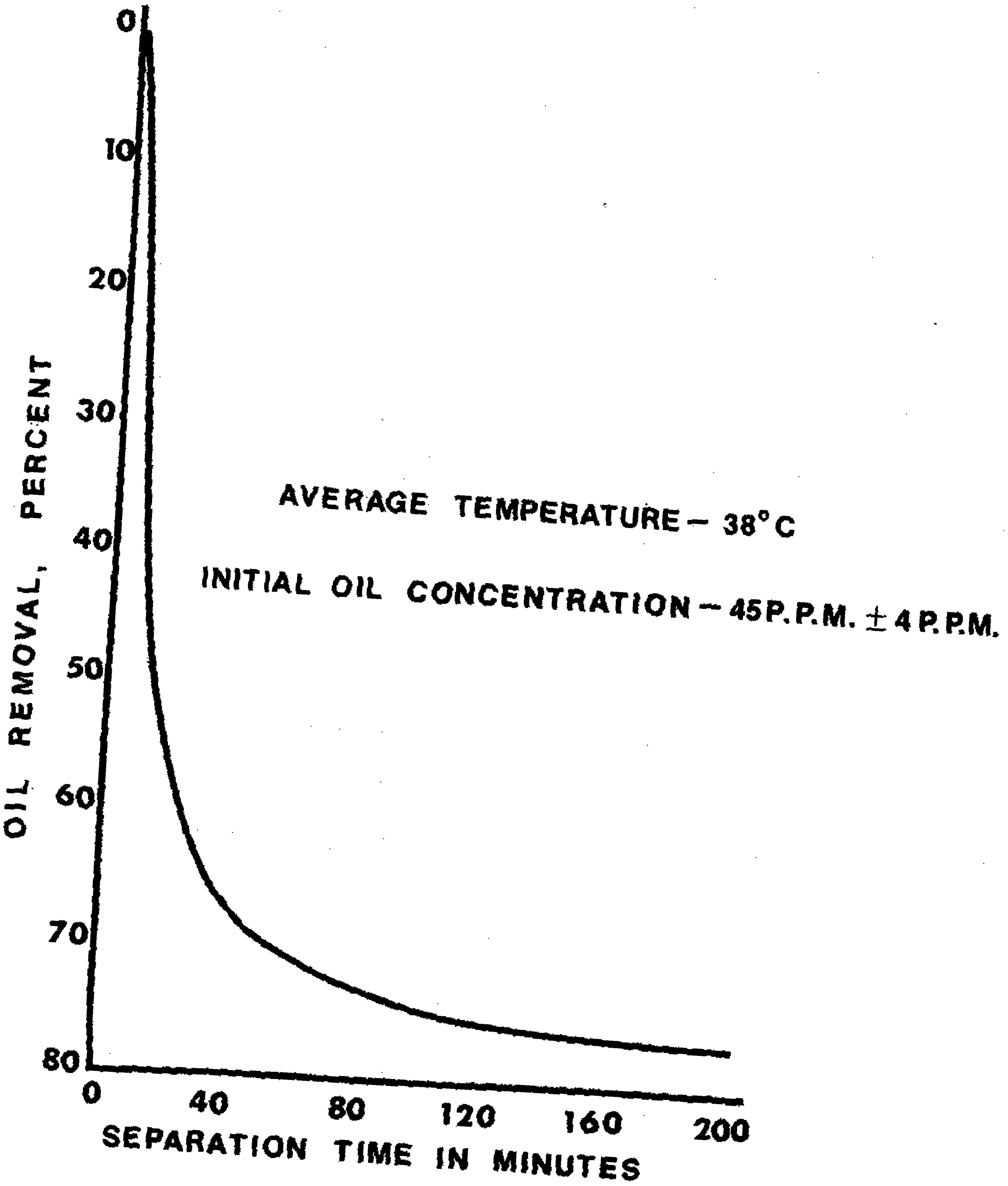


FIGURE 38 EFFECT OF DETENTION TIME ON OIL REMOVAL BY GRAVITY SEPARATION

centrifuges, both of which have been tested on wood preserving waste water at a few plants in the South. Waste waters containing emulsified oils frequently have oil contents in excess of 1000 mg/l after passing through gravity-type separators. Oils in this form normally must be removed by primary treatments involving flocculation.

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 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 discussion below is directed towards, chemical methods of breaking emulsions.

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 waste waters from all plants (Table 29, Section V). COD and BOD reductions of up to 83 percent have been achieved in creosote waste water by using a single cationic polymer at a rate of 40 mg/l. Similar results were observed at a plant treating with both creosote and pentachlorophenol that flocculated its waste prior to routing it to a sanitary sewer.

Oil reductions in refinery waste water of more than 95 percent were obtained by using 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 in 1971. Aluminum chloride, alum, activated-silica, clay and lime have been employed with refinery wastes, and reductions in BOD, COD, and oil content on the order of 50 percent were reported from this treatment.

Ferric chloride has been found to be an effective flocculating agent for both creosote and pentachlorophenol waste waters. 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 waste waters has involved the use of lime either singly or in combination with a polyelectrolyte. Thompson and Dust reported that the optimum dosage of lime, as judged from COD reductions, varied from 0.75 to 2.0 g/l, depending upon waste water characteristics. Percent reduction in this parameter increased with increasing dosage up to a maximum, and then was unaffected by further lime additions (Table 51). Phenol content, exclusive of pentachlorophenol, was not decreased by flocculation of the waste water. However, pentachlorophenol was regularly reduced to a concentration of about 15 mg/l in waste waters 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 to correspond approximately to the solubility of this chemical in water. Typical data showing the reduction of pentachlorophenol resulting from lime additions to a waste water are shown below:

Lime Dosage (mg/l)	Residual PCP Concentration (mg/l)
0	150
1.0	45
1.5	25
2.0	17

Lime, in dosages of 2.0 g/l, has been shown to obtain reductions in COD of up to 70 percent in a creosote waste water. Similar results have been achieved with alum, and both chemicals have been used successfully to treat creosote and vapor-drying waste water previously de-emulsified with sulfuric acid. Lime and caustic soda have been reported to be effective in flocculating oily waste water after treatment with polyelectrolytes failed to produce a floc.

Among numerous polyelectrolytes tested by Thompson and Dust relatively few were found that in the absence of lime were effective with wood preserving waste water. 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 waste water 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 marketed by a large chemical company. Reductions in COD for individual polyelectrolytes in this group ranged from 40 to 74 percent and averaged 62 percent. Several wood preserving plants currently use them in primary treatments of their waste water. Lime in combination with polyelectrolytes is used by other plants.

Vacuum and pressure filtration has also been used to break oil-water emulsions, permitting the recovery of the oil. Halff, 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 waste water 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.

<u>Sludge Dewatering</u> - 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 waste water 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 other polyelectrolytes are 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 waste water. Recent tests conducted by Dust have shown that the dewatering characteristics of beds of this type are unaffected by adding a total of 41 cm (16 in) of sludge from creosote waste water 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. Results of tests of the effectiveness of one machine in processing sludge from creosote waste water were promising. The sludge was dewatered to a solids content of 25 percent.

<u>Waste Waters Containing Heavy Metals</u> - Because heavy metals contained in waste water from plants that treat with salt-type preservatives and fire retardants may be toxic to microorganisms in low concentrations, they must be removed before subjecting the waste water to secondary treatments involving biological oxidation. Unlike primary treatments of oily waste waters 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

TABLE 52 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			

listing of the principal water-soluble preservatives and fire retardants currently marketed in the U.S., and the harmful constituents in each, is given in Table 52.

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

With the exception of boron, hexavalent chromium is the only ion shown in Table 52 which will not precipitate from solution when the pH of the waste water is raised to 7 or 8 with lime. Since trivalent chromium will precipitate from neutral or slightly alkaline solutions, the first step in treating waste waters 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. Chromium reduction proceeds most rapidly in acid solution. Therefore, the waste water 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.

When the chromium has been reduced, the pH of the waste water 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 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/l. 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 52, copper, zinc, and chromium can be reduced to levels substantially lower than 1.0 mg/l by the above procedure. Fluorides have a theoretical solubility at a pH of 8.5 to 9.0 of 8.5 mg/l, but residual concentrations on the order of 10 to 20 mg/l are more usual because of slow settling of calcium fluoride. The use of additional lime, alum coagulation and filtration through bone char are reported to reduce fluoride concentrations to 1.0 mg/l 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. Removal rates in the range of 94 to 98 percent have been reported for filtration through ferric sulfide beds, coagulation with ferric chloride, and precipitation with ferric hydroxide. However, none of these methods is entirely satisfactory, particularly for arsenic concentrations above 20 mg/l.

Information on treatment processes for removing boron from waste waters 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.

Representative data on the laboratory treatment of waste water containing CCA-type salt preservatives and a proprietary fire-retardant formulation composed mainly of ammonium and phosphate compounds are given in Table 53. Data for both concentrated solutions and diluted waste water 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 54. The latter data were obtained by analyzing effluent from equipment designed by Russell to process waste water automatically.

Waste waters 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 referred to earlier. Numerous studies have shown that copper, chromium, zinc, and arsenic have a toxic effect on biological waste treatment systems.

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. The technology involved in ion exchange has application to the wood preserving industry, but the economics of the process in the purification of preservative waste waters containing metal contaminants are unknown. It has been suggested that inert sulfate and sodium ions and organic materials in these waste waters would lower the metal-removing

TABLE 53 CONCENTRATIONS OF POLLUTANTS BEFORE AND AFTER LABORATORY TREATMENT OF WASTEWATER FROM TWO SOURCES

	Concentration 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

NOTE: Values expressed as mg/l.

TABLE 54 CONCENTRATION OF POLLUTANTS IN PLANT WASTEWATER CONTAINING SALT-TYPE PRESERVATIVES AND FIRE RETARDANTS BEFORE AND AFTER FIELD TREATMENT

	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

capacity of the exchangers sufficiently to make the process impractical under most circumstances.

Plant experience in treating waste water 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 waste water is generated. The better managed plants use the waste water 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 waste water 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 Besselieure, 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 sq m (2,000 sq ft) should be adequate for the tower (approximately 6 m (20 ft) in diameter) and associated equipment, including settling tank.

Processing Efficiency for Phenolic Wastes - The literature contains many references concerning waste water 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 studied the bacteria responsible for phenol reductions in industrial waste and reported good phenol removal from synthesized waste containing concentrations of 400 mg/l. Reductions of 23 to 28 percent were achieved in a single pass of the waste water through a pilot trickling filter having a filter bed only 30 cm (12 in) deep.

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

Harlow, Shannon, and Sercu described the operation of a commercial- size trickling filter containing "Dowpac" filter medium that was used to process waste water containing 25 mg/l phenol and 450 to 1,900 mg/l 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 other researchers. 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 waste water.

Davies, Biehl, and Smith reported on a combination biological waste-treatment system employing a trickling filter and an oxidation pond. The filter, which was packed with a plastic medium, was used for a roughing treatment of 10.6 million l/day (2.8 million gal/day) of waste water, 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 waste waters, using a series of 4 trickling filters has been studied. Each filter was operated at a different recycle ratio. The waste contained 22 to 125 mg/l 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 found that significant reductions in COD, BOD, and phenol content of refinery waste water 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 waste waters from the wood preserving industry was explored by Dust and Thompson. A pilot unit containing a 6.4 m (21 ft) filter bed of plastic media was used in their study. Creosote waste water was applied at BOD loading rates of from 400 to 3050 kg/1000 cu m/day (25 to 190 lb/ 1000 cu ft/day). The corresponding phenol loadings were 1.6 to 54.6 kg/1000 cu m/day (0.1 to 3.4 lb/1000 cu ft/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 7 months that included both winter and summer operating conditions.

Because of waste water 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 waste water 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 kg/1000 cu m/day (75 lb/1000 cu ft/day). The best removal rate was achieved when the hydraulic application rate was 2.851/min/sq m (0.07 gal/min/sq ft) of raw waste and 40.7 l/min/sq m (1.0 gal/min/sq ft) of recycled waste. The COD, BOD, and phenol removals obtained under these conditions are given in Table 55. Table 56 shows the relationship between BOD loading rate and removal efficiency. BOD removal efficiency at loading rates of 1060 kg/1000 cu m/day (66 lb/1000 cu ft/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 kg/1000 cu m/ day (1.2 lb/1000 cu ft/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 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/l are shown in Table 57 for a plant with a flow rate of 75,700 l/day (20,000 gal/day).

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

TABLE 55 BOD, COD, AND PHENOL LOADING AND REMOVAL RATES FOR PILOT TRICKLING FILTER PROCESSING A CREOSOTE WASTEWATER

Measurement	Characteristic		
	BOD	COD	Phenol
Raw Flow Rate (gpm/ sq ft)	0.07	0.07	0.07
Recycle Flow Rate (gpm/ sq ft)	1.0	1.0	1.0
Influent Concentration (mg/l)	1698	3105	31
Loading Rate (lb/1000 cu ft)	66.3	121.3	1.2
Effluent Concentration (mg/l)	137	709	1.0
Removal (%)	91.9	77.0	99+

TABLE 56 RELATIONSHIP BETWEEN BOD LOADING AND TREATABILITY FOR PILOT TRICKLING FILTER PROCESSING A CREOSOTE WASTEWATER

BOD Loading (lb/cu ft/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:

$$\frac{Le}{Lo} = e^{KD}/Q0.5 \quad \text{(Germain, 1966)}$$

in which Le = BOD concentration of settled effluent, Lo = BOD of feed, Q = hydraulic application rate of raw waste in gpm/ft^2, D = depth of media in feet, and K = treatability factor (rate coefficient).

TABLE 57 SIZING OF TRICKLING FILTER FOR A WOOD PRESERVING PLANT

(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/ sq ft) filter surface)	Recycle flow (gpm/ sq ft) filter surface)	Filter Surface area (sq ft)	Tower dia. (ft)	Volume of media (cu ft)
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

TABLE 58 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

initial cost, and have small land requirements. Package units designed to treat the waste water from an average wood preserving plant could be located on an area of approximately 93 sq m (1000 sq ft). Additional space would be required for a pretreatment equalization reservoir and, where required, flocculation tanks. A system will occupy an area of approximately 140 sq m (1500 sq ft), 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.

Processing Efficiency for Phenolic Wastes - Treatment of municipal and mixes of municipal and industrial wastes by the activated sludge process is common practice. In recent years the process has also been adapted to industrial wastes similar in composition to that of effluents from wood preserving plants. Ninety nine percent oxidation efficiency for BOD5 has been obtained in petrochemical wastes. Coe reported reductions of both BOD5 and phenols of 95 percent from petroleum wastes in bench-scale tests of the activated sludge process. Optimum BOD5 loads of 2247 kg/1000 cu m/day (140 lb/1000 cu ft/ 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 waste water from a coal-tar distilling plant in Ontario. Initial phenol and COD concentrations of 500 and 6,000 mg/l, respectively, were reduced in excess of 99 percent for phenols and 90 percent for COD.

Cooke and Graham 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 kg/1000 cu m/day (9 to 100 lb/1000 cu ft/day), phenol content was reduced from 281 mg/l to 62 mg/l, for a removal rate of 78 percent.

The employment of aerated reaction units on a continuous flow basis has been used to treat coke gasification plant waste. Badger and Jackson have 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/l of the chemical.

Nakashio successfully treated coal gas washing liquor containing 1,200 mg/l of phenols in a study that lasted more than a year. Phenol concentration was reduced by more than 99 percent. Similar phenol removal rates have been obtained by Reid and Janson in treating waste water containing cresols by the activated sludge process.

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

<u>Treatment of Wood Preserving Effluents</u> - Dust and Thompson conducted bench-scale tests of complete-mixed, activated sludge treatments of creosote and pentachlorophenol waste waters 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 58. A plot of these data showed that the treatability factor, K = 0.30 days-1 (Figure 39). The resulting design equation, with t expressed in days, is:

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

where: Lo = COD in raw waste
Le = COD in effluent

A plot of percent COD removal versus detention time in the aerator, based on the above equation, is shown in Figure 40. The figure shows that an oxidation efficiency of about 85 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/l of pentachlorophenol and 2,400 mg/l 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.

Removal rates for pentachlorophenol and COD are given in Table 59. 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

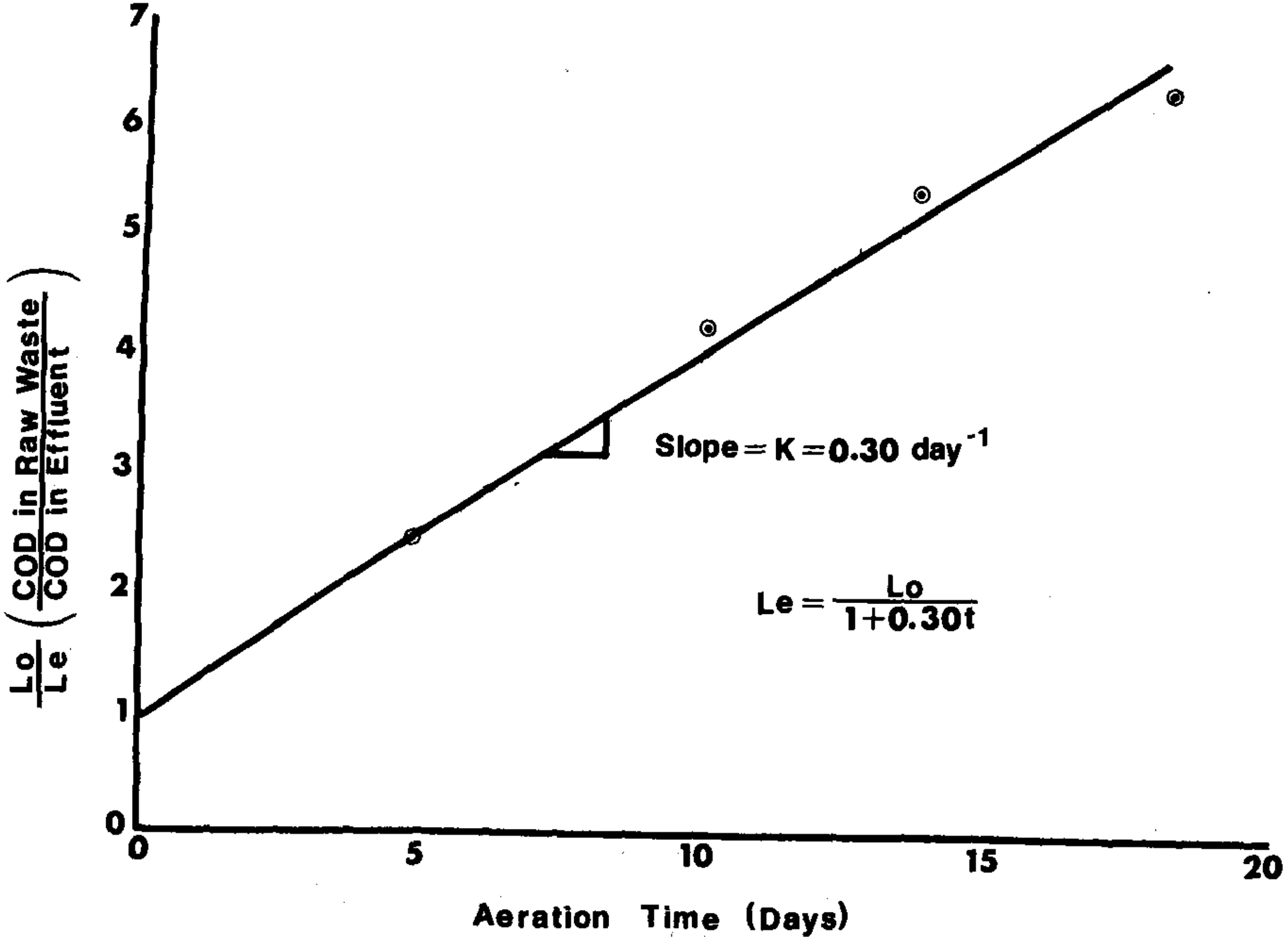


FIGURE 39 DETERMINATION OF REACTION RATE CONSTANT FOR A CREOSOTE WASTEWATER

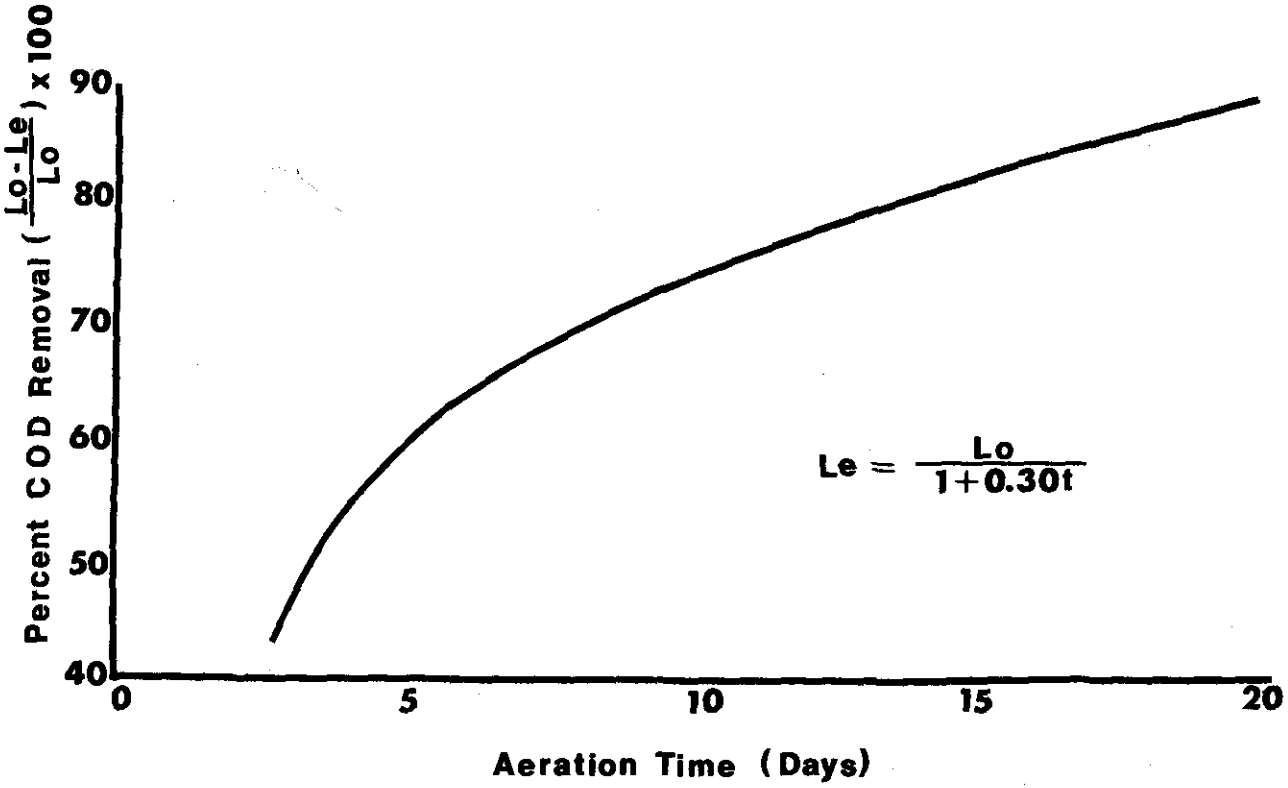


FIGURE 40 - COD REMOVAL FROM A CREOSOTE WASTEWATER BY AERATED LAGOON WITHOUT SLUDGE RETURN

TABLE 59 REDUCTION IN PENTACHLOROPHENOL AND COD IN WASTEWATER TREATED IN ACTIVATED SLUDGE UNITS

DAYS	RAW WASTE (mg/l)	EFFLUENT FROM UNIT (% Removal) "A"	"B"
	COD		
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
	PENTACHLOROPHENOL		
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

TABLE 60 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.

40 mg/l. 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 obtained removal rates for pentachlorophenol in excess of 97 percent using an 8-hour detention time and a feed concentration of 150 mg/l. The pentachlorophenol was supplied to the system in a mixture that included 100 mg/l 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 waste water 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 pertinent parameters. Its chief disadvantage is that its use requires a minimum area of approximately one ha/33,000 l of discharge/day (one ac/3500 gal of discharge/day). 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. At least 20 types of industrial wastes that have been treated by this method. Among these are several wastes high in phenol content. Removal efficiencies as high as 99.5 percent for both BOD and phenols were reported.

Fisher reported on the use of soil irrigation to treat waste waters from a chemical plant that had the following characteristics:

pH	9.0 to 10.0
Color	5,000 to 42,000 units
COD	1,600 to 5,000 mg/l
BOD	800 to 2,000 mg/l

Operating data from a 0.81 ha (2 ac) field, when irrigated at a rate of 18,690 l/ha/day (2000 gal/ac/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/l phenol and 20,000 to 54,000 mg/l COD. The waste was applied to the field at a rate of about 23,400 l/ha/day (2500 gal/ac/day). Water leaving the area had COD and phenol concentrations of 60 and 1 mg/l, 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 has also been studied. Wastes containing BOD_5 and phenol concentrations of 5,000 and 1,550 mg/l, respectively, were reduced by 95 and 99 percent when percolated through 0.9 m (36 in) 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 waste water were conducted by Dust and Thompson. In the laboratory tests, 210 liter (55 gal) drums containing a heavy clay soil 60 cm (24 in) deep were loaded at rates of 32,800, 49,260, and 82,000 l/ha/day (3,500, 5,250, and 8,750 gal/ac/day). Influent COD and phenol concentrations were 11,500 and 150 mg/l, 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 waste water 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.

The field portion of Dust and Thompson's study was carried out on an 0.28 ha (0.7 ac) plot prepared by grading to an approximately uniform slope and seeded with grasses. Wood preserving waste water from an equalization pond was applied to the field at the rate of 32,800 l/ha/day (3,500 gal/ac/day) for a period of nine

TABLE 61 REDUCTION OF COD AND PHENOL CONTENT IN WASTEWATER TREATED BY SOIL IRRIGATION

		Soil Depth (centimeters)			
Month	Raw Waste	0	30	60	120
		COD (mg/l)			
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
		Phenol (mg/l)			
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

months. Average monthly influent COD and phenol concentrations ranged from 2,000 to 3,800 mg/l and 235 to 900 mg/l, respectively. Supplementary nitrogen and phosphorus were not added. Samples for analyses were collected weekly at soil depths of 0 (surface), 30, 60, and 120 cm (1, 2, and 4 ft).

The major biological reduction in COD and phenol content occurred at the surface and in the upper 30 cm (1 ft) 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 61). 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 cm (1-, 2-, and 4-ft) depths. For phenols, the reductions were, in order, 98.9, 99.2, and 99.6 percent.

Color of the waste water 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 cm (2 and 4 foot) depths showed no discoloration.

The application of the waste water 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 waste water 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.

<u>Oxidation Ponds</u> - 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 related 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 containing algal cells, 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" refers to several industries that have successfully used this method.

Montes 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 kg/ha/day of BOD (75 lb/ac/day).

Phenol concentrations of 990 mg/l in coke oven effluents were reduced to about 7 mg/l in field studies of oxidation ponds conducted by Biczysko and Suschka. Similar results have been reported by Skogen 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 waste water (Table 48). However, the literature contains operating data on only one pond used for this purpose.

As originally designed and operated in the early 1960's, this 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 phosphorus, 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/ l.

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 waste water 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/l to 5 mg/l.

Even with the modifications described, the efficiency of the system remains seasonally dependent. Table 62 gives phenol and BOD_5 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 waste waters, 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. Chlorine gas and calcium and

TABLE 62 AVERAGE MONTHLY PHENOL AND BOD CONCENTRATIONS IN EFFLUENT FROM OXIDATION POND

(mg/liter)

Month	1968 Phenol	1968 BOD	1970 Phenol	1970 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	--	--

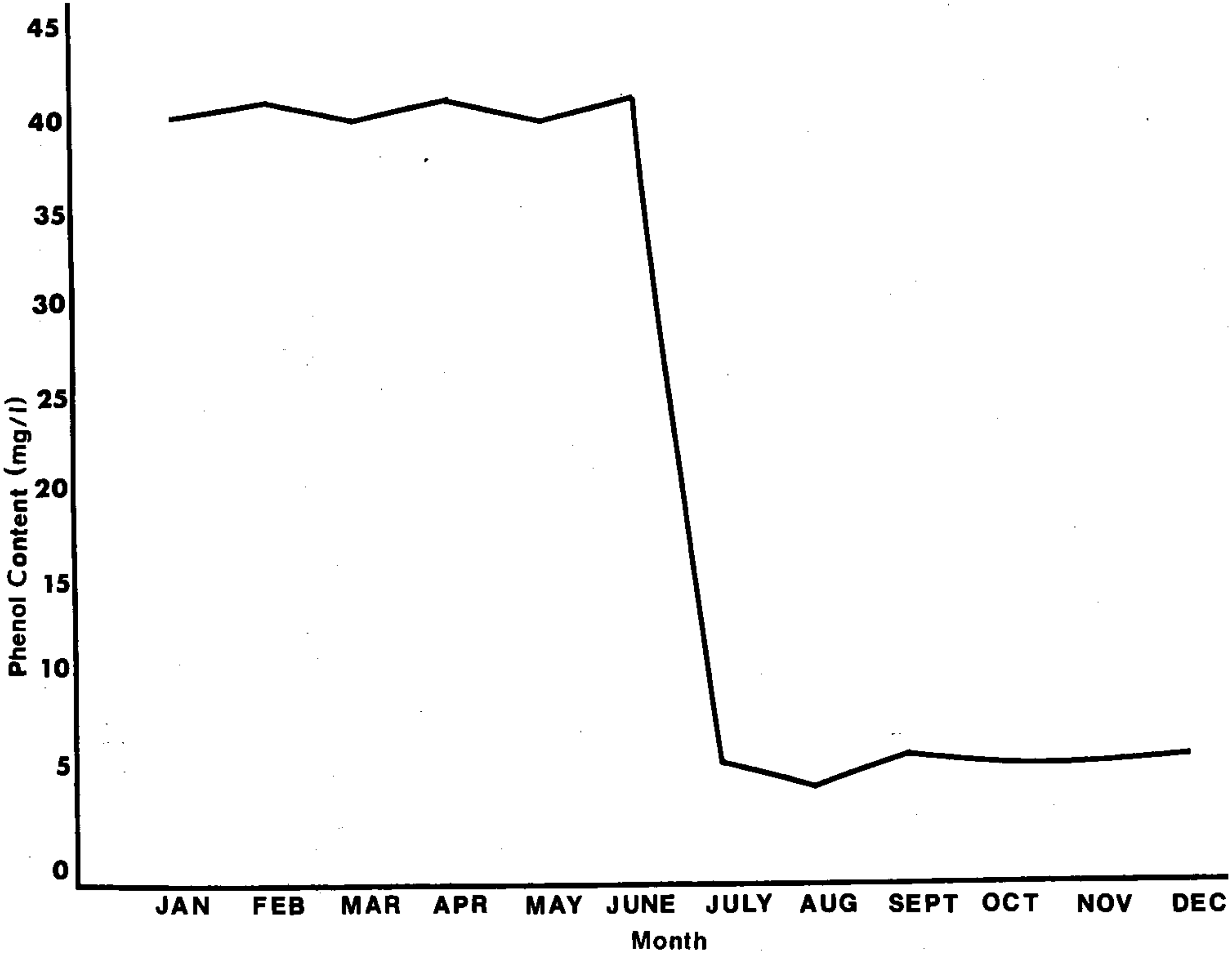


FIGURE 41 - PHENOL CONTENT IN WEYERHAEUSER'S OXIDATION POND EFFLUENT BEFORE AND AFTER INSTALLATION IN JUNE, 1966 OF AERATOR

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 waste water must be treated. However, for batch-type treatments involving small waste water 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, 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.

The theoretical ratio of chlorine to phenol required for complete oxidation is about 6:1. For m-cresol the ratio is 3.84:1. However, because of the presence in waste water of other chlorine-consuming compounds, much higher ratios are required. Thompson and Dust found that the minimum concentration of calcium hypochlorite needed to destroy all phenols in creosote waste water was equivalent to a chlorine:phenol ratio of from 14:1 to 65:1. The exact ratio varied with the pH, COD content, and source of the waste water. 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 waste water samples for COD, phenol, and pentachlorophenol content following chlorination with quantities of calcium hypochlorite equivalent to 0 to 3.0 g/l of chlorine. Typical results are shown in Table 63. Treatment of creosote waste water achieved a reduction in phenol content of 95 to 100 percent, as determined by procedures recommended by APHA (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 63, a residual phenol content of 5 to 10 mg/l 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/l or less.

In the same study, both chlorine gas and calcium hypochlorite were used to treat pentachlorophenol waste water adjusted to pH levels of 4.5, 7.0, and 9.5. The results, which are summarized in Tables 64 and 65, 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 waste water, the source of chlorine, and whether or not the waste was flocculated prior to chlorination.

TABLE 63 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	0.0	3760	5.4

TABLE 64 EFFECT OF CHLORINATION WITH CALCIUM HYPOCHLORITE ON THE PENTACHLOROPHENOL CONTENT OF WASTEWATER

Pentachlorophenol (mg/liter)

Ca(PCl)$_2$ as Chlorine (g/liter)	Unflocculated			Flocculated		
	pH			pH		
	4.5	7.0	9.5	4.5	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	0.0	3.6	7.0
3.0	3.5	6.0	5.0	0.0	0.0	4.0
4.0	2.0	6.0	4.0	0.0	0.0	0.0
5.0	2.0	5.8	4.0	0.0	0.0	0.0

TABLE 65 EFFECT OF CHLORINATION WITH CHLORINE GAS ON THE PENTACHLOROPHENOL CONTENT OF WASTEWATER

Pentachlorophenol (mg/liter)

Chlorine (g/liter)	Unflocculated			Flocculated		
	pH			pH		
	4.5	7.0	9.5	4.5	7.0	9.5
0.0	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	0.0	2.0	4.0
10.0	14.0	11.5	14.0	0.0	2.0	2.0

TABLE 66 EFFECT OF CHLORINATION OF PENTACHLOROPHENOL WASTE ON COD

Test Conditions	Available Chlorine (g/liter)	COD (mg/liter)
Calcium Hypochlorite	0.0	24,200
pH = 4.5	0.5	
	1.0	10,650
	1.5	
	2.0	10,600
	3.0	
	4.0	10,300
	5.0	
Calcium Hypochlorite	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	0.0	20,400
pH = 4.5	0.5	
	1.0	
	1.5	
	2.0	10,250
	3.0	
	4.0	10,500
	5.0	
	10.0	10,200
Chlorine Gas	0.0	23,600
pH = 7.0	0.5	
	1.0	
	1.5	
	2.0	9,760
	3.0	
	4.0	10,700
	5.0	
	10.0	11,250

A large proportion of the chlorine added to the waste water 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/l before and 10,300 mg/l after treatment with calcium hypochlorite, a reduction of 58 percent (Table 66). 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/l for calcium hypochlorite and 10 g/l for chlorine gas. However, practically all of the reduction in COD occurred at chlorine doses of 1 g/l or less, in the case of samples treated with the hypochlorite, and 2 g/l 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/l. This value was reduced to 10,250 mg/l by a chlorine dose of 2 g/l. The addition of 10 g/l of chlorine further reduced the COD to only 10,200 mg/l. These data indicate that a portion of the organic content of the waste water was resistant to chemical oxidation.

The reduction in COD caused by chlorination of raw waste water 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/l. 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/l.

Ingols and Ridenour 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 g of chlorine/g 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. Later studies by Ettinger and Ruchoft 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 67. These data indicate that a chlorine-to-phenol ratio of 5:1 would be adequate to form chlorination end products. Work reported by others 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.

TABLE 67 CHLORINE REQUIRED TO ELIMINATE TASTE IN AQUEOUS SOLUTIONS OF VARIOUS PHENOLIC COMPOUNDS

	Chlorine Required To Eliminate Taste (mg/1)	Chlorine Added To Produce Free Residual (mg/1)
Phenol	4	7
O-Cresol	5	5
M-Cresol	5	5
P-Cresol	3	4
2-Chlorphenol	3	5
4-Chlorophenol	3	6
2-, 4-Dichlorophenol	2	6
2-, 4-, 6-Trichlorophenol	*	3
2-, 4-, 5-Trichlorophenol	*	2
2-, 3-, 4-, 6-Tetrachlorophenol	*	1.5
Pentachlorophenol	*	1.0

*Could not be tasted

More recent work by the Manufacturing Chemists Association 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/l, the application of 50 and 100 mg/l 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 68.

In related studies, phenol in concentrations of 25 mg/l 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 0-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 chlorphenols 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.

Burttschell has 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

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-dischlorophenol. The development of taste was reported not to occur at pH values of less than 7.0.

Results of a study by Eisenhauer supported earlier work of other investigators that non-aromatic products are formed when phenols are treated with high levels of chlorine.

TABLE 68 CHLORINE DEMAND OF M-CRESOL AFTER VARIOUS CONTACT TIMES

m-Cresol Concentration (mg/l)	Chlorine (mg/l)	Contact Time (hr)	Chlorine Residual (mg/l)	Net Chlorine Demand	
				mg/l	$\frac{\text{m mol } cl_2}{\text{m mol m-Cresol}}$
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

Oxidation products resulting from the chlorination of pentachlorophenol have not been studied intensively. However, Thompson and Dust reported the presence of chloranil in samples of chlorinated waste water 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 waste water, 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 provide a partial answer.

Creosote waste water with phenol and COD contents of 508 and 13,500 mg/ l, 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-aminantipyrine 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 69.

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 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. The high initial cost of ozonation is offset in part by the fact that the equipment has a useful life expectancy of 25 years.

Treatment of waste water 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 was 12.0. Ozone demand at pH 12 was less than one-half that at pH 7 in

TABLE 69 CHLOROPHENOL CONCENTRATION IN CREOSOTE WASTEWATER TREATED WITH CHLORINE

pH	$Ca(PCl)_2$ As Chlorine (g/l)	Residual Phenols (mg/l) by APHA Method	ECD Analysis (mg/l) 2-, 4-dichlorophenol	2-, 4-, 6-trichlorophenol
	0	438.5	--	--
4.5	0.5	256.1	161.0	910.0
	1.0	30.8	9.9	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

treating petroleum waste waters. 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 for waste waters from different sources. According to Gloyna and Malina, only about 1/10 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 waste waters, and hence will not be considered further in this report.

Activated Carbon Filtration - Activated carbon is used commercially to treat petroleum and other types of industrial waste waters. It can also be used effectively to remove phenolic compounds from wood preserving waste streams. Although carbon has a strong affinity for nonpolar compounds such as phenols, adsorption is not limited to these materials. Other organic materials in waste water 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 on a creosote waste water are shown in Figure 42. Granular carbon was used and the contact time was 24 hours. The waste water 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 waste water at a carbon dosage of 8 g/l. 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/l. Similar results were obtained in tests using pentachlorophenol waste water.

Results of adsorption isotherms that were run on pentachlorophenol waste water, and other samples of creosote waste water followed a pattern similar to that shown in Figure 42. In some instances a residual content of phenolic compounds remained in waste water 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 kg of phenol and 1.2 kg COD/carbon were typical, but much lower rates were obtained with some waste waters.

Other Process Waste Water Handling Methods

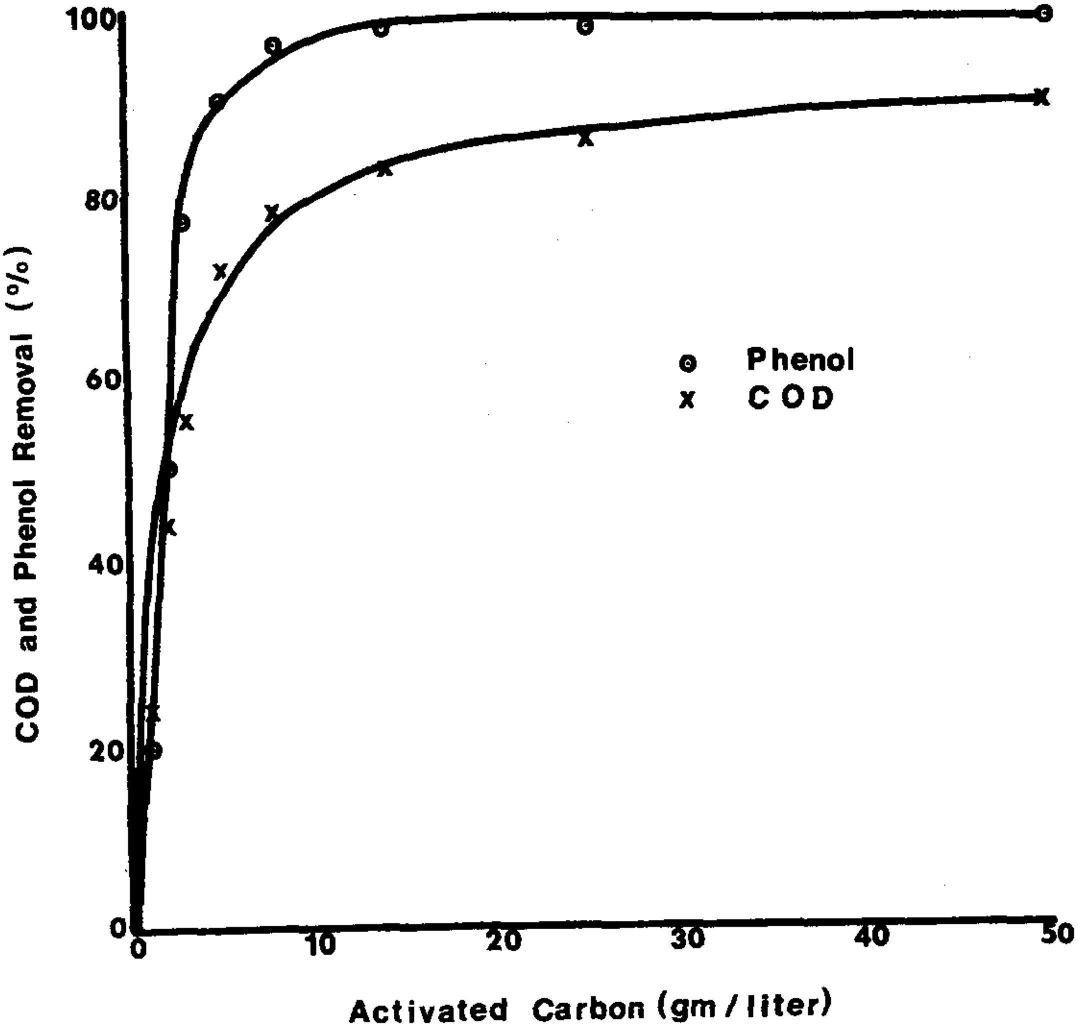


FIGURE 42 - RELATIONSHIP BETWEEN WEIGHT OF ACTIVATED CARBON ADDED AND REMOVAL OF COD AND PHENOLS FROM A CREOSOTE WASTEWATER

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 waste water on company property, and therefore have no discharge (Table 44). 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 coast region of the South.

The use of spray ponds to dispose of waste water 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 waste water 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, and is based on using natural gas as fuel, assuming an overall efficiency of 65 percent for the process.

Evaporation in Cooling Towers - In this process, effluent from the oilseparation system is discharged to the basin of a cooling tower and reused as cooling water. Normal evaporation associated with the operation of the tower accounts for an average loss of approximately 7,570 l/day (2000 gal/day) 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/l.

Incineration - Two plants in the U.S. are known to operate incinerators for waste water disposal. The one plant for which data are available currently operates a unit capable of "burning" 5,676 l/hr (1500 gal/hr) of waste water. Fuel cost alone for this unit, which is fired with Bunker C oil, is $15.00/3,785 l (1000 gal) of waste.

Data reported by the American Wood Preservers' Association indicates that incineration of waste water is economical only when the oil content of the waste is 10 percent or higher. Such high oil contents are not common for waste water from the wood preserving industry.

Required Implementation Time

Because of the relatively small volume of waste water 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 treatment 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 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 segment of the 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 waste water 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 and practices were visited in conjunction with this study. Selection of plants for visits was based on the type of waste water treating disposal system employed or both, and, insofar as possible, geographic location. Plants that dispose of their raw waste by discharging it to a sewer 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 because of reuse of waste water, evaporation, or both.

Plant visits were used to obtain samples, the analyses of which permitted an evaluation of the efficiency of the waste water 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 waste water treating systems were requested of all plants and provided by some.

A summary of the data obtained for each plant visted is presented in Table 70. 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.

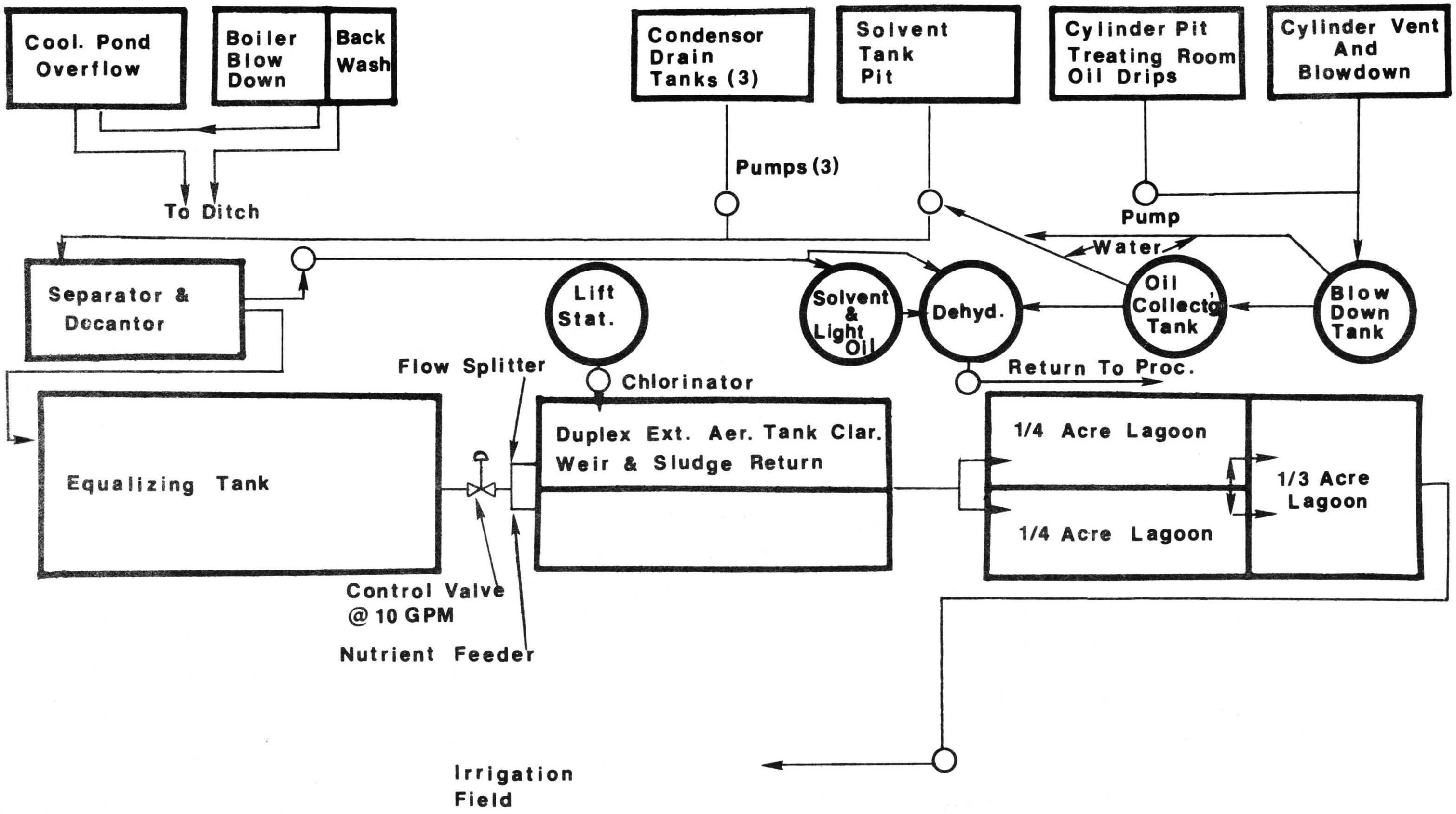


FIGURE 43 - WASTEWATER FLOW DIAGRAM FOR WOOD-PRESERVING PLANT EMPLOYING AN EXTENDED AERATION WASTE TREATMENT SYSTEM IN CONJUNCTION WITH HOLDING LAGOONS AND SOIL IRRIGATION

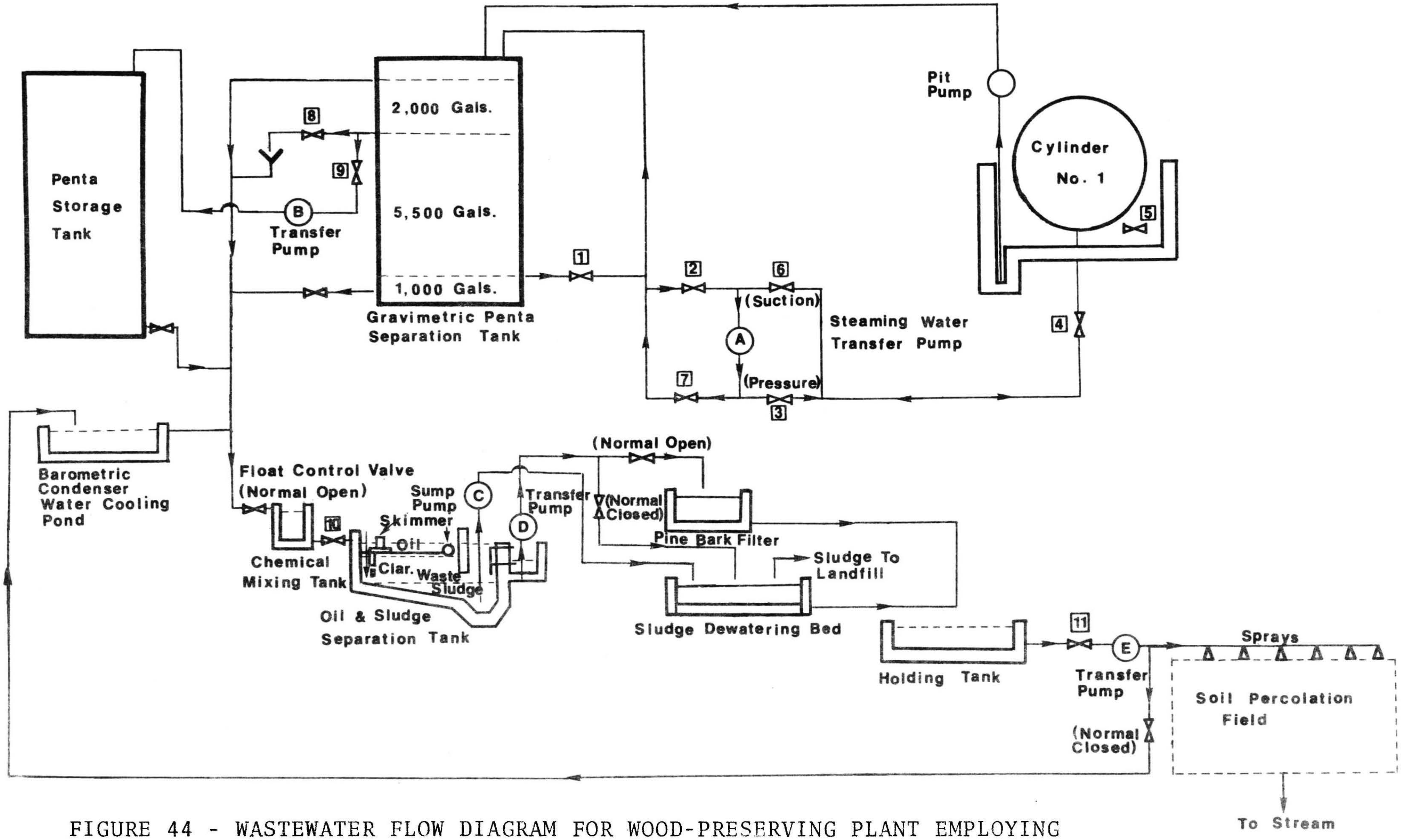


FIGURE 44 - WASTEWATER FLOW DIAGRAM FOR WOOD-PRESERVING PLANT EMPLOYING CHEMICAL FLOCCULATION, SAND FILTRATION, AND SOIL IRRIGATION

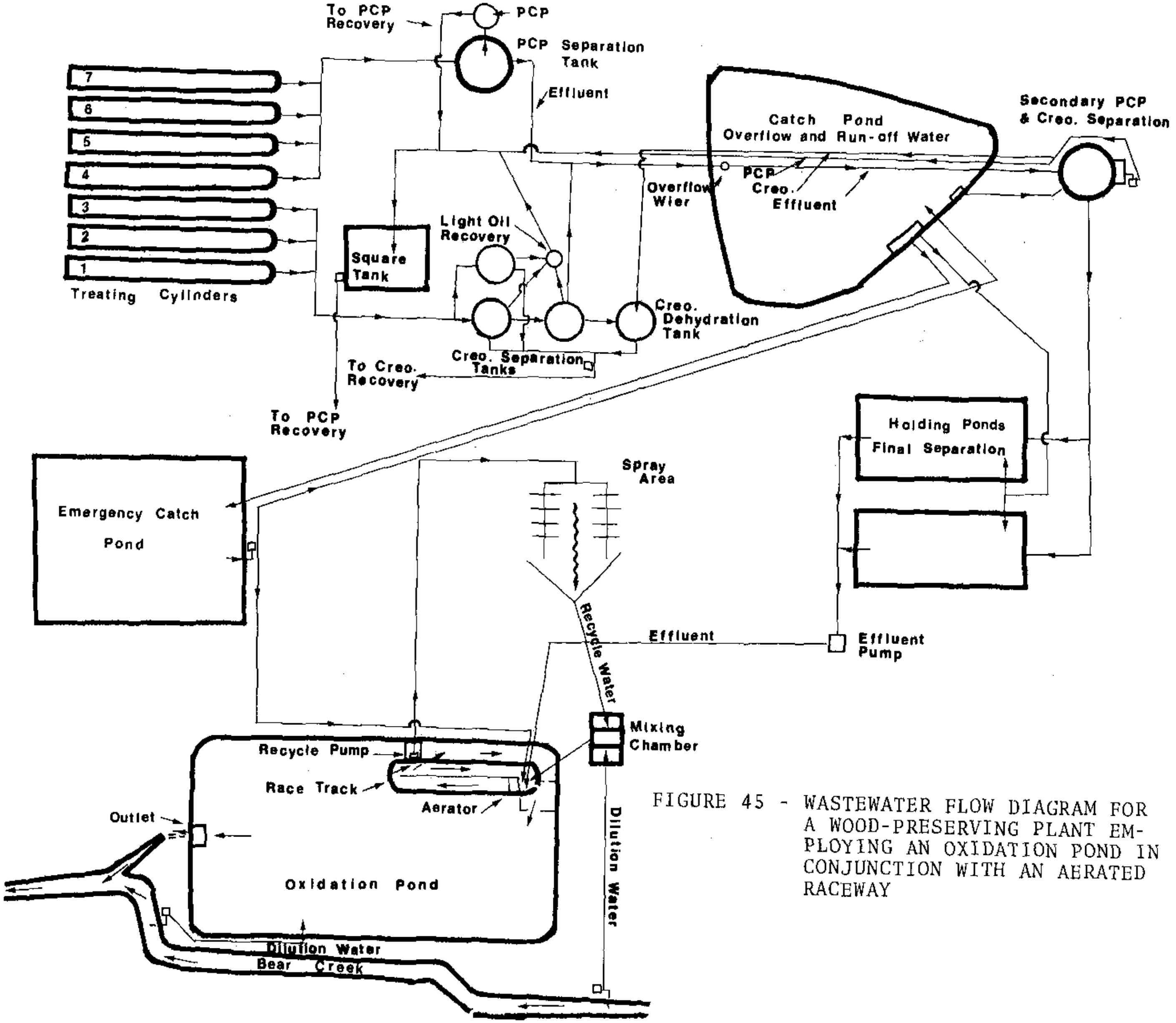


FIGURE 45 - WASTEWATER FLOW DIAGRAM FOR A WOOD-PRESERVING PLANT EMPLOYING AN OXIDATION POND IN CONJUNCTION WITH AN AERATED RACEWAY

TABLE 70 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 (cu m)	Cost ($)	Final Disposition of Waste
1	6.00	845	7	100	73,800	0	283	42,000	Sewer
2*	0.00	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.

SECTION VIII

COST, ENERGY, AND NON-WATER QUALITY ASPECTS

BARKING

Cost and Reduction Benefits of Alternative Treatment and Control Technologies

Only wet barking techniques result in any discharge of process waste waters. An elimination of the discharge of pollutants can be accomplished by all but hydraulic barkers through the recycle of process water.

A hydraulic barking operation servicing a 9.3 million sq m/yr will typically have a waste load of about 13,100 kg/day (100 million sq ft/yr) plant (28,800 lb/day) of suspended solids and 660 kg/day (1,450 lb/day) of BOD5, and a flow of approximately 6500 cu m/day (1.73 million gal/day). Recycle of this effluent has not been shown to be practicable technology. In the pulp and paper industry, however, hydraulic barker effluent is commonly treated biologically along with other waste waters.

One hydraulic barker such as the one presented here can handle the barking operation of mill producing 9.3 million sq m (100 million sq ft/yr) of plywood on a 9.5 mm (3/8 in) basis.

Alternative A: No Waste Treatment or Control

Effluent waste load is estimated at 660 kg/day of BOD5 and 13,100 kg/day of suspended solids for the selected plant.

Costs: None
Reduction Benefits: None

Alternative B: Clarification and Biological Treatment

This alternative includes clarification of waste waters and then combination with other wastes for biological treatment. An activated sludge system can achieve 95 percent BOD5 removal with a resulting effluent load of 35.0 kg/day (77 lb/day) for a 100 million sq ft/yr plywood on 3/8 in basis plant.

INVESTMENT AND OPERATING COST ESTIMATE
ALTERNATIVE B

Clarification and Biological Treatment

Item	Cost
1. Installed Equipment	$1,070,500
2. Yearly Operating Costs	138,200

TOTAL COST/YR $ 196,300

VENEER AND PLYWOOD MANUFACTURING SUBCATEGORIES

Cost And Reduction Benefits of Alternative Treatment And Control Technologies For A Selected Plant

The typical combination veneer and plywood mill selected to represent the veneer and plywood subcategories is a mill producing 9.3 million sq m/yr on a 9.53 mm basis (100 million sq ft/yr on a 3/8 in basis). It is assumed to have the following:

(1) Log conditioning by means of hot water vats with direct steam impingement and a resulting discharge;
(2) No containment of dryer washwater;
(3) A phenolic glue system without recycle of washwater.

This is a hypothetical mill and is not typical in the sense that it represents the average mill. It is typical of a softwood plywood mill built in the past twenty years, but without any degree of waste water treatment and control. This hypothetical plant might be located in a number of places throughout the U.S., however, it is more likely that it will be located in the southeast because of the fact that hot water vats are used.

A single mill has been chosen to represent both the veneer and plywood subcategories, as the two manufacturing operations often take place in the same plant, and the costs would thus be applicable to a combination operation. In a plant producing only plywood, however, only the costs of alternative treatment B (glue wash water recycle) would apply.

Basis of Assumptions Employed In Cost Estimation

Investment costs are based on actual engineering cost estimates as described in the following paragraph.

Yearly operating costs are based on actual engineering cost estimates using $7.00/hr for salaries and $0.01 kwh for electricity. The annual interest rate for capital cost was estimated at 8%. Salvage value was set at zero over 20 years for physical facilities and equipment. The total yearly cost equals: (investment cost/2) X (0.08) + (investment cost) X (0.05) + yearly operating cost.

Alternative A: No Waste Treatment Or Control

Effluent waste load is estimated at 485 kg/day of BOD (1080 lb/day) for the selected 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. Collection, holding, and screening is now practiced in 60 percent of the mills surveyed. In 1972, 50 mills practiced recycling and it is believed that more than 50 percent of the softwood plywood mills now recycle or plan to recycle glue wash water. BOD waste load is estimated at 410 kg/day (900 lb/day) for the selected typical plant at this control level.

Recycling of glue wash water is the most significant pollution control step in the reduction of phenolic compounds; free phenols are reduced by 73 percent. Associated costs for a 9.3 million sq m/yr plant on a 9.53 mm basis (100 million sq ft/yr on a 3/8 in basis) are described below.

INVESTMENT COST ESTIMATE
ALTERNATIVE B

Item	Cost
1. 3785 l (1000 gal) concrete sump	$ 1,300
2. 18925 l (5,000 gal) holding tank	1,000
3. 1080 l (285 gal) pressure tank	350
4. Rotating screen	1,800
5. Pumps	3,700
6. Valves, fittings, controls and engineering costs	9,350
TOTAL COST	$17,500

OPERATING COST ESTIMATE

Item	Cost
1. Operation and Maintenance	$ 2,200
2. Electricity	800
TOTAL COST/YR	$ 3,000

Summary:

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 kg/day (170 lb/day). Total plant reduction in BOD would be 15.8 percent.

Alternative C: Complete Retention of Waste Water From Log Conditioning

Alternative C would result in complete recycle of water from hot water vats with containment of excess waste waters. Modification of hot water vats to provide heat by means of coils rather than direct steam impingement is assumed.

INVESTMENT COST ESTIMATE
ALTERNATIVE C

Item	Cost
1. 320 cu m (85,000 gal) settling tank	$ 1,900
2. Pump and motor	1,300
3. Containment pond, 30.5 m x 30.5 m (100 ft x 100 ft)	4,300
4. Piping, contingencies and labor	4,500
TOTAL COST	$12,000

OPERATING COST ESTIMATE
ALTERNATIVE C

Item	Cost
1. Operation and Maintenance	$ 6,300
2. Electricity	2,200
TOTAL COST/YR	$ 8,500

Summary

Costs: Incremental costs of approximately $12,000 over Alternative B would be incurred, thus producing total costs of $29,500.

Reduction Benefits: An incremental reduction in plant BOD of 406 kg/day (894 lb/day) is evidenced when compared to Alternative B. Total plant reduction in BOD is 99.3 percent.

Alternative D: Complete Retention of Dryer Washwater

Alternative D would result in the complete retention of dryer washwater. Modification of washing operations to reduce the volume of water used assumes reduction of water by scraping, pneumatic cleaning and general water conservation with complete retention of waste water by irrigation or containment on site. Effluent waste load is estimated at 0 kg/day of BOD for the selected typical plant at this control level. Complete control of wastes without discharge to receiving waters is effected.

INVESTMENT COST ESTIMATES
ALTERNATIVE D

Alternative D-1: Spray Irrigation.
Associated Costs:

Item	Cost
1. 37850 l (10,000 gal) storage tank	$ 2,700
2. Pump and motors	1,200
3. Piping	2,600
4. Labor and contingencies	3,200
TOTAL COST	$ 9,700

Alternative D-2 - Containment by Lagooning

A conservative estimate of 76.2 cm/yr (30 in/yr) of evaporation is assumed.

Item	Total Cost
30.5 m x 30.5 m pond	$ 4,300

OPERATING COST ESTIMATES
ALTERNATIVE D

Item	Cost
1. Operation and Maintenance	$ 7,900
2. Electricity	2,300
TOTAL COST/YR	$10,200

Summary:

Costs: Investment costs of $5,000 to $10,000 over Alternative C would be incurred, thus producing total costs of about $37,000 ($35,000 to $40,000).

Reduction Benefits: An incremental reduction in plant BOD of 3 kg/day (6 lb/day) is evidence when compared to Alternative C, producing a total plant reduction in BOD discharge of 100 percent.

SUMMARY OF ALTERNATIVE COSTS

Alternative	BOD Removal	Investment Cost	Yearly Operating	Total Yearly Cost

A	0%	0	0	0
B	15.8%	17,500	3,000	4,575
C	99.3%	29,500	5,000	7,655
D	100.0%	37,000	7,700	9,030

TABLE 72

SUMMARY OF WASTE LOADS FROM TREATMENT ALTERNATIVES (kg/day)

	RWL	A	B	C	D
BOD	485	485	412	3	0
TSS	352	352	330	11	0
Phenols	0.25	0.25	0.09	0.07	0

HARDWOOD VENEER AND PLYWOOD MANUFACTURING CONSIDERATIONS

Hardwood veneer and plywood manufacture normally occurs at a plant considerably smaller in size than a softwood manufacturing facility. As discussed above, the softwood plant has a production rate of about 9,290,000 sq m/year (1000,000,000 sq ft/yr) whereas a hardwood veneer and plywood mill of average size will produce about 464,500 sq m/year (5,000,000 sq ft/yera) of veneer and plywood.

Because of the significantly lower production (or throughput rate) less water is used and as a result, treatment and control schemes necessary to reduce or eliminate the discharge of waste water pollutants are on a smaller scale than those applicable to waste waters generated by a softwood manufacturing facility.

Presented below in tabular format is information showing the pollutants generated, the pollutant reduction achievable by application of technology and the costs associated with these technologies.

RAW WASTE

	Flow cu m/day (mgd)	Waste Load			
		Concentration mg/l		Loading, kg/day (lb/day)	
		BOD	SS	BOD	SS
Conditioning	0.043	700	600	30	26
Vats	(0.0115)			(67)	(58)
Dryer	0.429	750	3000	0.4	1.6
Washwater	(0.000 14)			(0.9)	(3.5)

TREATMENT	Investment Cost ($)	Yearly Operating ($)	TOTAL Annual ($)	BOD Removal (%)
Conditioning Vats				
Lagoon	3,000	600	870	30
Activated Sludge	32,500	8,500	11,025	90
Glue Wash Water Recycle System	2,000	300	480	100
Dryer Wash Water Lagoon	50	50	50	32

As can be seen from the information presented in the table above it is, from an economic viewpoint, more feasible to modify the manufacturing procedures to accomplish the elimination of the discharge of pollutants than it is to install treatment technologies to reduce the level of discharge.

Mills With Existing Steam Vats

In Sections I, II, and IX of this report, a variance is recommended for mills with existing steam vats. In Section VII, it is noted that existing technology for treatment and control of waste waters 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. These modifications will not be required for best practicable control technology as defined by the Act.

As discussed in Section VII, biological treatment is applicable to waste waters from steam vats. A summary of costs and effluent levels for biological treatment of waste waters from mills with existing steam vats is presented below:

1. A system consisting of a vacuum separator followed by an aerated lagoon would cost approximately $81,000 for the selected mill utilizing a steam vat and would reduce the load to around 41 kg/day (90 lb/day) of BOD.

2. An activated sludge plant may result in slightly higher BOD removals for a cost of about $138,000 and a resulting BOD discharge of about 20 kg/day (45 lb/day) for the

selected mill.

Related Energy Requirements of Alternative Treatment and Control Technologies

It is estimated that 180 kwh of electricity is required to produce 93 sq m (1000 sq ft) of plywood. 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, and (4) amount of pollution control devices.

For a typical mill producing 9.3 million sq m/yr (100 million sq ft/yr) of plywood on a 9.53 mm (3/8 in) basis, total energy is estimated at 4500 kw. At a cost of one cent/kwh 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:	$900
For Alternative D:	$1000

Nonwater Quality Aspects of Alternative Treatment and Control Technologies

Air Pollution: While there are no appreciable air pollution problems associated with any of the treatment and control alternatives, in veneer and plywood manufacturing operations there are air pollution problems presently in existence that may cause water pollution problems. The main source of air pollution is from the veneer dryers as the stack gases from the dryers contain volatile organics.

Veneer Dryers: Since there are currently no emission control systems installed on any 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 by 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 are not great. Only condensation and scrubbing use water. Water used in condensation is only cooling water and thus not contaminated. The most efficient scrubber appears to be that using a selective solvent rather than water for absorption. Scrubbing water can usually be recycled.

Odors: Odors presently associated with veneer and plywood are not considered to be a pollution 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, hydrogen sulfide 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.

HARDBOARD - DRY PROCESS

Cost and Reduction Benefits of Alternative Treatment and Control Technologies

The following cost estimates are based upon actual preliminary cost estimates for a waste treatment system for the dry process industry. The waste water volume from this industry is low and the major approach for further reducing waste flow is by inplant modifications and changes in inplant procedures. The mill selected to represent the dry process hardboard industry has a production of 227 kkg/day (250 ton/day), and a waste water flow of 945 l/day (250 gal/day). The waste water discharges result only from caul washing. The basic results are summarized in the paragraphs below.

Basis of Assumptions Employed In Cost Estimates

Investment costs are based on actual engineering cost estimates. Yearly operating costs are based on engineering cost estimates using $10.00/hr for salaries, $0.01 kwh for electricity and 1973 market cost for chemicals. Annual interest rate for capital cost is estimated at 8%, a salvage value of zero over 20 years for physical facilities and equipment, and a straight line depreciation cost are assumed. The total yearly cost equals: (investment cost/2) X (0.08) + (investment cost) X (0.05) + yearly operating cost.

Alternative A: No Waste Treatment or Control

Effluent consists of 945 l/day (250 gal/day) of caul wash water. There is no log or chip wash, no resin wash water, humidifier water or housekeeping water discharge.

Costs: None
Reduction Benefits: None

Alternative B: Retention of Caul Washwater

This alternative includes the collecting of caul washwater in a holding tank and trucking to land disposal after pH neutralization. There are no provisions in the following cost estimates for handling water from fire fighting. As the number of fires and the amount of water used vary so widely, no estimation was made for handling this potential source of water. There are new techniques being developed to limit the oxygen concentrations in the air stream which will greatly reduce, if not eliminate, future fire problems in the dry process hardboard industry.

INVESTMENT COST ESTIMATE
ALTERNATIVE B

Item	Cost (May, 1973)
1. 18,925 l (5,000 gal) storage tank (includes installation and fittings)	$ 4,000
2. 1892 l (500 gal) storage tank (acid resistant) (includes installation and fittings)	1,500
3. Chemical feed pump	500
4. Pumps and piping	6,000
5. Instrumentation (pH) and controls	1,000
6. Chemical mixer	500
7. Tank Truck 7570 l (2,000 gal)	8,500
8. Land	3,000
TOTAL	$25,000

OPERATING COST ESTIMATE
ALTERNATIVE B

Item		Cost
1. Labor (4 man hr/wk)		$ 2,080
2. Electricity		65
3. Chemicals		500
4. Maintenance		355
	TOTAL COST/YR	$ 3,000

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 wash water by hauling to land disposal. There are no problems concerning the reliability of the system as caul wash water 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 startup and shutdown procedures do not cause a problem. This 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.

HARDBOARD-WET PROCESS

Basis Of Assumptions Employed In Cost Estimation

Investment costs are based on actual engineering cost estimates.

Yearly operating costs are based on actual engineering cost estimates using $10,00/hr for salaries, $0.01 kw/hr for electricity and present market cost for chemicals. The annual interest rate for capital cost is estimated to be 8%, and a salvage value of zero over 20 years for physical facilities and equipment, and straight line depreciation cost are assumed. The total yearly cost equals (investment cost/2) (0.08) plus (investment cost) (0.05) plus yearly operating cost.

Cost and Reduction Benefits of Alternative Treatment and Control Technologies

The mill selected to represent the wet process industry has a production of 127 kkg/day (140 tons/day), a waste water flow of 1,432 cu m/day(0.378 million gal/day), a BOD of 33.75 kg/kkg production (67.5 lb/ton), and a suspended solids concentration of 9 kg/kkg production (18 lb/ton). The results of the cost estimates are shown below.

Alternative A: Screening and Primary Clarification

Raw waste water characteristics for the typical mill having a BOD of 33.75 kg/kkg production (67.5 lb/ton) represents a mill with recirculation but no inplant treatment facilities.

INVESTMENT COST ESTIMATE
ALTERNATIVE A

Primary Treatment

Item		Cost (May 1973)
1.	Drum Screen, installed	$ 8,000
2.	Clarifier - 7.6 m diam x 3.05 m deep (25 ft diameter - 10 ft deep)	36,000
3.	Sludge Pond - 0.405 ha - 2.44 m deep (1 ac - 8 ft deep) with liner - including land cost	43,000
4.	Alum System	10,000
5.	Miscellaneous	10,000
	Subtotal	$107,000
	20% Engineering and Contingencies	22,000
	TOTAL COST	$129,000

OPERATING COST ESTIMATE
ALTERNATE A

Primary Treatment

Item		Cost
1.	Manpower	$ 8,000
2.	Electricity	2,000
3.	Steam	--
4.	Water	--
5.	Chemicals	18,000
6.	Maintenance	3,000
	TOTAL COST/YR	$31,000

Summary:

Costs: $129,000

Reduction Benefits: A BOD reduction of 3.4 kg/ ton (ten percent) and a suspended solids reduction of 6.8 kg/kkg (75 percent) would result.

Alternative B-1: 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 kg/kkg (6.8 lb/ton) BOD and 2.25 kg/kkg (4.5 lb/ton) suspended solids.
The excess water is taken from the process water chest and put through a rotating drum type screen to remove the larger particles of fiber and suspended solids. The filtered effluent is discharged to the feed well of a primary clarifier. The underflow is pumped to a sludge digester. A portion of this sludge may be returned to the process water chest. The sludge from the sludge disgester is pumped to a holding lagoon.

The overflow from the primary clarifier is discharged into an activated sludge system consisting of an aerated lagoon followed by a secondary clarifier. The underflow from the secondary clarifier is transferred to the sludge digester and the overflow is discharged to waste.

INVESTMENT COST ESTIMATE
ALTERNATIVE B-1

Primary Treatment with Activated Sludge

Item	Cost (May 1973)
1. Primary Treatment	$130,000
2. Activated Sludge	503,000
TOTAL COST	$633,000 *

*Includes 20% for engineering and contingencies

OPERATING COST ESTIMATE
ALTERNATIVE B-1

Primary Treatment with Activated Sludge

Item	Cost
1. Manpower	$233,000
2. Electricity	28,000
3. Steam	--
4. Water	--
5. Chemicals	29,000
6. Maintenance	24,000
Yearly Costs	$314,000

Alternative B-2: Addition of Aerated Lagoon to Alternative A

Here, the excess water is taken from the process water chest and put through a rotating drum type screen to remove the larger particles of suspended fiber and solids. The filtered effluent is discharged into the feed well of a clarifier.

The under flow from the clarifier is pumped to a 0.405 ha (one acre) pond for sludge dewatering. A portion of this sludge is returned to process. The clarifier overflow is discharged into an aerated lagoon for 20 days retention and the aerated effluent is transferred into a lagoon of 5 days retention time. Effluent from the 5 day lagoon is discharged to the environment.

INVESTMENT COST ESTIMATE
ALTERNATIVE B-2

Screen, Clarifier, and Aeration Lagoon

Item		Cost (May 1973)
1.	Rotating Drum Screen installed	$ 8,000
2.	Clarifier 7.6 m diam x 3.05 m depth 25 ft diam - 10 ft depth	36,000
3.	Sludge Pond - 0.045 ha - 3.05 m depth (1ac - 10 ft depth)	41,000
4.	Aerated Lagoon - 20 day retention	225,000
5.	Lagoon - 5 day retention	50,000
6.	Miscellaneous	40,000
	Subtotal	$400,000
	20% Engineering and Contingencies	80,000
	TOTAL	$480,000

OPERATING COST ESTIMATE
ALTERNATIVE B-2

Item		Cost
1.	Manpower	$ 87,000
2.	Electricity	21,000
3.	Steam	--
4.	Water	--
5.	Chemicals	29,000
6.	Maintenance	24,000
	TOTAL COST/YR	$161,000

Summary:

Costs: Incremental costs are approximately $435,000 over Alternative A, thus the total costs are $544,000.

Reduction Benefits: A BOD reduction of 27 kg/kkg (90 percent) and a suspended solids increase from 200 mg/l to 250 mg/l.

<u>Alternative C: Addition of An Aerated Lagoon Treatment System to the Activated Sludge Treatment (B-1).</u>

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 kg/kkg (3.2 lb/ton) BOD and 2.8 kg/kkg (5.6 lb/ton) of suspended solids. The excess water is taken from the process water chest and put through a rotating drum type screen to remove the larger particles of fiber and suspended solids. The filtered effluent is discharged into the feed well of a clarifier. Underflow from the clarifier is pumped to a sludge digester with a portion of this flow returned to the process water chest. Supernate from the sludge digester is transferred to a lagoon. The primary clarifier overflow is treated by the activated sludge process consisting of an aerated lagoon and a secondary clarifier. After activated sludge treatment, the processes effluent is transferred to a secondary aeration lagoon where after treatment it is discharged to waste.

INVESTMENT COST ESTIMATE
ALTERNATIVE C

Primary Treatment, Activated Sludge, Aeration Lagoon

Item		Cost (May, 1973)
1. Primary Treatment		$130,000
2. Activated Sludge Treatment		500,000
3. Aerated Lagoon		350,000
	TOTAL*	$980,000

includes 20% for engineering and contingencies

OPERATING COST ESTIMATE
ALTERNATIVE C

Primary Treatment, Activated Sludge, Aeration Lagoon

Item		Cost
1. Manpower		$233,000
2. Electricity		48,000
3. Steam		--
4. Water		--
5. Chemicals		29,000
6. Maintenance		49,000
	TOTAL COST/YR	$359,000

Summary:

Costs: Incremental costs of $299,000 over Alternative B would be incurred, thus producing a total cost of $843,000.

Reduction Benefits: A BOD reduction of 1.8 kg/kkg (150 mg/l) (overall reduction of 95%), and a suspended solids reduction of 0 percent. (overall reduction of 69 percent.)

Alternative D-1: Installation of Pre-Press Evaporation of Process Water Discharge to Lagoon

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 waste water discharges totaling 7.4 l/sec (117 gal/min) being discharged from the pre-press and the hot press. The total waste flow would be passed through a screen, primary clarifier, and evaporator. The evaporator condensate is then discharged.

INVESTMENT COST ESTIMATE
ALTERNATIVE D-1
PRE-PRESS EVAPORATION, LAGOON

Item	Cost (May 1973)
1. Davenport Press with Auxiliaries	$172,000
2. Rotating Drum Screens installed	8,000
3. Clarifier	26,000
4. Liquor Holding Tank (8 hours)	30,000
5. Quadruple Effect Evaporators with surface Condensers (304 SS wetbed parts)	250,000
6. Cooling Tower with Transfer Pumps (2)	30,000
7. Sludge Lagoon (100 days)	22,500
8. Alum Storage and Metering System	10,000
Subtotal	$546,000
20% Engineering and Contingencies	109,000
TOTAL	$655,000

OPERATING COST ESTIMATE
ALTERNATIVE D-1
PRE-PRESS EVAPORATION, LAGOON

Item	Cost
1. Manpower	$175,000
2. Electricity	8,000
3. Steam	92,000
4. Water	1,000
5. Chemicals	18,000
6. Product Worth (deduct)	89,000
7. Maintenance	36,000
TOTAL COST/YR	241,000

Summary:

Costs: Total cost of this system would be $655,000.

Reduction Benefits: The BOD$_5$ of this system would average 2.0 kg/kkg production (4.0 lb/ton) and the suspended solids would average 0.46 kg/kkg production (1.0 lb/ton) for an overall reduction of 99.4 percent and 86 percent, respectively.

ACTIVATED SLUDGE TREATMENT OF CONDENSATE PRIOR TO DISCHARGE
ALTERNATIVE D-2

Approximately 90 percent of the contaminated condensate flow from the evaporators is treated biologically in an activated sludge process. The pH is first adjusted with lime and polymers are added to assist settling in the clarifier. The treated flow enters an aeration lagoon of approximately one day retention time. The flow is transferred to the feed well of a clarifier designed for 16,300 l/sq m/day (400 gal/sq ft/day) The overflow from the clarifier is discharged to the environment.

The underflow is pumped back to the inlet of the aeration lagoon with part of this flow sent to a sludge digester and on to a holding lagoon.

INVESTMENT COST ESTIMATE
ALTERNATIVE D-2

Activated Sludge Treatment Of Evaporator Condensate

Item	Cost (May, 1973)
1. Neutralization System - Lime with Bucket Elevator, Lime Storage Tank Feeder, Shutoff Gate, Slurry Holding Tank with Agitator. Slurry Pumps	$23,000
2. Aeration Basin-621 cu m (164,000 gal) with Aerator, Pumping Station	39,400
3. Clarifier - 1.7.6 m diam (25 ft diam) - Steel with Feed Well Rake Mechanism and Drive, 3 sludge pumps (100 gal/min @ 50 ft TDH)	36,000
4. Waste Sludge Handling	
a. Aerobic Digester Basin - 140 cu m (37,000 gal) 3.6 m(12-ft) deep with liner - Aerator	37,400
b. Two ha (five acre) lagoon with liner 1.8 m (6-ft) deep	15,000
Subtotal	$150,800
20% Engineering and Contingencies	30,200
TOTAL	$181,000

OPERATING COST ESTIMATE
ALTERNATIVE D-2
ACTIVATED SLUDGE TREATMENT OF EVAPORATOR CONDENSATE

Item	Cost

1. Manpower	$233,000
2. Electricity	5,000
3. Steam	- -
4. Water	- -
5. Chemicals	11,000
6. Maintenance	8,000
TOTAL COST/YR	$257,000

Summary:

Costs: The add on cost for this system is $181,000.

Reduction Benefits: The BOD5 of this system would average 0.2 kg/kkg production (0.4 lb/ton) and the suspended solids would average 0.46 kg/kkg (0.9 lb/ton).

SUMMARY OF TREATMENT EFFICIENCIES OF ALTERNATIVES

Flow (cu m/day)	1,432	1,432	1,432	1,432	627	627
	Alternatives					
Parameters	A	B-1	B-2	C	D-1	D-2
Raw BOD mg/l	3,000	3,000	3,000	3,000	6,825	6,825
Eff. BOD mg/l	2,700	300	600	150	450	45
Raw SS mg/l	800	800	800	800	200	200
Eff. SS mg/l	200	250	250	250	100	250
Raw BOD kg/kkg	33.8	33.8	33.8	33.8	33.8	33.8
Eff BOD kg/kkg	26.7	2.8	6.8	1.7	2.0	0.2
Raw SS kg/kkg	9.0	9.0	9.0	9.0	0.9	0.9
Eff. SS kg/kkg	2.1	2.5	2.5	2.5	0.5	1.3

SUMMARY OF ALTERNATIVE COSTS, AUGUST 1971

Alternative	% BOD Removal	Investment Cost	Yearly Operating Cost	Total Yearly Cost	$&
A	10	$109,000	$ 26,700	$36,500	
B-1	90	544,000	270,000	319,000	
B-2	80	413,000	138,500	175,000	
C	95	843,000	308,800	385,000	
D-1	93.5	566,000	207,000	258,000	
D-2	99.4	722,000	428,000	493,000	

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 shutdown 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 0.6 ha (1.5 ac) would be required for this system. The additional energy required to operate this system is estimated to be 22 kwh. There are no noise or radiation effects related to this process; however, the disposal of 285 kg/day of solids into a sludge lagoon may be a source of 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 sludge produced does not readily settle. This can frequently cause high suspended solids in the effluent. Temperature apparently has an effect not only in reducing the biological reaction rates during cold weather, but also in affecting the settling rates of the mixed liquor suspended solids.

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 kilowatts are needed to operate the process. There is essentially no noise or radiation effects associated with the process; however, the disposal of waste solids each day can cause 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. Sludge loadings 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 kw 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 and may involve process modifications. 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 waste water flow from 1,432 cu m/day (0.378 million gal) to 629 cu m/day (0.166 million gal). Waste water 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 (being produced at two mills). A portion of the condensate is recycled back inplant and the remaining process water is treated in an activated sludge system similar to the system described in Alternative B.

Evaporation systems must be fed at a relatively constant rate as they are sensitive to shock loads. Maintenance requirements are high because of 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 minor, but energy requirements for steam and electricity are significant. For example, approximately 150 kw 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.

WOOD PRESERVING-STEAM

Alternative Treatment and Control Technologies

Cost figures which have been obtained for wood preserving plants 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: A - Oil separation; B - Coagulation and filtration; Biological treatment in aerated lagoons; - Biological treatment by or activated sludge; D - Chlorination as a polishing treatment. The two biological treatments are alternates, and either one or the other is intended to be used. For estimating purposes, a waste water flow of 53,000 l/day (14,000 gal/day) was used. The waste loading and quality of effluent which is expected from each stage of treatment suggested is as follows:

QUALITY OF EFFLUENT FROM EACH STAGE OF A WASTE TREATMENT SYSTEM

Parameter	Raw Waste	Treatments (mg/l) A	B	C	D
COD	40,000	7,260	3,630	410	300
Phenols	190	190	190	2.5	0.5
Oil & Grease	1,500	225	80	45	25

ENGINEERING ESTIMATES FOR A WOOD PRESERVING - STEAM PLANT

Alternative A: Oil Separation

Standard oil separation equipment, equipped for both surface and bottom removal, can be used for this purpose. Depending on the treating preservatives used, provisions must be made for both surface and bottom removal creosote tends to settle while pentachlorophenol in oil will rise to the surface.

INVESTMENT COST ESTIMATE
ALTERNATIVE A
Oil Separation

Item	Cost
1. Land including clearing	$ 2,000
2. Oil separator, installed	18,000

3. Pumps, motors, starters, lighting	1,200
4. Pipe, valves, fittings	2,500
5. Piping labor	600
6. Electrical labor	500
Subtotal	$24,800
Engineering contingencies	4,960
TOTAL	$29,760

Summary:

Capital cost	$29,760
Annualized cost including operation and and maintenance	$0.31/1000 1

Alternative B: Coagulation and Filtration

The coagulation and filtration system would also serve to equalize variations in rate of flow. Several possibilities present themselves, but to economize on space a multi-compartment tank or several tanks, rather than lagoons were selected. Basically, the waste water would enter a tank from which a constant flow could be admitted to a rapid mix tank where a proportioning pump would add the coagulant chemical. Approximately one half hour of rapid mixing would be followed by one hour of slow mixing of the waste water/coagulant. This would be followed by about 6 hours of sedimentation. The filtration system would be slow sand filters with a total area of about 93 sq m (1000 sq ft).

INVESTMENT COST ESTIMATE
ALTERNATIVE B
Coagulation and Filtration

Item	Cost
1. Land including clearing	$10,000
2. Equalization tank	2,000
3. Coagulation tank	15,000
4. Pumps, motors, starters, lighting	1,500
5. Sand filters	4,000
6. Pipe, valves, fittings	2,000
7. Piping labor	1,000
8. Electrical labor	600
Subtotal	$36,100
Engineering and contingencies	7,220
Total for B	$42,320

Summary:

Capital cost	$42,320
Annualized cost including operation and maintenance	$0.70/1000 1

Alternative C-1: Biological Treatment, Aerated Lagoon

This treatment should result in a waste water having a BOD of about 3000 mg/l or about 375 lb/day. Assuming a normal aeration efficiency, an aerated lagoon would require an input of about 15 hp to provide the necessary treatment. The necessary detention time would require a volume of 1.06 million l (280,000 gal). For about a 3 m depth (10 ft), 353 sq m (less than 0.1 ac) of surface area will be required. Two aerators of 7.5 hp each were selected and are sufficient to provide the necessary aeration.

Item	Cost
1. Land including clearing	$3,000
2. Liner, installed @ $0.50 per sq ft	3,000
3. Two 7.5 hp aerators, installed	7,600
4. Pumps, motors, starters, lighting	1,500
5. Pipes, valves, fittings	1,200
6. Piping labor	800
7. Electrical labor	500
Subtotal	$17,600
Engineering and contingencies	3,520
Total for C-1	$21,120

Summary:

Capital cost	$21,120
Annualized cost including operation and maintenance	$0.70/1000 l

Alternative C-2: Biological Treatment, Activated Sludge

The proposed activated sludge plant design is based on the same influent BOD loading of about 3000 mg/l or about 375 lb/day. Assuming 0.2 lb BOD will produce one lb of mixed liquor suspended solids (MLSS) and assuming a desirable concentration of 2500 mg/l of MLSS, an aeration tank volume of 341,000 l (90,000 gal) is required. Therefore a 378,000 l/day (100,000 gal/day) activated sludge package plant was selected.

INVESTMENT COST ESTIMATE
ALTERNATIVE C-2
Biological Treatment, Activated Sludge

Item	Cost
1. Land, package plant and installation	$100,000
2. Engineering and contingencies	20,000
TOTAL COST	$120,000

Summary:

Capital cost	$120,000
Annualized cost including operation and maintenance	$1.75/1000 l

Alternative D: Polishing Treatment, Chlorination

The chlorination facility is intended to provide for a chlorine dosage of up to 500 mg/l. For a design flow of 53,000 l/day (14,000 gal/day) this will require up to 27 kg (60 lb) of chlorine per day. A detention time of 3 to 6 hours will be provided. For ease of handling, 200 lb cylinders were selected.

INVESTMENT COST ESTIMATE
ALTERNATIVE D
Polishing, Chlorination

Item	Cost
1. Chlorinator, installed	$4,000
2. Detention tank, installed	1,000
3. Automatic sampler, installed	1,200
4. Truck hand stand	800
Subtotal	$7,000
Engineering and contingencies	1,400
TOTAL COST	$8,400

Summary:

Capital cost	$8,400
Annualized cost including operation and maintenance	$0.64/1000 l

Alternative E: Effluent Measurement

A recording flow measurement device was selected.

INVESTIMATE COST ESTIMATE
ALTERNATIVE E

Flow Recording Device

Item	Cost
1. Measuring element with recorder	$2500
2. Installation	500
Subtotal	$3,000
Engineering and contingencies	600
TOTAL COST	$3,600

Summary:

Capital cost	$3,600
Annualized cost including operation and maintenance	$0.16/1000 l
Total capital costs for complete treatment with lagoons:	$106,200
Annualized cost for same system:	$3.45/1000 l

WOOD PRESERVING

As discussed in Section III through VII, discharge of waste water pollutants can be controlled by wood preserving plants in this subcategory by implementation of in-process control technologies. Therefore there are no costs directly related to pollution control.

Non-Water Quality Aspects

None of the waste water 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 waste water 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.

WOOD PRESERVING - BOULTONIZING

The most common method of waste disposal in this subcategory is evaporation. Following oil separation the waste water is pumped to a cooling tower for reuse as cooling water. For an average waste flow of 15,100 l/day (4,000 gal/day), approximately one-half of the water is evaporated during the normal operation of the tower. The excess water, about 7,600 l/day (2,000 gal/day), is evaporated by raising the temperature of the water in the tower reservoir using a small heat exchanger. Pan evaporation may also be used. However, since the volume of water involved and the heat energy required for evaporation is about the same for the two methods, the calculations which follow are based on using a cooling tower.

The cost of a cooling tower of a size needed at an average plant is $24,000, including heat-exchanger and overhead fan to expedite evaporation. Because a tower would be required regardless of pollution control activities, the total investment cannot legitimately be charged to those activities. Thus, in computing capital investment only 50 percent of the tower cost was used. This percentage was selected because the tower is used as a pollution-control device to evaporate only one-half of the waste water from a typical plant. The balance is lost regardless of pollution-control objectives.

Capital investment in other equipment directly concerned with pollution-control is estimated to be $20,000. All of this sum is for oil separation, storage and transport of recovered oil, and holding tanks and pumps for handling oil separator effluent. The total investment amounts to $32,000.

Operating costs, exclusive of energy requirments, are estimated to be $2,595/yr, or about $1.14/1000 l ($4.32/1000 gal). This item is broken down as follows:

Item		Cost
1. Labor		$1800
2. Repair Parts		795
	TOTAL	$2595

Labor cost is based on 300 man-hr/yr and an hourly wage rate of $6.00.

Energy is the most expensive item in disposing of wastewater by evaporation. Fuel cost to evaporate 7,600 l/day (2,000 gal/day) is estimated to be $14.54, for an annual cost of $4,361. This estimate is based on using natural gas for fuel, a heat of vaporization at 38°C (100°F) of 1739 kg cal/kg (1035 BTU/lb), an overall heating efficiency of 65 percent, and gas costing $19.42/1000 cu m ($.55 1000 cu m). Electric power to operate an overhead fan is estimated to cost $150 annually.

The total annual cost of this scheme for waste disposal is approximately $12,228 or about $5.38/1000 l ($20.38/1000 gal) of excess water evaporated. If water evaporated because of the normal operation of the cooling tower is included, the per unit cost would be only one-half as great.

BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

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 or subcategory. This average is not based upon a broad range of plants within the timber products processing category, but rather based upon performance levels achieved by exemplary plants or best operating unit operations.

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, and;
(f) Nonwater quality environmental impact, including energy requirements.

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.

BARKING

Identification of Best Practicable Control Technology Currently Available

Barking is an almost industry-wide pre-processing operation which has been treated as a separate subcategory for the reasons given in Sections III and IV of this document. The barking operation consists solely of removing bark by pressure or abrasion processes. These processes may be further broken down into "wet" and "dry" methods. None of the processes identified create significant water pollution problems, with the exception of the hydraulic barking process.

As discussed in Sections V and VII, the barking equipment such as drum barker, ring barkers, bag barkers and cutterhead barkers either do not use water or the water supply quality requirements are such that the water can be recycled after treatments such as screening and settling. Water used in the non-high water pressure barking systems does not usually have to be fresh water. Process waste waters such as cooling water, fire control water, log conditioning water could be used as the medium to assist in removing the bark from the wood, controlling dust, and transporting the bark from the barking machine.

Hydraulic Barking

Section V discusses the supply water quality requirements for the hydraulic barking process. Because of the high pressures to which the water is subjected, and the fine openings in the nozzles that the water must pass through during the operation, the water must be essentially free from suspended material. Also, dissolved materials in the supply water may cause corrosion problems, that result in excessive maintenance costs and unreasonable down time for the system. Technology exists which can significantly reduce the discharge loading from hydraulic barker operations. This technology consists of:

1. The application of primary screening and settling followed by;
2. Biological treatment.

Rationale for the Selection of Best Practicable Control Technology Currently Available

Age and Size of Equipment and Facilities

The primary factor involved is the age of equipment and the raw materials used, as discussed in Section IV. As noted therein, hydraulic barkers are being phased out throughout the industry because of a decrease in the number of over-size logs, and the associated water pollution control problems.

Engineering Aspects

As discussed in Sections III through VIII of this document, the volume of process waste water generated by the hydraulic barking operation is estimated to be in the range of 5,860 to 7,600 cu m/day for a 9.31 million sq m/yr on a 0.953 cm basis, plywood plant.

The pollutants present in this water are suitable for application of biological treatment. Certain segments of the timber products processing industry may find uses for this process water while others may chose to dispose of the hydraulic barker effluents into existing biological treatment systems. The veneer and plywood subcategories may not have this option available.

Biological treatment of hydraulic barker effluent alone is usually not practiced. However, in the pulp and paper industry the effluent may be treated biologically with other process waste waters. Application of primary settling and biological treatment to the waste can remove from 70 to 90 percent of suspended solids and 80 to 85 percent of BOD5.

At least one hydraulic barking system applies physical-chemical treatment to its effluent and accomplishes nearly 100% recycle. However, this system has been in operation only since June, 1973 and is not considered to be sufficiently proven to be defined as best practicable control technology for hydraulic barker effluents at this time.

The best practicable control technology currently available is based on the following production raw waste and waste water flow assumptions. These assumptions are based on information presented in Section V:

Production (veneer or plywood)	252 cu m/day
Effluent from the barker	6,540 cu m/day
BOD5 concentration	100 mg/l
Suspended solids (SS) concentration	2000 mg/l

The limitations are based on the following treatment efficiencies:

Primary screening and settling		
	SS Removal	75%
Biological treatment		
	BOD5 Removal	80%
	SS Removal	50%

Available information indicates that variation in the effluent from a biological treatment system processing wastes from the wood based industries is 300 percent.

Non-Water Quality Impact and Energy Requirements

There is no significant non-water quality impact as the result of the use of this technology. Solid wastes generated are currently burned as fuel in the bark boiler, or disposed of as with other barking technologies, including use as mulch or disposal by landfill.

Summary

Based upon the information contained in Sections III through VIII of this document and summarized above, a determination has been made that the degree of effluent reduction attainable and the maximum allowable discharge in the Barking subcategory thorugh the application of the best practicable technology currently available is no discharge of waste water pollutants to navigable waters.

A variance shall be allowed for those barking operations utilizing a hydraulic barker. Based upon the information contained in Section III through VIII of this document and summarized above, a determination has been made that the degree of effluent reduction attainable and the maximum allowable discharge in the Barking subcategory for hydraulic barkers in preparation for veneer or plywood manufacture, is through the application of the best practicable control technology currently available, as follows:

	30-day Average (lb/cu ft) kg/cu m	Daily Maximum (lb/cu ft) kg/cu m
BOD5	0.5 (0.03)	1.5 (0.09)
Total Suspended Solids	2.3 (0.14)	6.9 (0.43)
pH	Within the range 6.0 to 9.0	

VENEER

Identification of Best Practicable Control Technology Currently Available

The manufacture of veneer may or may not result in the generation of process waste water, depending on the types of manufacturing procedures used. The unit operations required in veneer manufacture have been discussed in detail in Section III, the wastes derived from each of the operations characterized in Section V, and treatment and control technology, when applicable, detailed in Section VII.

An extensive technology exists which, when applied to each of the unit operations in this subcategory, will result in no discharge of waste water pollutants. While the technology exists, it is not, however, uniformly applied.

To meet this standard of no discharge requires the implementation of the following control technologies:

1. Substituting, for direct steam conditioning of logs, (a) hot water spray tunnels, (b) indirect steaming or (c) modified

steaming with the use of steam coils. Hot water spray tunnels where water is heated and then sprayed on the logs can be placed in existing steam vats with only minor modifications, and the hot water collected and reused after settling and screening. Modified steaming produces, after the steam contacts the wood, a condensate which may be revaporized and reused. The small volume wood based sludge that is generated can be disposed or the procedures discussed in Section VII.

2. Discharge of contaminated waste water from hot water vats, where the water is heated indirectly, to a settling basin, with possible pH adjustment, and later reuse.

3. Manual removal of a portion of solid waste in the veneer dryer, the use of air to blow out dust before using water, installation of water meters on water hoses used for washing and the disposal of excess veneer dryer washing water by irrigation, or containment and evaporation. At least one 9.3 million sq m plant has reduced its water use for this purpose to 2,000 l/wk (530 gal/wk). By limiting water use to 3,000 l/wk, this water can be handled by containment or irrigation.

Rationale for the Selection of Best Practicable Control Technology Currently Available

Age and Size of Equipment and Facilities

As discussed in Section IV, the age and size of a veneer manufacturing plant do not bear directly on the quantity or quality of the waste water pollutants generated. The age of a plant may, however, be a factor in the type of log conditioning procedure used, and thus in the selection of a variance and its associated waste water control technology.

Processes Employed and Engineering Aspects

All plants in this subcategory use essentially the same or similar production methods and equipment. Sections III and VII treat these process aspects in great detail.

Each of the technologies outlined above have been identified as being in use in some portion of the veneer subcategory of the timber products processing industry. No plant, however, has been found to utilize all of these control procedures. About 100 of the 500 veneer and plywood plants have retention of water from log conditioning, and 90 plants have control systems which eliminate the discharge of dryer wash water.

Process Changes

Certain peripheral process modifications will inevitably be necessary in the veneer manufacturing subcategory, in order to meet the no discharge regulation. As indicated in the economic analysis in Section VIII, a modification of log conditioning procedures is more economically feasible than the addition of the biological treatment units necessary to reduce BOD and solids loading from the open steaming conditioning process.

Employing the processes above, a softwood veneer plant supplying a 9.31 million sq m/yr plywood on a 0.53 mm basis production facility that uses steam vats with direct steaming would have a continuous effluent of about 1.9 l/sec (30 gal/min) with a BOD loading of about 410 kg/day at 2500 mg/l concentration and a suspended solids loading of 325 kg/day at 2000 mg/l concentration. Applying 85 percent BOD removal efficiency can reduce BOD to 61 kg/day, or 2.3 kg/1000 sq m of production, on a 9.53 mm basis.

A hardwood veneer plant supplying a 0.465 million sq m/yr (5 million sq ft/yr) plywood production plant using steam vats with direct steaming would have a continuous effluent of about 0.5 l/sec (8 gal/min) with a BOD loading of 30 kg/day at 200 mg/l concentration and a suspended solids loading of 26 kg/day at a concentration of 700 mg/l. Applying 85 percent BOD removal efficiency can reduce BOD to 4.5 kg/day, or 3.4 kg/1000 cu m.

As discussed earlier, alternative procedures for conditioning of logs exist and indications are that the more practical procedures would be the selection of those methods that eliminate the discharge of pollutants.

The volumes of water required for cleaning of veneer dryers have been determined to be relatively small. Softwood veneer dryer waste water is in the range of 2600 l/day and hardwood about 530 l/day. BOD_5 waste loads are, for softwood 2.0 kg/day and for hardwood 0.5 kg/day. Softwood plant production base is 9.5 million sq m/yr. Hardwood plant production base is 0.46 million sq m/yr.

Because of the small volumes of water the relative ease of disposal on land, and the impracticality of application of biological treatment to this waste water a discharge will not be allowed, except to an existing biological treatment system. The small waste loads attributed to dryer wash water will have no effect on the operation and efficiency of the treatment system. The pollutant discharge from the biological treatment system serving a timber products processing complex will not be increased to allow credit for the veneer dryer cleaning input.

Nonwater Quality Impact and Energy Requirements

There are potentially three nonwater related pollutants: (1) emission of particulates from the veneer dryer, (2) odors released from anaerobic containment ponds, and (3) solid wastes.

There are currently no emission control systems installed on veneer dryers. There is, however, transferrable technology applicable.

Particulates can be controlled utilizing inertial collectors of the cyclone or mechanical type. Volatile and condensable hydrocarbons can be controlled by condensation, adsorption or scrubbing, incineration, or combinations of the three. As air emission standards become more stringent, control of particulate matter may require the use of wet scrubbers, thus resulting in a waste water relatively high in solids content.

The bulk of the solid waste from veneer 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 the small amounts of this material which result may be at the plant site or the waste material may be collected by the local municipality with eventual disposal by landfill. The proper disposal of these wastes will ensure that they present no significant non-water quality environmental problem.

In terms of energy requirements, a 9.3 million sq m/year veneer and plywood plant will have a total energy demand of 4500 kw and a manufacturing energy cost of $180,000. Additional costs for implementation of the pollution control technology discussed here and in Section VII range from $0 to $2300/yr. These figures are more closely examined in Section VIII.

Summary

Based upon the information contained in Sections III through VIII of this document and summarized above, a determination has been made that the degree of effluent reduction attainable for all sources in the veneer manufacturing subcategory excluding those which use direct steam conditioning as described below, through the application of the Best Practicable Control Technology Currently Available is no discharge of process waste water pollutants to navigable waters.

A variance will be allowed for those plants that both (1) as part of their existing equipment use a log conditioning method that injects steam directly into the conditioning vat, and (2) find it infeasible to implement the technology discussed above.

Based upon the information contained in Sections III through VIII of this document and summarized above, a determination has been made that the degree of effluent reduction attainable for all sources in the Veneer manufacturing subcategory which use the direct steam conditioning as described above, through the application of the Best Practicable Control Technology Currently Available is as follows:

	BOD		
	30-Day Average kg/cu m (lb/cu ft)	Daily Maximum kg/cu m (lb/cu ft)	pH
Softwood Veneer:	0.24 (0.015)	0.72 (0.045)	6.0-9.0
Hardwood Veneer:	0.54 (0.034)	1.62 (0.10)	6.0-9.0

PLYWOOD

Identification of the Best Practicable Control Technology Currently Available

Plywood may include several distinct process steps. Alternatively some of these may take place in the veneer manufacturing and processing location. These steps are: (1) drying, (2) clipping, (3) gluing, (4) pressing, and (5) trimming and packaging.

The unit operations required in plywood manufacturing have been discussed in detail in Section III, the waste derived from each of the operations characterized in Section V, and treatment and control technology, as applicable, detailed in Section VII.

Technologies exist which, when applied to the unit operations in this subcategory, will result in no discharge of pollutants. While the technology exists, it is not uniformly applied. To meet this standard of no discharge requires the implementation of a portion or all of the following control technologies:

1. The use of steam to clean spreaders where applicable and the use of high pressure water for cleaning;
2. The use of glue applicators that spray the glue on rather than rollers;
3. The use of glue washwater for glue makeup; and
4. Evaporation and spray application of glue water on bark going to the incinerator.

Rationale for the Selection of Best Practicable Control Technology Currently Available

Age and Size of Equipment and Facilities

As discussed in section IV, the age and size of a plywood manufacturing plant do not bear directly on a quantity or quality of the waste water pollutants generated.

Processes Employed and Engineering Aspects

All plants in this subcategory use essentially the same or similar production methods and equipment. Sections III and VII treat these process aspects in great detail.

Each of the technologies outlined above have been identified as being in use in some portion of the plywood subcategory of the timber products processing industry. Yet no plant has been found which utilizes all of these control procedures. About 100 of the 500 veneer and plywood plants have retention of water from log conditioning, and about 90 plants have control systems which eliminate the discharge of dryer wash water.

Process Changes

Certain peripheral process modifications will inevitably be necessary in the plywood manufacturing subcategory, in order to meet the no discharge regulation. These are discussed in detail in section VII and summarized above.

Nonwater Quality Impact and Energy Requirements

The bulk of the solid waste from plywood mills is comprised of wood residues. 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 eventual disposal by landfill. The amount of solids generated from these procedures is not expected to be great and proper disposal will ensure that they present no significant nonwater quality environmental problem.

In terms of energy requirements, a 9.3 million sq m/yr veneer and plywood manufacturing plant will have a total energy demand of 45,000 kw and a yearly energy cost of $180,000. Additional costs for implementation of the pollution control technology discussed here and in Section VII range from $0 to $2300/yr. These figures are more closely examined in Section VIII.

Summary

Based upon the information contained in Sections III through VIII of this document and summarized above, a determination has been made that the degree of effluent reduction attainable in the Plywood manufacturing subcategory through the application of the Best Practicable Control Technology Currently Available is no discharge of process waste water pollutants to navigable waters.

HARDBOARD-DRY PROCESS

Identification of Best Practicable Control Technology Currently Available

The manufacture of hardboard using the dry process, as discussed in Sections III and IV is accomplished through a series of operations that for the purposes of developing effluent guidelines and standards were considered on a unit operation basis. Water requirements, waste water generation and quality, and opportunities for reuse and disposal, either within the unit operation or in other operations in the dry process hardboard manufacturing process, were determined from this information. Dry process hardboard manufacturing focuses on seven primary unit operations: (1) log washing, (2) chipping, (3) fiber preparation, (4) dry-felting, (5) pressing and tempering, (6) humidification, and (7) trimming and packaging.

It has been demonstrated that technologies exist (discussed in Section VII) which, when applied to each of the unit operations, will result in no discharge of pollutants. To meet the standard of no discharge requires the implementation of the following control technologies:

1. Recycle of log wash and chip wash water and disposal of the solids by landfill or use as boiler fuel.
2. Operation of the resin system as a closed system, with wash water being recycled as make-up in the resin solution.
3. Neutralization of caul water, and disposal by impoundment or spray irrigation.
4. Elimination of discharge from humidification by the implementation of in-plant control, including reasonable operating and process management processes.

Rationale for the Selection of Best Practicable Control Technology Currently Available

Processes Employed and Engineering Aspects

Log washing in the dry process hardboard manufacturing subcategory is practiced by about 15 percent of the mills. The volume and the characteristics of the waste waters vary depending on harvesting, transportation and storage practices and conditions. Wash water may be fresh, process, or cooling water and can be recycled after settling. Blowdown is required only infrequently and one of the two plants currently washing logs is disposing of the small volume of water by land irrigation. Settled sludge may be disposed of by landfill.

Water used in the formulation of binders for hardboard can be incorporated in the hardboard and disposed of by evaporation in the pressing operation. Waste water is generated only during cleaning of the resin system, and the opportunity for use of the washwater in makeup of resin solutions exists. For these reasons the resin system can be operated on a closed system, and 6 out of 16 dry process hardboard mills are currently achieving no discharge from their resin systems.

Caul washwater is a relatively small volume of water, amounting to approximately 4 l/kkg of production. This water is a caustic solution used to loosen the organic buildup on the cauls or press plates. It is replaced periodically when the concentration of dissolved organics builds up to a level that inhibits cleaning of the plates. Before disposal the washwater is usually neutralized and the relatively small volume disposed of by impoundment or spray irrigation.

There are no waste water losses in fiber preparation other than evaporative losses, no waste water is generated in the forming and pressing operations, and more than half of the mills report no discharge of process water from the humidification operation.

Process Changes

There are no process changes necessary in order to eliminate the discharge of waste water pollutants, but rather the implementation of recycle and careful water management procedures. Settling ponds may be necessary in some instances as indicated.

The primary costs and changes associated with achieving no discharge of waste water pollutants are related to the removal of caul washwater as a pollutant. Waste water generation from this operation in normal operating practice is about 41/kkg (1 gal/ton) of production. A system including volume retention of one week's caul washwater (6,700 l) and transportation costs to a land disposal site would cost about $25,000/yr. Operation and maintenance costs for this system would be about $3,000/yr.

Nonwater Quality Impact and Energy Requirements

The single nonwater quality environmental impact from the treatment and control technologies presented is the problem of disposal of minor volumes of sludges. Proper disposal will ensure that solid waste presents no significant non-water quality impact.

Energy costs are limited to pumping and instrument operation and are estimated to be less than $100/yr. About 50 percent of the plants in this subcategory will be required to add treatment and control systems to comply with this alternative.

Summary

Based upon the information contained in Sections III through VIII of this document and summarized above, a determination has been made that the degree of effluent reduction attainable in the Hardboard-Dry Process manufacturing subcategory through the application of the Best Practicable Control Technology Currently Available is no discharge of process waste water pollutants to navigable waters.

No limit is established for fire control water. This effluent will be collected and should receive at least primary screening before discharge.

HARDBOARD-WET PROCESS

Identification of Best Practicable Control Technology Currently Available

Wet process hardboard is manufactured using seven distinct process steps or unit operations: (1) log washing, (2) chipping, (3) fiber preparation, (4) wet-felting (mat formation), (5) drying and pressing, (6) humidification, and (7) trimming and packaging. Each of these unit operations has been discussed in detail in Section III, the wastes derived and characterized in Section V, and treatment and control technologies detailed in Section VII.

Technology is currently available and demonstrated which can reduce the level of pollutants to zero in all of the unit operations, with the exception of those singular to the fiber preparation and mat forming process. Treatment and control schemes are in use in individual plants within this subcategory, which reduce pollutant discharge to the best practicable control technology limits as set forth herein.

To meet the limitation in wet process hardboard manufacturing requires the implementation of the recycle and water management policies described in Section VII and summarized in the following paragraphs on the wet process hardboard subcategory.

The best practicable control technology currently available which will result in reduced pollutant loading requires the implementation of all or part of the following:

1. Recycle of process water as dilution water, utilization of heat exchangers to reduce temperature, and gravity settling, screening, filtration, or flotation to reduce suspended solids.
2. Treatment of total waste water flow by primary settling combined with screening, and followed by aerated lagoons or activated sludge or both, with probable pH adjustment prior to biological treatment.

3. Disposal of sludge by aerobic digestion in sludge lagoons, recycle inplant, or as land fill.

Rationale for the Selction of Best Practicable Control Technology Currently Available

Processes Employed and Engineering Aspects

The level of technology summarized above, and the effluent reductions suggested are being attained by 22 percent of the manufacturing plants in this subcategory. Four (4) mills are reaching 60 to 90 percent efficiencies for suspended solids removal through the use of filters and gravity separators. One mill has reduced its discharge, by inplant modifications without end of line treatment, to 2.3 cu m/kkg of production (630 gal/ton) and BOD discharge to 8.5 kg/kkg (17 lb/ton). Two (2) plants are known to use chemical treatment combined with sedimentation and flotation to reduce solids, COD, and soluble organics. All of the ten wet process plants have screening and primary clarification, 3 mills have activated sludge systems, 2 use activated sludge followed by an aerated lagoon, and 2 plants evaporate process water and dispose of the solids by land disposal or selling the concentrated solids as cattle feed.

Information obtained from 5 wet process plants showed an average waste water discharge of 9.0 cu m/kkg of production (2376 gal/ton). Raw waste water characteristics were 27.8 kg/kkg (61.1 lb/ton) BOD, and 8.4 kg/kkg (18.5 lbs/ton) suspended solids.

The treatment and control technologies summarized above are each in use in at least one manufacturing plant in this subcategory, and each has a demonstrated high degree of engineering reliability.

Process Changes

There are no significant process changes required; rather the addition of certain treatment capabilities and implementation of water recycle and conservation practices will be needed to meet these limitations.

Non-Water Quality Impact and Energy Requirements

Sludge generated in the treatment systems must be disposed of, and as land fill is one suggested means of disposal, there may be some minor environmental impact. Proper disposal techniques will ensure that the non-water quality impact is minimal.

Energy costs for alternative technologies are: screening and primary settling, $2,000/yr; activated sludge after screening and clarification, $28,000/yr; aerated lagoon after screening and clarification, $21,000/yr; and aerated lagoon after screening, clarification and activated sludge, $48,000/yr (based on an electricity cost of $0.01/kwh).

Summary

Based upon the information contained in sections III through VIII of this document, a determination has been made that the degree of effluent reduction attainable and the maximum allowable discharge in the wet process hardboard subcategory through the application of the best practicable control technology currently available is as set forth in the following table:

	30-Day Average kg/kkg (lb/ton)	Daily Maximum kg/kkg (lb/ton)
BOD5	2.6 (5.2)	7.8 (15.6)
Total Suspended Solids	5.5 (11.0)	16.5 (33.0)
pH	6.0-9.0	6.0-9.0

WOOD PRESERVING

Identification of Best Practicable Control Technology Currently Available

The manufacturing process in this subcategory consists primarily of indirect heat conditioning and preservative injection operations. There are numerous differences in specific processes and types of preservatives, but waste water characteristics, as detailed in Section V, are similar and thus subject to the same treatment methods. Many of the pollutants superficially characteristic of this subcategory are traceable to nonprocess wastes which shall be discussed in future studies. Sections VII and VIII detail specific technology and the costs associated with the technologies.

The discharge of waste water pollutants may be eliminated through the implementation of the following control technologies:

1. Elimination of equipment and piping leaks, and minimization of spills by the use of good housekeeping techniques:
2. Recovery and reuse of contaminated water, generated in processes employing salt-type preservatives and fire-retardant formulations, as make-up water for treating solutions;
3. Modification of existing nonpressure processing equipment in order to eliminate the introduction of water from precipitation in the treating tanks, and;
4. Segregation of contaminated and uncontaminated water streams. The latter includes condensate from heating coils and heat exchangers, and noncontact cooling water.

Rationale for Best Practicable Control Technology Currently Available

Process Changes

No significant process changes are necessary to meet these standards but control techniques would have to be implemented. This technology is based on the fact that there exist opportunities to reuse the limited amount of waste water generated; the recycling of process water from salt type treatment is practicable and is being practiced in at least one plant in the subcategory; and, there is no process waste water generated in nonpressure processes.

Non-Water Quality Impact and Energy Requirements

The suggested technologies are based primarily on modification of inplant practices and controls, and as a result have little impact on other environmental considerations. Limited amounts of sludge would be generated from the suggested biological systems. Sludge, however, is readily biodegradable and thus presents no great environmental problem if disposed of properly.

The cost associated with achieving the effluent limitations are minimal for this subcategory.

Oil separation, already in place at 95% of wood preserving plants has a cost of $0.31/1000 l for annualized cost including operating and maintenance. Evaporation for 7,600 l/day for a hypothetical plant may be expensive and is related to the cost of natural gas. The total annual cost would be about $6.00/1000 l.

Summary

Based upon the information contained in Sections III through VIII of this document, a determination has been made that the degree of effluent reduction attainable in the Wood Preserving subcategory through the application of the best practicable control technology currently available is no discharge of process waste water pollutants to navigable waters.

WOOD PRESERVING - BOULTONIZING

Identification of Best Practicable Control Technology Currently Available

Wood conditioning by the Boulton process involves five distinct process steps: 1) placing wood to be treated into a treating cylinder, 2) sealing the cylinder, 3) putting treating chemical into the cylinder, 4) applying heat and pressure (by steam coils or heat exchanger) and 5) drawing a vacuum to remove moisture. The extracted water passes through a condenser and goes to a hot well. The waste water volume is only that amount removed from the wood itself.

The best practicable control technology currently available which will result in no discharge of waste water pollutants includes:

1. The elimination of equipment and piping leaks, and minimization of spills by the use of good housekeeping techniques, and;
2. Disposal of the small volumes of water removed from the wood, by evaporation or percolation.

This technology is currently utilized in at least 4 plants which are now achieving no discharge of waste water pollutants. Sections VII and VIII detail specific technology and cost analyses.

Rational For Best Practicable Control Technology Currently Available

The waste water generated by this manufacturing procedure is in the range of 100 l/cu m of wood treated. This volume of waste water can be disposed of by evaporation, possibly assisted by the heat available from auxiliary operations. The volume or ability to dispose of the waste water is not influenced by the age or size of the facility.

The capital cost of achieving no discharge of pollutants from this subcategory ranged between $5,500 and $112,000 depending on the practices and methods used at four different plants. These costs were obtained from plants that have installed the technology that achieves no discharge. technology.

Summary

Based upon the information contained in sections III through VIII of this document and summarized above, a determination has been made that the degree of effluent reduction attainable in the Wood Preserving - Boultonizing subcategory through the application of the best practicable control technology currently available is no discharge of process waste water pollutants to navigable waters.

WOOD PRESERVING - STEAM

Identification of Best Practicable Control Technology Currently Available

Conditioning and preservative injection are the primary sources of waste water pollutant generation in this subcategory. Condensate from steaming is the most heavily contaminated since it comes in contact with the preservative in the treating vessel; vacuum cycle water following steam conditioning, and water used to clean equipment are also heavily contaminated. These operations have been discussed in detail in Section III, wastes derived and characterized in Section V, and treatment and control technologies, when applicable, discussed in Section VII.

To meet the standards set forth herein will require the use of the following inplant control and treatment technologies:

1. Installation of oil recovery equipment (oil separators) to reduce influent to biological systems to less than 100 mg/l;
2. Minimization of waste water volume by the implementation of rigorous inplant water conservation practices;
3. Elimination of equipment and plumbing leaks;
4. Segregation of contaminated and uncontaminated waste streams, and;
5. Use of one or a combination of the following: biological treatment (tricking filter, activated sludge), soil irrigation, oxidation ponds, chemical oxidation, containment and spray evaporation, pan evaporation, evaporation in cooling towers, and incineration of high concentration oily waste waters.

Rational for the Selection of the Best Practicable Control Technology Currently Available

Age and Size of equipment and facilities

As discussed in Section VI, the age and size of the wood preserving plants in this subcategory bear little relation to the quantity or quality of the process waste water generated and because the treatment and control methods indicated as best practicable control technology currently available are "end-of-the-line" processes.

Processes Employed and Engineering Aspects

Inplant procedures which are currently in use in the industry, and which will minimize the volume of waste water that must be treated, include the recirculation of direct-contact cooling water and segregation of contaminated and uncontaminated waste streams. All of the methods proposed are standard in that they are used by a number of plants. None present unique problems from an engineering point of view.

Most wood preserving operations using oily based preservatives have oil-recovery systems. Apart from environmental considerations, it is economically feasible to recover and reuse oil rather than discharge it. Chemical methods involving flocculation and sedimentation on the oil separator effluent are most widely used, generally are least expensive, and are effective with wood preserving waste water.

Trickling filter treatment efficiency on a creosote plant waste water has been shown to achieve 91 percent BOD removal, 77 percent COD removal and at least 99 percent phenol removal. Activated sludge has been demonstrated to reduce COD by 90 percent and phenols by 99 percent. Aerated lagoon systems can accomplish the same efficiency, the main disadvantage being the necessity for more extensive land area.

Land disposal has relatively simple operating procedures, low capital investment, minimum equipment needs, low operating and maintenance costs, and good quality effluent in terms of color and oxygen demand. Its chief disadvantage is the land requirement (in the range of 1 ha/3000 l/day). BOD and phenol removal efficiencies as high as 99.5 percent are reported.

Chlorine and ozone have been used successfully to remove phenols from wood preserving waste water. Chlorine dioxide can also be used. Chlorination will reduce COD to the same degree as flocculation with lime and a polyelectrolyte. Carbon adsorption will remove 96 percent of the phenols and 80 percent of the COD from a creosote waste water at an 8:1 dosage.

Effluent from the oil separation system can be discharged to a cooling tower. Normal evaporation rates for a cooling tower accounts for a loss of 7,500 l/day (2000 gal/day). Problems with condenser efficiency are associated with the presence of oil in the cooling water.

Non-Water Quality Aspects and Energy Requirements

None of the waste water treatment and control technologies discussed above have a significant effect on nonwater environmental quality. The limited volume of sludge generated by coagulation and biological treatments of waste water is currently being disposed of in approved landfills by most plants. Because the organic components of these sludges are biodegradable, proper disposal will ensure that these wastes should present no threat to the environment.

Summary

Based upon the information contained in Sections III through VIII of this document and summarized above, a determination has been made that the degree of effluent reduction attainable in the Wood Preserving-Steam subcategory through the application of the best practicable control technology currently available is as set forth in the following table:

	30-Day Average kg/1000 cu m (lb/1000 cu ft)	Daily Maximum kg/1000 cu m (lb/1000 cu ft)
COD	550 (34.5)	1100 (68.5)
Phenols	0.65 (0.04)	2.18 (0.13)
Oil and Grease	12.0 (0.75)	24.0 (1.5)
pH	6.0-9.0	6.0-9.0

SECTION X

THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

INTRODUCTION

The effluent limitations which must be achieved by July 1, 1983, 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 transfer of technology from one industry process to another. A specific finding must be made as to the availability of control measures to eliminate the discharge of pollutants, taking into account the cost for 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 available technology economically achievable, and
(f) nonwater quality environmental impact (including energy requirements).

In contrast to the best practicable control technology currently available, the best available technology economically achievable assesses the availability in all cases of in-process modifications and 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 technology economically achievable. The best available technology economically achievable 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 process waste water 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.

BARKING

Identification of the Best Available Technology Economically Achievable

As summarized in Section IX, the best practicable control technology currently available is no discharge of waste water pollutants into navigable waters. Therefore, the best available technology economically achievable in the Barking subcategory is no discharge of waste water pollutants to navigable waters.

This limitation can be achieved by:

1. Selection of a barking method that does not have a waste water effluent;
2. Selection of a barking method that has a relatively low volume of water use, and treating and reusing that water either within the unit operation or within the total manufacturing operation, or;
3. Application of treatment of hydraulic barker effluent and recycle of that water to the degree that eliminates the discharge of pollutants to navigable waters.

As noted in sections VII and IX of this document, treatment of hydraulic barker effluent is already in place in one plant and is currently resulting in the achievement of almost 100 percent recycle of process water in that plant.

This recycle is being achieved by a treatment process that includes screening, coagulation, clarification, pH control, and algae control.

Effluent Reduction Attainable Through the Application of the Best Available Technology Economically Achievable

Based upon the information contained in Sections III through IX of this document, and consistent with the discussion presented above, a determination has been made that the effluent limitation representing the degree of effluent reduction attainable in the Barking subcategory through the application of the best available technology economically achievable is no discharge of process waste water pollutants to navigable waters. Application of the factors listed in Section IX does not allow variation from the no discharge limitation set forth in this section for any point source subject to such effluent limitation.

VENEER

Identification of the Best Available Technology Economically Achievable

The best practicable control technology currently available, as defined in Section IX, is no discharge of waste water pollutants.

The best available technology economically achievable in the Veneer subcategory is:

1. The substitution, for direct steam conditioning of logs (a) hot water spray tunnels, (b) indirect steaming, or (c) modified steaming with the use of steam coils;
2. Discharge of contaminated waste water from hot water vats to settling ponds for reuse, and;
3. The use of dry veneer dryer cleaning methods or proper land disposal of the quantities of waste water generated from wet cleaning procedures.

Effluent Reduction Attainable Through the Application of the Best Available Technology Economically Achievable

Based upon the information contained in Sections III through VIII of this document, and consistent with the discussion in Section IX a determination has been made the the effluent limitation representing the degree of effluent reduction attainable in the Veneer manufacturing subcategory through the application of the best available technology economically achievable is no discharge of process waste water pollutants to navigable waters. Application of the factors listed in Section IX does not require variation from the effluent limitation set forth in this section for any point source subject to such effluent limitation.

PLYWOOD

Identification of Best Available Technology Economically Achievable

As summarized in Section IX, best practicable control technology currently available is no discharge of process waste water pollutants to navigable waters. waters. Therefore, best available technology economically achievable is no discharge of waste water pollutants into navigable waters. This limitation can be achieved by:

1. Elimination of discharge from the gluing operation in the plywood subcategory including reduction of the amount of fresh water used by the use of waste water for glue formulation, monitoring of glue and glue waste water concentrations, the use of steam to clean spreaders where applicable, the use of high pressure water for cleaning operations, and the use of spray applicators for glue.
2. Dry housekeeping procedures and judicious use of wet cleaning water.

Effluent Reduction Attainable Through the Application of the Best Available Technology Economically Achievable

Based upon the information contained in Sections III through VIII of this document, and consistent with the discussion in Section IX a determination has been made that the effluent limitation representing the degree of effluent reduction attainable in the Plywood manufacturing subcategory through the application of the best available technology economically achievable is no discharge of process waste water pollutants to navigable waters.

HARDBOARD - DRY PROCESS

Identification of the Best Available Technology Economically Achievable

As summarized in Section IX, the best practicable technology currently available in the Hardboard - Dry Process subcategory consists of:

1. Recycle of log wash and chip wash or disposal by landfill;
2. The operation of resin system as a closed system, with recycle and reuse of resin wash water as make-up in the resin solution;
3. Neutralization of caul wash water and disposal by impoundment or spray irrigation, and;
4. Elimination of discharge from humidification by the implementation of inplant control, including operating and process management procedures.

Effluent Reduction Attainable Through the Application of the Best Available Technology Economically Achievable

Based upon the information contained in Sections III through IX of this document, and consistent with the discussion in Section IX, a determination has been made that the effluent limitation representing the degree of effluent reduction attainable in the Hardboard - Dry Process subcategory through the application of the best available technology economically achievable is no discharge of process waste water pollutants to navigable waters.

HARDBOARD - WET PROCESS

Identification of the Best Available Technology Economically Achievable

The best available technology economically achievable in the Hardboard-Wet process subcategory includes:

1. Recycle of process water as dilution water utilizing temperature control and suspended solids control to reduce the total plant discharge to 4.5 cu m/kkg (1186 gal/ton), the BOD_5 to 33.8 kg/kkg (67.5 lb/ton) and the suspended solids to 9 kg/kkg (18 lb/ton);

2. Installation of a pre-press and evaporation system;

3. Discharge of process water only from the pre-press and the wet press;

4. Treatment of the total waste water flow by screening, primary settling, and evaporation;

5. Recycle of a portion of the condensate back to the process;

6. Activated sludge treatment of the excess condensate, and;

7. Sludge disposal by appropriate means.

Processes Employed and Engineering Aspects

The press system has been used on semi-chemical pulp and on a calcium bisulphite system. Presses have been designed and operated to take pulp from 10-15 percent up to 55 percent consistently (by weight). The filtrate removes a higher percentage of the dissolved solids to treatment and results in a cleaner pulp going through the stock system thus reducing the rate of dissolved solids buildup in the system. Full scale trials run on a semi-chemical pulp mill in Scandinavia showed a waste liquor recovery of 85 percent on a weight basis.

The discharge water from the press is passed over a screen to remove fiber clumps, which are returned to the process. The screen effluent is diverted to a clarifier feedwell where liquid alum is added to aid flocculation. The clarifier is expected to remove 75 to 90 percent of the suspended solids. Waste liquor is then evaporated to 65 percent solids and disposed of by incineration or as a byproduct. Contaminated condensate from the evaporators may be treated in an activated sludge system.

Screening and primary clarification (for 10 percent BOD5 removal) would cost \$109,000 initial investment and \$26,700 for added yearly operating expenses. All existing plants currently have screening and primary clarification in place. A prepress and evaporation system would initially cost \$566,000 with a yearly operating cost of \$207,000 for a 93.5 percent BOD5 removal. And a prepress combined with evaporation and activated sludge treatment of the condensate would accomplish 99.4 percent BOD5 removal for an initial cost of \$722,000 and yearly operating cost of \$428,000.

Effluent Reduction Attainable Through the Application of the Best Available Technology Economically Achievable

Based upon the information contained in sections III through VIII of this document a determination has been made that the effluent limitation representing the degree of effluent reduction attainable in the Hardboard-Wet Process subcategory through the application of the best available technology economically achievable is a maximum discharge as follows:

	30-Day Average kg/kkg (lb/ton)	Daily Maximum kg/kkg (lb/ton)
BOD5	0.9 (1.8)	2.7 (5.4)
Total Suspended Solids	1.1 (2.2)	3.3 (6.6)
pH	6.0-9.0	6.0-9.0

WOOD PRESERVING

Identification of the Best Available Technology Economically Achievable

As summarized in section IX and developed earlier in the document, the best available technology economically achievable in the Wood Preserving subcategory includes:

1. Minimization of waste water volume by the implementation of rigorous inplant water conservation practices;

2; Segregation of contaminated and uncontaminated water streams;

2. Installation of oil recovery equipment to reduce influent to treatment system;

4. Elimination of equipment and plumbing leaks, and;

5. Use of one or a combination of the following biological treatment (trickling filter, activated sludge), soil irrigation, oxidation ponds, chemical oxidation, containment and spray evaporation, pan evaporation, evaporation in cooling towers, and incineration of high concentration oily waste waters.

Effluent Reduction Attainable Through the Application of the Best Available Technology Economically Achievable

Based upon the information contained in Sections III through IX of this document, and consistent with the discussion above, a determination has been made that the effluent limitation representing the degree of effluent reduction attainable in the Wood Preserving subcategory through the application of the best available technology economically achievable is no discharge of process waste water pollutants into navigable waters.

WOOD PRESERVING-BOULTONIZING

Identification of the Best Available Technology Economically Achievable

As summarized in section IX and developed earlier in this document, the best available technology economically achievable in the Wood Preserving-Boultonizing subcategory includes:

1. Minimization of waste water volume by the implementation of rigorous inplant water conservation practices;
2. Segregation of contaminated and uncontaminated water streams.
3. Installation of oil recovery equipment to improve the quality of the influent to treatment system;
4. Elimination of equipment and plumbing leaks;
5. Use of one or a combination of the following treatments: soil irrigation, oxidation ponds, containment and spray evaporation, pan evaporation, evaporation in cooling towers.

Effluent Reduction Attainable Through the Application of the Best Available Technology Economically Achievable

Based upon the information contained in Sections III through IX of this document, and consistent with the discussion above, a determination has been made that the effluent limitation representing the degree of effluent reduction attainable in the Wood Preserving-Boultonizing subcategory through the application of the best available technology economically achievable is no discharge of process waste water pollutants to navigable waters.

WOOD PRESERVING-STEAM

Identification of the Best Available Technology Economically Achievable

The low waste water flow rate 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 effective preventive maintenance and housekeeping program. The following technologies related to these factors have been considered in determining the best available technology economically achievable:

1. Minimization of the volume of discharge 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, and (f) segregation of contaminated and uncontaminated water streams;

2. Modification of oil-recovery systems or replacement, as required, to insure efficient removal of oils; and

3. Implementation of preventive maintenance and good housekeeping programs to reduce spills and leaks and provide a standard procedure for cleaning up those that occur.

Rationale for the Selection of the Best Available Technology Economically Achievable

Processes Employed and Engineering Aspects

Some of the methods of reducing waste flow are standard industry practice, and would normally be adopted earlier than 1983. These include waste stream segregation and recycling of contaminated cooling water.

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 waste water that must be disposed of and also reducing emulsion formation. Modified-closed steaming, while reducing the volume of waste water 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 treating 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 kcal/hr/sq m of surface area (2.7 BTU/hr/sq ft) for each degree of temperature difference between the inside and outside of the vessel. For an uninsulated retort 2.13 m (7 ft) in diameter and 36.57 m (120 ft) long, the daily heat loss would be 7.56 million kcal (30 million BTU) 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. As a result, , steam requirements and, the volume of condensate produced would be reduced significantly.

A well executed preventive maintenance and housekeeping program is an integral part of the treatment and control technology required to achieve best available technology economically achievable limitations. Spills and leakages can largely negate the efforts directed toward other, more obvious aspects of waste water 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.

In addition to the inplant controls described above, polishing treatments may be required to achieve the best available technology economically achievable limitations. Treatments such as chemical oxidation and carbon filtration have been used in treatment of wood preserving waste waters or petroleum waste waters. Chlorination of pentachlorophenol waste water has reduced phenol content 95 to 100% at dosages up to 3.0 g/l of $CaOCl_2$ as chlorine. At a dosage of 8 g/l and 24 hour contact time, 96% of phenols and 80% of COD was removed from creosote waste water. Dosages over 8 g/l showed little additional improvement. Similar results were obtained in tests using pentachlorophenol waste water.

Effluent Reduction Attainable Through the Application of the Best Available Technology Economically Achievable

Based upon the information contained in Sections III through IX of this document, and consistent with the discussion above, a determination has been made that the effluent limitation representing the degree of effluent reduction attainable in the Wood Preserving-Steam subcategory through the application of the best available technology economically achievable is a maximum discharge as follows:

	30-Day Average kg/1000 cu m (lb/100 cu ft)	Daily Maximum kg/1000 cu m (lb/1000 cu ft)
COD	110 (6.9)	220 (13.7)
Phenols	0.064 (0.003)	0.21 (0.014)
Oil and Grease	3.4 (0.2)	6.8 (0.4)
pH	6.0-9.0	6.0-9.0

SECTION XI

STANDARDS OF PERFORMANCE FOR NEW SOURCES

INTRODUCTION

This level of effluent reduction 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.

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.

BARKING

Effluent Reduction, Identification and Rationale for Selection of New Source Performance Standards

Based on the information contained and developed in sections III through IX of this document, a determination has been made that the standard of performance representing the degree of effluent reduction attainable for new sources in the Barking subcategory, excluding hydraulic barking operations, through the application of the best practicable demonstrated control technology, processes, operating methods, or other alternatives is no discharge of process waste water pollutants to navigable waters.

The standard of performance for new sources is based on the following production raw waste and waste water flow assumptions. These assumptions are based on information presented in Section V:

Production (veneer or plywood)	252 cu m/day
Effluent from the barker	6,540 cu m/day
BOD5 concentration	100 mg/l
Total Suspended solids (TSS) concentration	2000 mg/l

The limitations are based on the following treatment efficiencies:

Primary screening and settling	75% Removal SS
Biological treatment BOD5 Removal	

Available information indicated that variation in the effluent from a biological treatment system processing wastes from the timber products processing industry is 300 percent.

Based upon the information contained in sections III through VIII of this document and summarized above, a determination has been made that the standard of performance representing the degree of effluent reduction attainable and the maximum allowable discharge for new sources in the Barking subcategory that use the hydraulic barking process shall be as follows:

	30-Day Average kg/cu m (lb/cu ft)	Daily Maximum kg/ cu m (lb/cu ft)
BOD5	0.5 (0.03)	1.5 (0.09)
Total Suspended Solids	2.3 (0.14)	6.9 (0.43)

VENEER

Effluent Reduction, Identification, and Rationale for Selection of New Source Performance Standards

Limitations prescribed for new sources are applicable to all plants in the veneer segment of the timber products processing industry. No variation will be allowed for log conditioning by open steaming. As discussed in section IX, alternative procedures to conditioning by open steaming exist and are in use in the industry currently.

Based on the information contained and developed in Sections III through VIII of this document, a determination has been made that the standard of performance representing the degree of effluent reduction attainable for new sources in the Veneer subcategory through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives is no discharge of process waste water pollutants to navigable waters.

PLYWOOD

Effluent Reduction, Identification, and Rationale for Selection of New Source Performance Standards

As summarized in section IX, there currently exists treatment and control technologies applicable and in practice in this subcategory that are capable of eliminating the discharge of pollutants.

Based on the information contained and developed in Section III through VIII of this document, a determination has been made that the standard of performance representing the degree of effluent reduction attainable for new sources in the Plywood manufacturing subcategory through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives is no discharge of process waste water pollutants to navigable waters.

HARDBOARD - DRY PROCESS

Effluent Reduction, Identification, and Rationale for Selection of New Source Performance Standards

As summarized in section IX, there currently exist treatment and control technologies applicable and in practice in this subcategory that are capable of eliminating the discharge of pollutants.

Based on the information contained and developed in Sections III through IX of this document, a determination has been made that the standard of performance representing the degree of effluent reduction attainable for new sources in the Hardboard-Dry subcategory through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives is no discharge of process waste water pollutants to navigable waters.

HARDBOARD - WET PROCESS

Effluent Reduction, Identification, and Rationale for the Selection of New Source Performance Standards

The waste loadings generated by the manufacture of hardboard by the wet process come mainly from dissolved organics released during the fiber preparation process. Section VII discusses and sections IX and X summarize technologies which will result in a significant reduction of process waste water pollutants.

Based on the information contained and developed in sections III through VIII of this document, a determination has been made that the standard of performance representing the degree of effluent reduction attainable for new sources in the Hardboard-Wet subcategory through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives is as defined below:

	30-Day Average kg/kkg (lb/ton)	Daily Maximum kg/kkg (lb/ton)
BOD_5	0.9 (1.8)	2.7 (5.4)
Total Suspended Solids	1.1 (2.2)	3.3 (6.6)
pH Range	6.0 - 9.0	6.0 - 9.0

WOOD PRESERVING

Effluent Reduction, Identification, and Rationale for the Selection of New Source Performance Standards

As described in section IX, there currently exist treatment and control technologies applicable and in practice in this subcategory that are capable of eliminating the discharge of pollutants.

Based on the information contained and developed in Sections III through VIII of this document, a determination has been made that the standard of performance representing the degree of effluent reduction attainable by the Wood Preserving subcategory through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives is no discharge of process waste water pollutants to navigable waters.

WOOD PRESERVING-BOULTONIZING

Effluent Reduction, Identification, and Rationale for the Selection of New Source Performance Standards

As described in section IX, there currently exist treatment and control technologies applicable and in practice in this subcategory that are capable of eliminating the discharge of pollutants.

Based on the information contained and developed in Section III through IX of this document, a determination has been made that the standard of performance representing the degree of effluent reduction attainable by the Wood Preserving-Boultonizing subcategory through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives is no discharge of process waste water pollutants to navigable waters.

WOOD PRESERVING-STEAM

Effluent Reduction, Identification, and Rationale for the Selection of New Source Performance Standards

The process by which wood is treated by plants in this subcategory 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, and the replacement of existing preservatives with new or different chemicals is not anticipated in the foreseeable future.

A consideration of the overall 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 U.S. currently kiln dry a portion of their stock prior to treatment. Only about 10 percent use kiln drying for all their stock. The capital investment is high for this technology, amounting to $60,000 per kiln. A minimum of 5 kilns would be required if all the material treated by a typical three-retort plant were dried prior to preservative treatment. Total investment would be $300,000, including $47,000 for each kiln and $13,000 for accessory equipment, gas and electric service and the laying of tracks. Total operating costs for the system would be approximately $98,000 per year. Kiln drying also 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.

A reduction in the volume of discharge can also be obtained by air seasoning stock before treating it. Some air seasoning takes place on the yeard, in the normal processing of material 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. Furthermore, deterioration is a problem in the South when stock is stored for the time required for it to air season.

Steam conditioning or vapor drying in a separate retort would require three additional retorts for the typical three retort plant. Capitol investment would be $150,000, with an additional cost of $110,000 for accessory equipment and installation. Total operating costs would be about $64,000/yr.

It is apparent from the foregoing discussion that there is no simple, economically viable method to reduce the volume of discharge from plants in this subcategory other than that based on the best available technology economically achievable.

Energy Requirements

Kiln drying all stock would have a fuel cost of $72,000/yr for the typical plant, based on a gas consumption of 99 cu m/hr for 312 days/yr operation.

Fuel and electricity costs for a separate retort system for conditioning would be $30,000 and $500, respectively.

Summary

Based on the information contained and developed in Sections III through VIII of this document and summarized above, a determination has been made that the standard of performance representing the degree of effluent reduction attainable for new sources in the Wood Preserving -Steam subcategory through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives is as defined below:

	30-Day Average kg/1000 cu m (lb/1000 cu ft)	Daily Maximum kg/1000 cu m (lb/1000 cu ft)
COD	110 (6.9)	220 (13.7)
Phenols	0.064 (0.003)	0.21 (0.014)
Oil and Grease	3.4 (0.21)	6.8 (0.4)
pH Range	6.0-9.0	6.0-9.0

SECTION XII

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The data base and current state of pollution control in this segment of the timber products processing industry was developed and presented by Environmental Science and Engineering, Inc., Gainesville, Florida, Richard H. Jones, vice president; and John D. Crane, project manager, organized and directed the activity; Robert A. Morrell and Leonard P. Levine served as project leaders for the veneer and plywood, and hardboard portions of the industry. Recognition is given to the secretarial staff of Environmental Science and Engineering for their efforts in providing the Agency with a draft report within a limited time schedule. Dr. John Meiler also served as a consultant to Environmental Science and Engineering for the hardboard industry.

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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 waste water by the growth of zoogleal 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 waste water treatment process in which a mixture of waste water and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated waste water (mixed liquor) by sedimentation and wasted or returned to the process as needed.

Aerated Lagoon - A natural or artificial waste water 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.

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 Waste water Treatment - Forms of waste water 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, aerated lagoons and activated sludge processes are examples.

Blowdown - The removal of a portion of any process water to maintain the constituents of the solution at desired levels.

BOD5 - 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 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 hardboard wetlap 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.

Chipper - A machine which reduces 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 veneer sheets to various sizes and also may remove defects.

Closed Steaming - A method of steaming in which the steam required is generated in the retort by passing 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.

Container Veneer - See veneer.

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 segment of a plywood panel.

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 - See retort.

Cylinder Condensate - Condensation that forms on the walls of the retort during steaming operations. Also, of process in which unseasoned wood is subjected to exposure to an atmosphere of steam to reduce its moisture content and improve its pereability.

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 of a piece of plywood.

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.

DO - Dissolved Oxygen is a measure of the amount of free oxygen in a water sample.

Drum Barker - See debarker.

Dry-clipping - Clipping of veneer which takes place after drying.

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.

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.

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 - 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 strength, resistance to moisture, fire, insects, or decay, or to improve some other property of the product. Alternative spelling: fibreboard.

Fiber Preparation - The reduction of wood to a fibrous condition for hardboard manufacture, utilizing mechanical, thermal, or explosive methods.

Figure - Decorative natural designs in wood which are valuable 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.

Formation (Forming) - The felting of wood or other cellulose fibers into a mat for hardboard. Methods employed: airfelting and wet felting.

Glue - Adhesive which is used to join veneer sheets together into 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 and thermoplastic while the other two are synthetic and thermosetting.

Glue Spreaders - Means of applying glue to veneer, either by 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.

Grading - The selection and categorization of different woods and wood products 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: fibrousfelted 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 wood stem composed of nonliving 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 waste water.

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 waste water in which aerobic or anaerobic stabilization occurs.

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.

MGD - Million gallons per day.

mg/l - Milligrams per liter (equals parts per million, ppm, when the specific gravity is 1.0).

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.

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 microorganisms to promote organic decomposition. They are:

Nitrogen, Ammonia (NH_3), mg/l, as N

Nitrogen, Total Kjeldahl (NH_3 and Organic N), mg/l, as N

Nitrogen Nitrate (NO_3), mg/l, as N

Total Phosphate, mg/l as P

Ortho Phosphate, mg/l as P

Oil-Recovery System - Equipment used to reclaim oil from waste water.

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 injected directly into the cylinder.

Pearl Benson Index - A measure of color producing substances.

Pentachlorophenol - A chlorinated phenol with the formula C_6Cl_5OH 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 a number of layers of wood, or veneers, joined together by means of an adhesive. Plywood consists of two main types:

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 hardboard 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.

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 waste water 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 - A basin or tank in which water or waste water containing settable solids is retained to remove by gravity a part of the suspended matter. Also called sedimentation basin, sedimentation tank, settling tank.

Slicing - See veneer cutting.

Sludge - The accumulated solids separated from liquids, such as water or waste water, 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 waste water 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.

Total Suspended Solids (TSS) - 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 - The material which settles in an Immhoff cone over a period of time.

Spray Evaporation - A method of waste water disposal in which water is sprayed into the air to expedite evaporation.

Spray Irrigation - A method of disposing of some organic waste waters 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 about 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 indivdual 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 considerably. Includes, for example, oil-tempered hardboard. Synonym: 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 - See synthetic resin.

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 waste water 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.

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 container 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, taping, 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 (inflows) of a mill versus water loss (outflows).

Wet Barkers - See debarker.

Wet-Felting - Term applied to the forming of a fiberboard from a suspension of pulp in water usually on a cylinder 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 organics, removed from wood.

Wood Preservatives - A chemical or mixture of chemicals with fungistatic and insecticidal properties that is injected into wood to protect it from biological deterioration.

TABLE 71

CONVERSION TABLE

MULTIPLY		by	TO OBTAIN	
	ABBREVIATION	CONVERSION	ABBREVIATION	
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
board foot	bd ft	12.0	cu ft	cubic feet
British Thermal Unit	BTU	0.252	kg cal	kilogram-calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories/ kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/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 (°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	kilowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
pounds/cubic ft	lb/cu ft	16.05	kg/cu m	kilograms/cubic meters
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (guage)	psig	(0.06805 psig +1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square centimeters
square inches	sq in	6.452	sq cm	square centimeters
1000 board ft	1000 bd ft	2.36	cu m	cubic meters
tons (short)	ton	0.907	kkg	metric tons (1000 kilograms)
yard	yd	0.9144	m	meters

*Actual conversion, not a multiplier

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