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Multimedia Pollution Assessment of the Wood Products Industries

Jordan (Edward C.) Co., Inc., Portland, ME

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MULTIMEDIA POLLUTION ASSESSMENT OF THE WOOD PRODUCTS INDUSTRIES

by

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16. ABSTRACT

This report presents a summary and commentary on pollutants, abatement technologies, and regulations in the wood products industries. Industries included in the study are pulp, paper and paperboard, veneer/plywood, particleboard, millwork and structural members, fabricated wood products, fabricated paper products, and gum and wood chemicals, and wood preserving. Water pollution abatement legislation has established guidelines based on Best Practicable Control Technology Currently Available (BPCTCA). These guidelines primarily address conventional pollutants, including five-day biochemical oxygen demand (BOD5), total suspended solids (TSS) and pH. In addition, guidelines based on Best Available Technology Economically Achievable (BATEA) and Best Conventional Pollutant Control Technology (BCPCT) are currently being established to address conventional, priority (toxic), and nonconventional (neither conventional nor toxic) pollutants. Existing external air pollution control devices, in conjunction with internal process controls, can be effective in the reduction of air pollutants, especially particulates and sulfur dioxide. Although many wood wastes are burned for heat recovery, sludge and refuse are typically disposed of in landfills. Since sludges generated by the wood preserving segment are considered a hazardous waste under RCRA (May, 1980), new landfilling practices will need to be met by the industry for disposal.

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report assesses multimedia pollution control in wood products industries through February 1979. The data presented in the report on the pulp, paper, and paperboard industry and the Resource Conservation Recovery Act (RCRA) were updated through May 1980.

A summary of legislative requirements for establishment of emission standards are presented. This report should be useful to EPA personnel concerned with environmental quality related to the wood products industries and other Federal agency personnel concerned with wood treatment processes.

For further information on these subjects, interested readers should contact the Food and Wood Products Branch of the Industrial Pollution Control Division.

David G. Stephan
Director
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ABSTRACT

This report presents a summary and commentary on pollutants, abatement technologies, and regulations in the wood products industries. Information was primarily obtained from a study performed by Battelle Laboratories for the U.S. Environmental Protection Agency and available effluent guidelines development.

Water pollution abatement legislation has established guidelines based on Best Practicable Control Technology Currently Available (BPCTCA). These guidelines primarily address conventional pollutants, including five-day biochemical oxygen demand (BOD5), total suspended solids (TSS) and pH. In addition, guidelines based on Best Available Technology Economically Achievable (BATEA) and Best Conventional Pollutant Control Technology (BCPCT) are currently being established to address conventional, priority (toxic), and nonconventional (neither conventional nor toxic) pollutants.

Existing external air pollution control devices, in conjunction with internal process controls, can be effective in the reduction of air pollutants, especially particulates and sulfur dioxide. Air pollutants often limited by state governments include particulates and sulfur dioxide, as well as total reduced sulfur (TRS) compounds. Generally, southern states have stricter particulate standards, while northwestern states have stricter reduced sulfur compounds standards. The major impacts associated with these pollutants are odor problems and potential respiratory effects.

Solid waste generation in the wood products industry consists primarily of wood wastes, wastewater treatment plant sludge and refuse generated by personnel activities. Although many wood wastes are burned for heat recovery, sludge and refuse are typically disposed of in landfills. Since sludges generated by the wood preserving segment are considered a hazardous waste under RCRA (May 1980), new landfilling practices will need to be met by the industry for disposal.

This report was submitted in fulfillment of Contract No. 68-03-2605 by the Edward C. Jordan Co., Inc. under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period May 1, 1978, to June 1980, and work was completed as of June 1980.

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ABBREVIATIONS

AC --alternating current
ACA --ammonical copper arsenite
ADT --air dry ton
ASB --aerated stabilization basin
BACT --best available control technology
BART --best available retrofit technology
BATEA --best available technology economically achievable
BMP'S --best management practices
BOD5 --biochemical oxygen demand (five-day)
BPCTCA (BPT) --best practicable control technology currently available
CMN --coarse, molded, newsprint
CMP --chemi-mechanical pulp
COD --chemical oxygen demand
DO --dissolved oxygen
EPA --Environmental Protection Agency
ESP --electrostatic precipitators
GAC --granular activated carbon
gal --gallon(s)
kks/day --1,000 kilograms per day
ks/ha --kilograms per hectare
kwh --kilowatt-hour
lb --pound(s)
mg/l --milligram(s) per liter
mst --median survival time
Na --sodium
NAAQS --national ambient air quality standards
NSSC --neutral sulfite semi-chemical
NTU --nephelometric turbidity unit
PCB --polychlorinated biphenyls
PCP --pentachlorophenol
PSD --prevention of significant deterioration
Pt-Co --platinum cobalt unit(s)
RBC --rotating biological contactor
RCRA --resource conservation and recovery act
SIP --state implementation plan
t --2,000 pounds (short ton)
TOC --total organic carbon
TRS --total reduced sulfur
TSP --total suspended particulates
TSS --total suspended solids
TU --toxic unit
ug/l --microgram(s) per liter
Z/A --Zurn/Attisholz

METRIC CONVERSION FACTORS

The U.S. Environmental Protection Agency (EPA) policy is to express all measurements in metric units. When this results in undue cost or lack of clarity, conversion factors are provided for the nonmetric units used in the report. Generally, this report uses English units of measure. For conversion to the metric system, use the following conversion factors.

TABLE OF CONVERSION FACTORS

Multiply english unit	By conversion factor	To obtain metric (SI)unit
Acres	0.405	hectares
Acre-feet	1233.5	cubic meters
Barrel, oil	158.97	liters
British Thermal Unit	0.252	kilogram-calories
British Thermal Unit/pound	0.555	kilogram calories/kilogram
Cubic feet/minute	0.028	cubic meters/minute
Cubic feet/second	1.7	cubic meters/minute
Cubic feet	0.028	cubic meters
Cubic feet	28.32	liters
Cubic inches	16.39	cubic centimeters
Degree Fahrenheit	0.555(°F-32)*	degree centrigrade
Feet	0.3048	meters
Gallon	3.785	liters
Gallon/minute	0.0631	liters/second
Horsepower	0.7457	kilowatts
Inches	2.54	centimeters
Inches of mercury	0.03342	atmospheres
Pounds	0.454	kilograms
Million gallons/day	3785	cubic meters/day
Mile	1.609	kilometer
Pound/square inch (gauge)	0.06805 psig +1*	atmospheres (absolute)
Square feet	0.0929	square meters
Square inches	6.452	square centimeters
Tons (short)	0.907	metric tons (1000 kilograms)
Yard	0.9144	meters

*Actual conversion, not a multiplier.

Source: Battelle Columbus Laboratories (166).

ACKNOWLEDGMENTS

This report has been prepared under the direction of Donald R. Cote, P.E., principal-in-charge; Roy C. Walden, P.E. and Willard C. Warren III, P.E. served as project managers. Special thanks are extended to Lloyd C. Fogg for editing the manuscript and to Patricia Beaulieu and Constance Michaud for typing the report.

The constructive comments received from Donald Wilson and other EPA staff members in their review of preliminary drafts of the report are sincerely appreciated.

Much of the material herein was summarized from documents previously prepared for the EPA, most notably:

1. P.S.K., Choi, W.J. Mueller, J.A. Jacomet, D.L. Hessel, J.A. Gerling, and T.J. Collier. "Multimedia Pollution Assessment in Pulp, Paper and Other Wood Products Industry," of Battelle Columbus Laboratories, Columbus, Ohio 1976 (unpublished)

2. "Cross Media Impact of the Disposal of Hazardous Wastes From the Wood Products and Related Industries," by Battelle Columbus Laboratories, Columbus, Ohio (unpublished).

The efforts of these and other authors in gathering much of the base data included in this report is acknowledged and appreciated.

SECTION 1

INTRODUCTION

OBJECTIVES

This report is intended as a summary and commentary on pollutants, abatement technologies and regulations in the wood products industries.

Summarized in this document are:

1. Wastewater effluent, air emissions and solid waste generated by the wood products industries, and associated environmental impacts;
2. Abatement technology and associated effects and economics; and
3. Pertinent existing and proposed legislation and its relation to items 1 and 2 above.

The primary basis of this report is a study performed by Battelle Laboratories for the U.S. Environmental Protection Agency (EPA). Available information from effluent guidelines development and other sources has been used to update and expand data from the Battelle effort.

The wood products industries, for the purpose of this report, have been broken down into two main groups: 1) the pulp, paper, and paperboard industry; and 2) the other wood products industries. A brief description of each and its subcategories is presented in the following paragraphs.

INDUSTRY DESCRIPTION

Pulp, Paper, and Paperboard

At the time of this study, the pulp, paper, and paperboard industry consisted of approximately 730 operating facilities. Of these 514 have been classed in specific subcategories, and the remainder are in miscellaneous subcategories composed of combined process or unique process mills. Operations vary from large integrated kraft pulp, paper, and paperboard mills producing over 1.8 million kilograms per day or 2,000 tons/day, to small nonintegrated single machine mills making less than 0.9 kkg/day (1 ton/day) of product.

There are three general classifications of mills: Integrated mills; secondary fiber mills, and nonintegrated mills. At integrated mills, pulp is produced from wood and nonwood raw materials (e.g., hemp or flax); paper and board products are produced onsite. At secondary fiber mills, no pulp is produced onsite; most of its furnish is derived from wastepaper. At nonintegrated mills, the furnish consists of purchased wood pulp or other fibers. No pulp is made onsite, but some wastepaper can be used, as long as the mill does not have a complete deinking process.

Pulping processes at the integrated mills range from simple groundwood operations, using only mechanical defibration of full logs and limited bleaching operations, to the complex dissolving pulp mills employing extensive chemical pulping operations and attendant recovery systems coupled with multistage bleaching operations. Also included with the integrated pulp mills are those producing pulps from a variety of nonwood fibers such as flax, hemp, cotton, abaca, and sisal. Pulping operations include groundwood and modified groundwood operations, sulfite (acid) processes, unbleached and bleached kraft or soda processes (alkaline), and modified high-yield processes utilizing mild chemical treatments coupled with mechanical defibration.

Mills using secondary fiber are a large and growing segment of the industry. At these mills wastepaper is utilized in various forms. At one extreme are processes involving the direct slushing of wastepapers with no additional processing, followed by conversion into coarse products such as construction papers, corrugating media and other coarse board stock. At the other extreme are mills using high quality wastepapers which subsequently are deinked by chemical means, screened, cleaned, and processed through multistage bleaching systems in a manner very similar to wood pulping. High quality deinking pulps are utilized in the production of fine quality tissue, printing, and business papers.

Fibers are purchased by nonintegrated mills, which manufacture a wide range of products. The products range from specialty board items through the highest quality fine papers.

The U.S. pulp, paper, and paperboard industry is concentrated in the northeastern, southern, and western states as shown in Figure 1.

Other Wood Products Industries

The other wood products industries are diverse and are broken down in the following point source categories.

Veneer/Plywood --

In 1972 there were approximately 593 veneer plywood plants operating in the United States Of these, approximately 366 processed hardwood, and 227 processed softwood. Hardwood products are used for decorative purposes. Softwood products are used in structural applications.

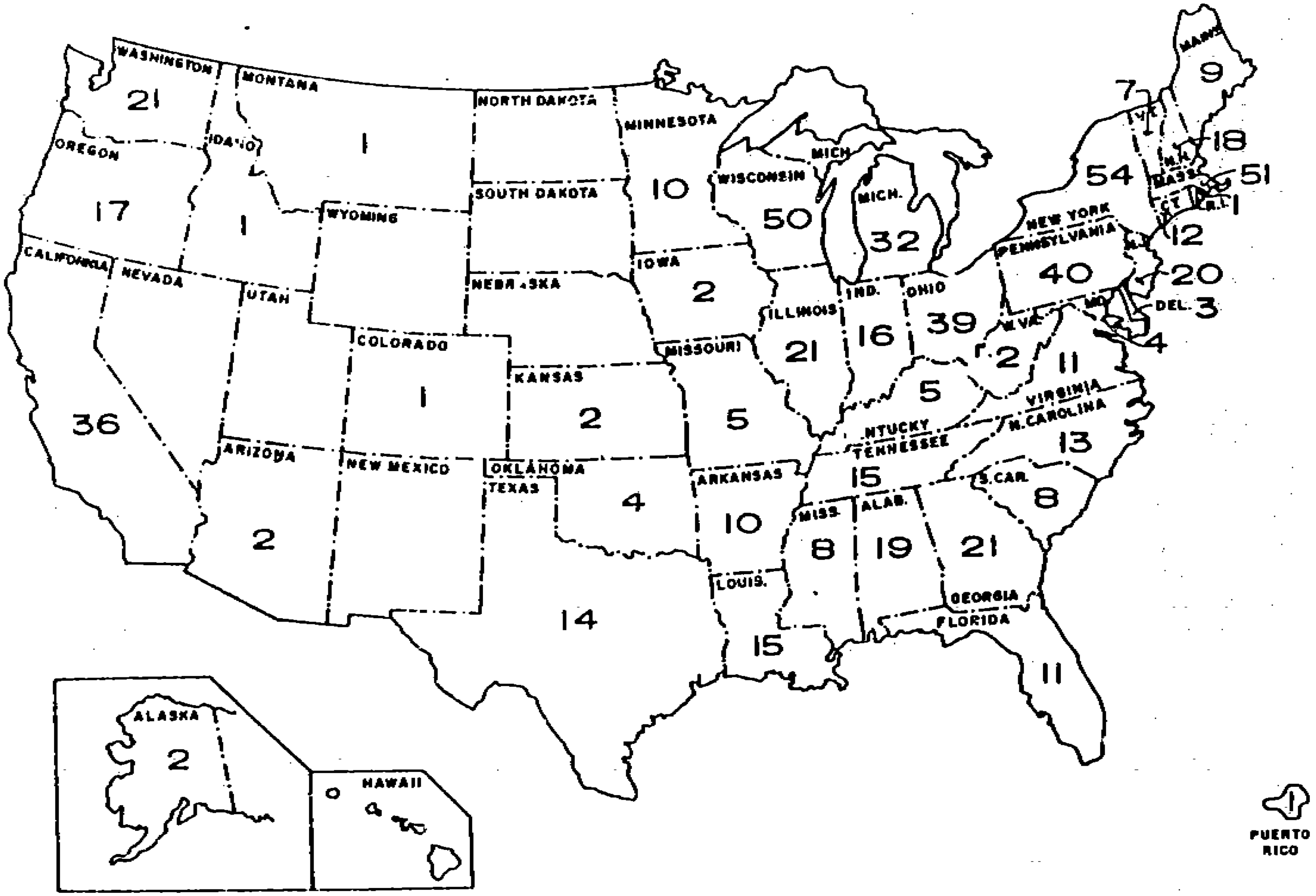


Figure 1. Pulp, paper, and paperboard mills in the United States.

The typical hardwood plywood plant is a small, privately-owned mill producing 5 to 10 million ft^2 of product per year. This is in contrast to the production pattern in the softwood plywood section, which is typified by a mill with a 100 to 125 million ft^2 output per year. Furthermore, softwood plywood plants tend to be multiplant operations owned by a broad-based forest products company. Figures 2 and 3 present the density of hardwood and softwood mills across the United States.

Particleboard --

The particleboard industry consists of approximately 74 plants. Producers range from large multi-forest product companies producing particleboard from their wood wastes, to relatively small furniture companies producing particleboard for captive consumption. The largest four firms control approximately 36 percent of the industry capacity.

Particleboards are board products which differ from conventional fiberboards in that they are composed of distinct particles of wood or other ligno-cellulosic materials which are bonded together with an organic binder. The "particles" vary in size and must be distinguished from the fibers used in insulation and hardboard. Other terms used for particleboard include chipboard, flakeboard, silverboard, shaving board, and wood waste board. Figure 4 shows the distribution of particleboard manufacturing facilities across the United States.

Millwork --

The millwork industry manufactures molding, doors and windows, and cabinetry. The industry is quite fractionated with the eight largest companies producing only 13 percent of the output in 1970.(1) Among producers of molding, which accounts for 20 percent of the industry output, 35 companies possess approximately 80 percent of the capacity.(1)

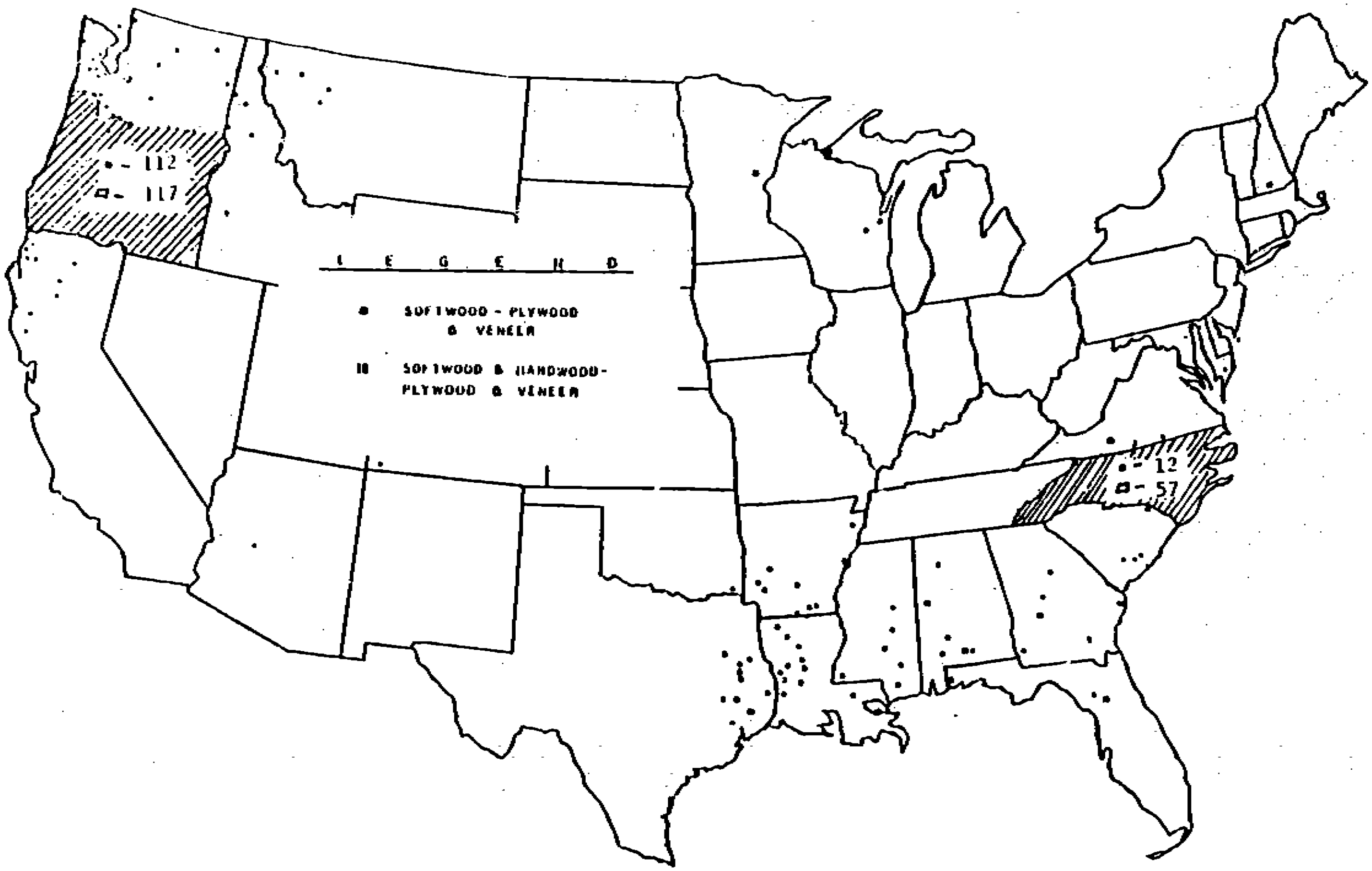
Some molding companies are integrated with sawmills, although most are separate. Local producers of windows, doors, and cabinetry are usually small operations. The total number of plants is not well-documented. Figure 5 presents the distribution of mills across the United States in 1967. The number of mills in each state include any mills primarily involved in mill work production.

Structural Wood Members --

In 1972, 642 firms were actively engaged in the manufacture of structural wood members and were reported to be operating 678 establishments. The industry is quite diverse, with the top 50 companies supplying only 46 percent of the total shipments.(1) This industry is primarily engaged in the manufacture of laminated or fabricated trusses, arches, and other structural members of lumber.

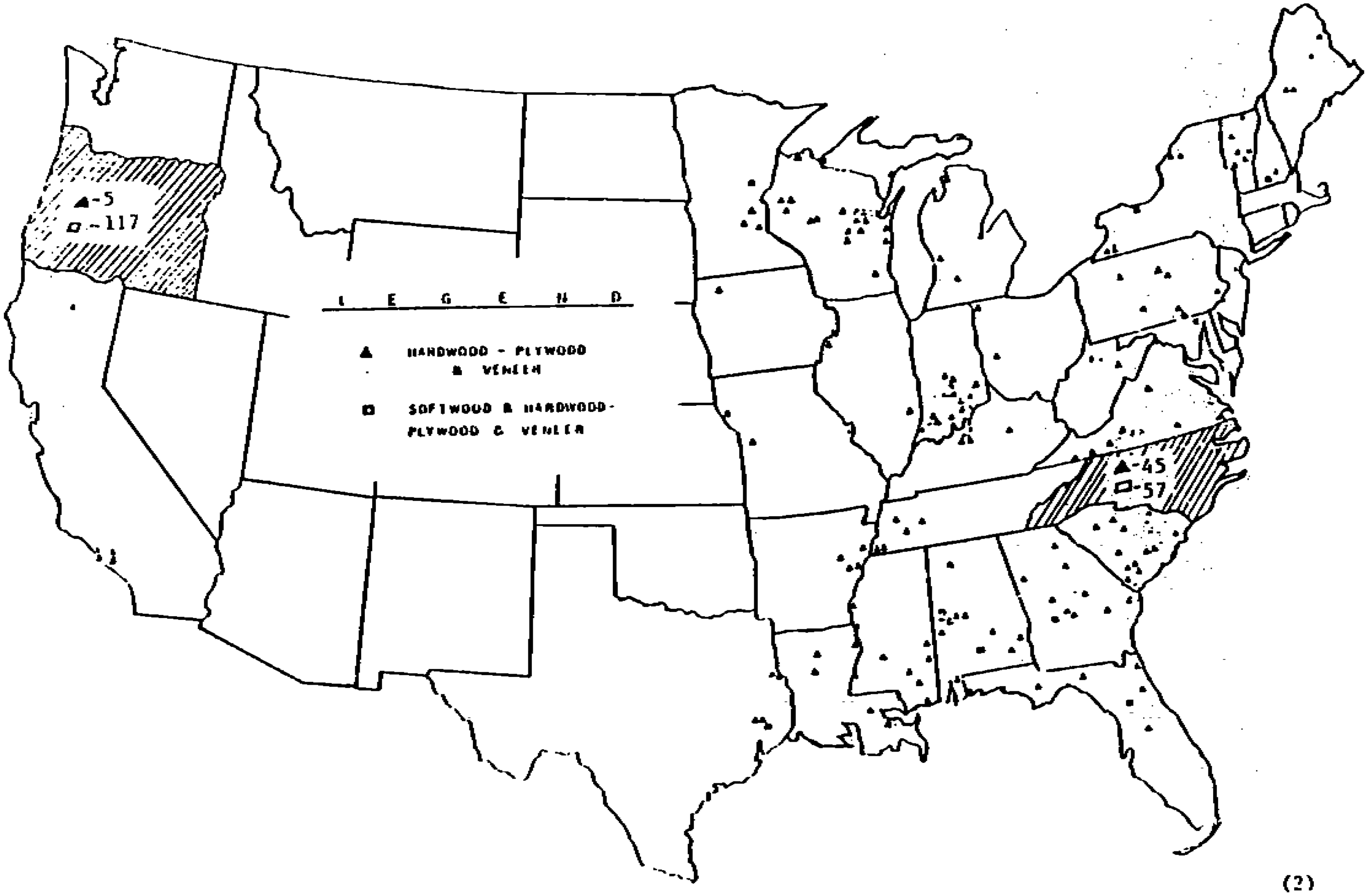
Wood Furniture and Fixtures --

The large number of products included in this group prohibits a listing of each. The processes involved include the machining and fabrication (fastening or gluing) of primary forest products such as lumber, plywood, and board. Figure 6 shows the concentration of mills by state.



(2)

Figure 2. Distribution of softwood veneer and plywood mills throughout the United States.



(2)

Figure 3. Distribution of hardwood veneer and plywood mills throughout the United States.

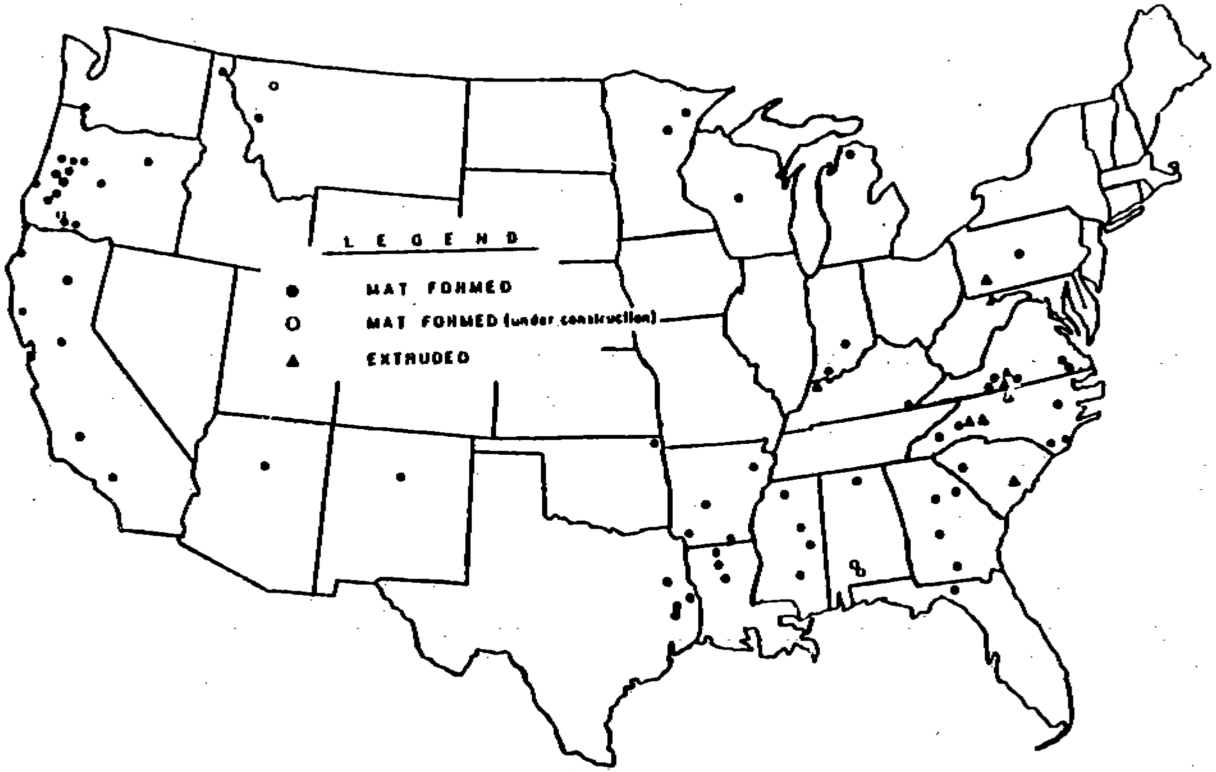


Figure 4. Particleboard manufacturing facilities. (184)

Hawaii - 13

Figure 5. Millwork plants. (184)

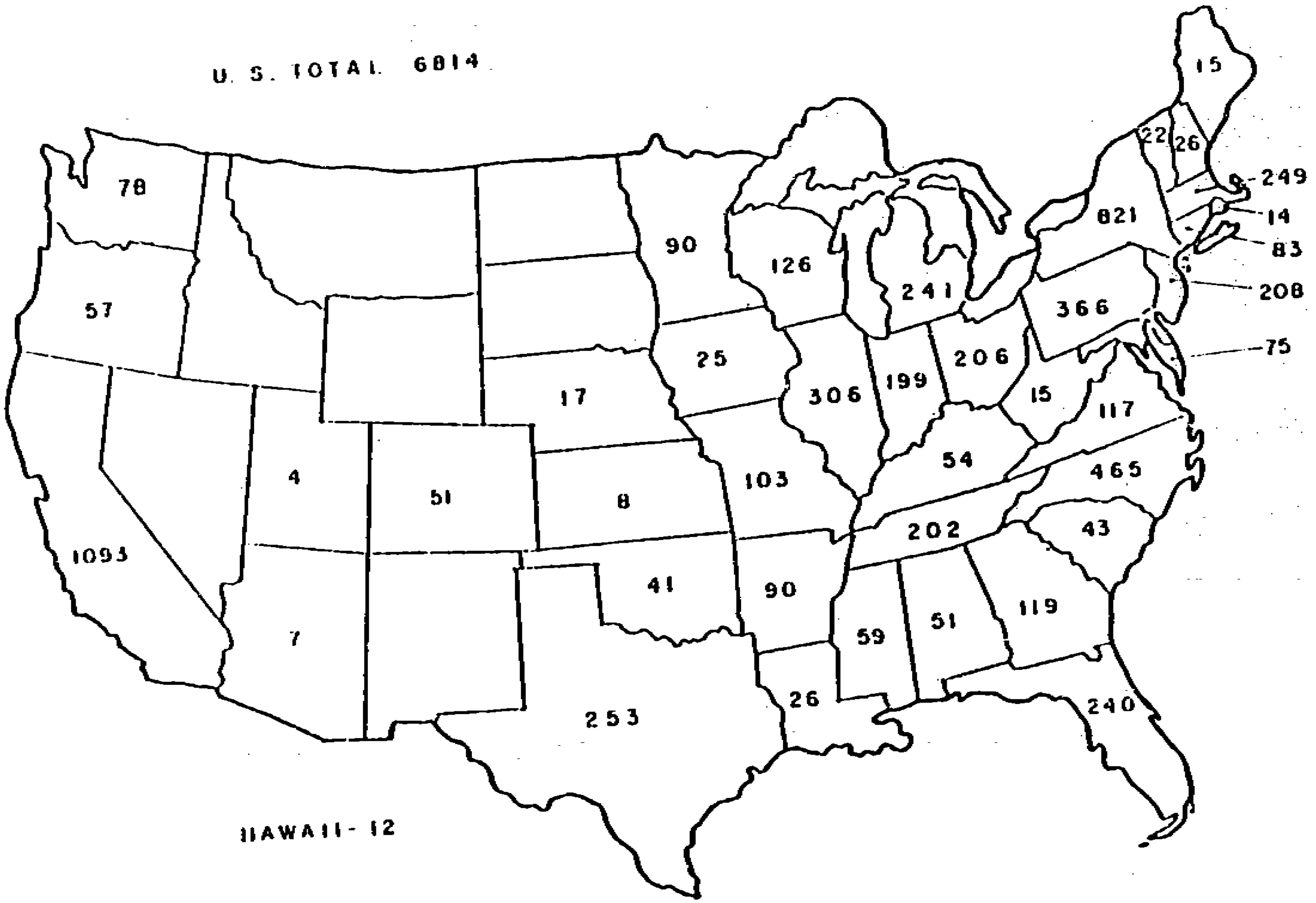


Figure 6. Furniture and fixture plants. (184)

Gum and Wood Chemicals --

Major products from this industry include: wood turpentine, wood rosin, tall oil, fatty acids, gum rosin, gum turpentine, and pure oil. Twelve major companies account for the majority of production in this industry. The more efficient use of rosin for sizing in the paper industry and decline in the use of gum for naval stores indicate a downward trend for this industry in the future.

Wood Preserving --

There are approximately 415 companies engaged in wood preserving in the United States. Fifty percent of the industry capacity is controlled by ten companies. Over three-quarters of the plants are concentrated in two distinct regions. One area extends from east Texas to Maryland and corresponds roughly to the natural range of southern pines, the major species utilized. The second, smaller area is located along the Pacific Coast, where Douglas fir and western red cedar are the predominant species. Figure 7 depicts the location of the wood preserving plants in the United States.

The wood preserving industry applies chemical treatment to round or sawn wood products for the purpose of imparting insecticidal, fungicidal, or fire resistant properties to the wood. The three most prevalent types of preservatives used in wood preserving are creosote, pentachlorophenol (PCP), and various formulations of water-soluble inorganic chemicals, the most common of which are the salts of copper, chromium, and arsenic. Fire retardants are formulations of salts, the principal ones being borates, phosphates, and ammonium compounds. Eighty percent of the plants in the United States use at least two of the three types of preservatives. Many plants treat with one or two preservatives plus a fire retardant.

Insulation Board --

There are 16 plants in this subcategory that use wood as the predominant raw material. Insulation board is a form of fiberboard, which in turn is a broad generic term applied to sheet materials constructed from ligno-cellulosic fibers. Insulation board is a "non-compressed" fiberboard, which is differentiated from "compressed" fiberboards, such as hardboard, on the basis of density. Densities of insulation board range from about 0.15 to a maximum 0.50 g/cu cm (9.5 to 31 lb/cu ft).(6) Figure 8 shows the geographical distribution of insulation board mills in the United States.

Hardboard --

There are 16 wet process hardboard mills across the United States as shown in Figure 9. Hardboard is a form of fiberboard, which is a broad generic term applied to sheet materials constructed from ligno-cellulosic fibers. Hardboard is a "compressed" fiberboard, with a density over 0.50 g/cu cm (31 lb/cu ft). The thickness of hardboard products ranges between 2 and 13 mm (nominal 1/12 to 7/16 in.).(6)

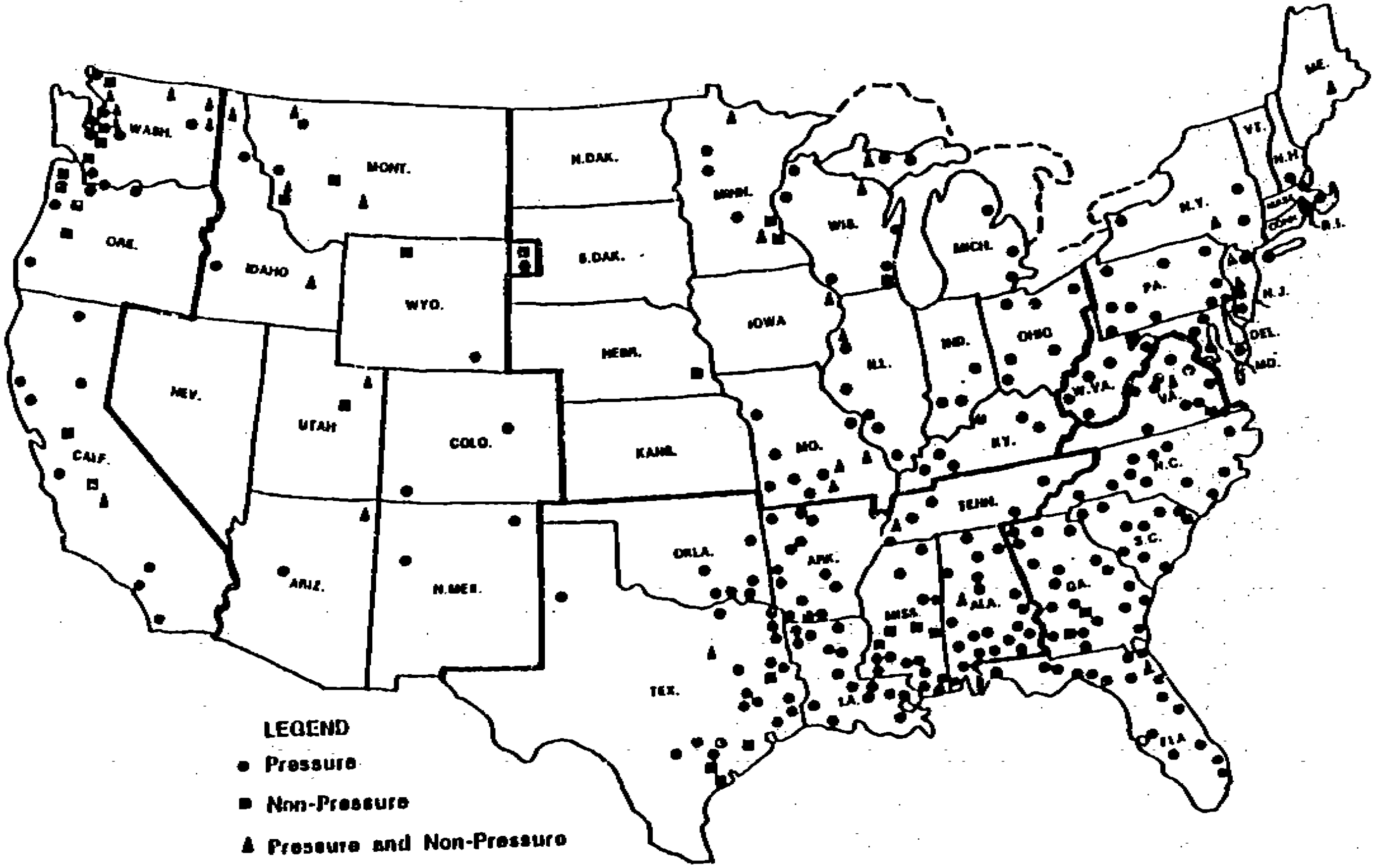
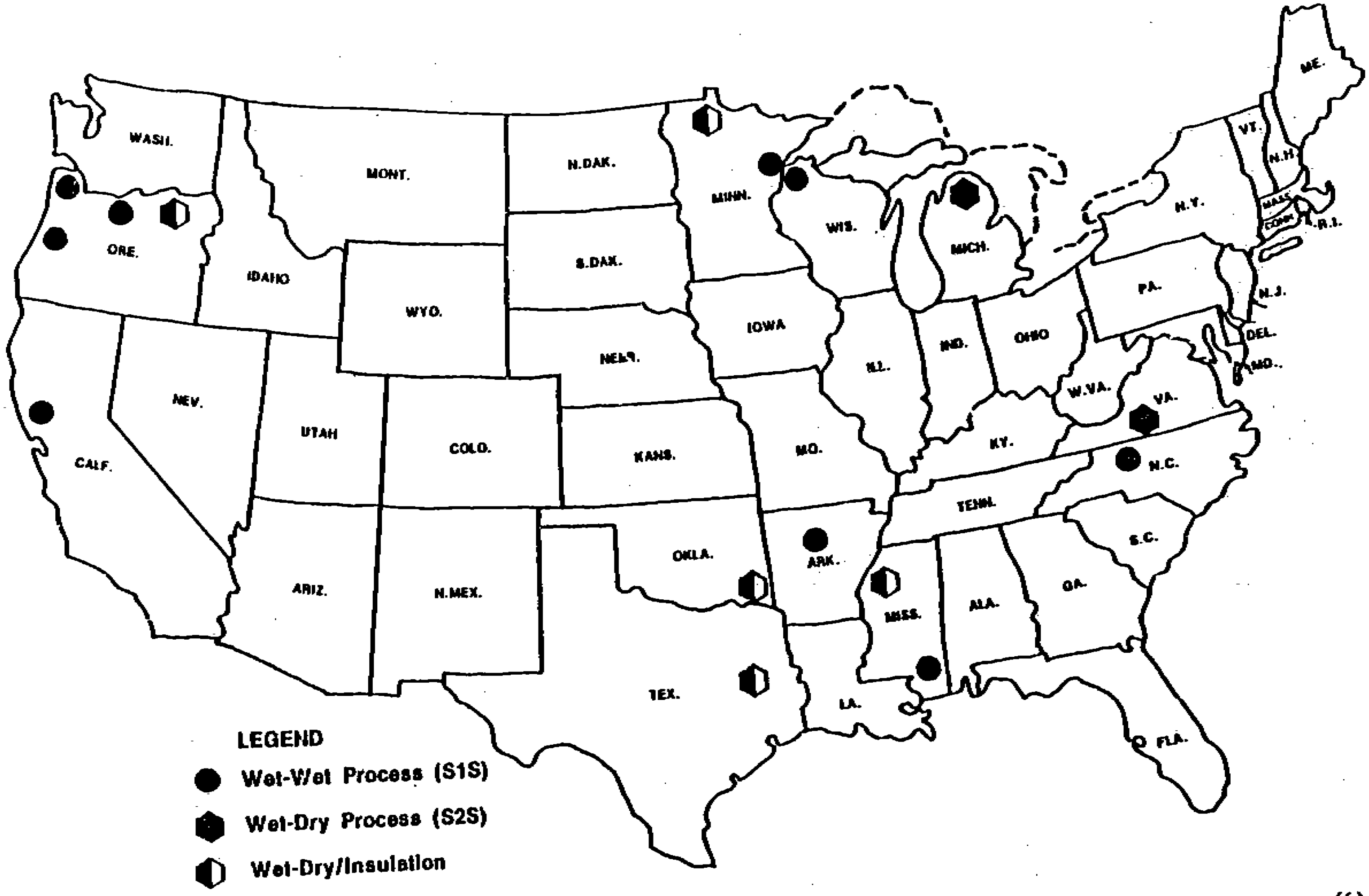


Figure 7. Geographical distribution of wood preserving plants in the United States. (2)



(6)

Figure 8. Geographical distribution of insulation board manufacturing facilities in the United States.

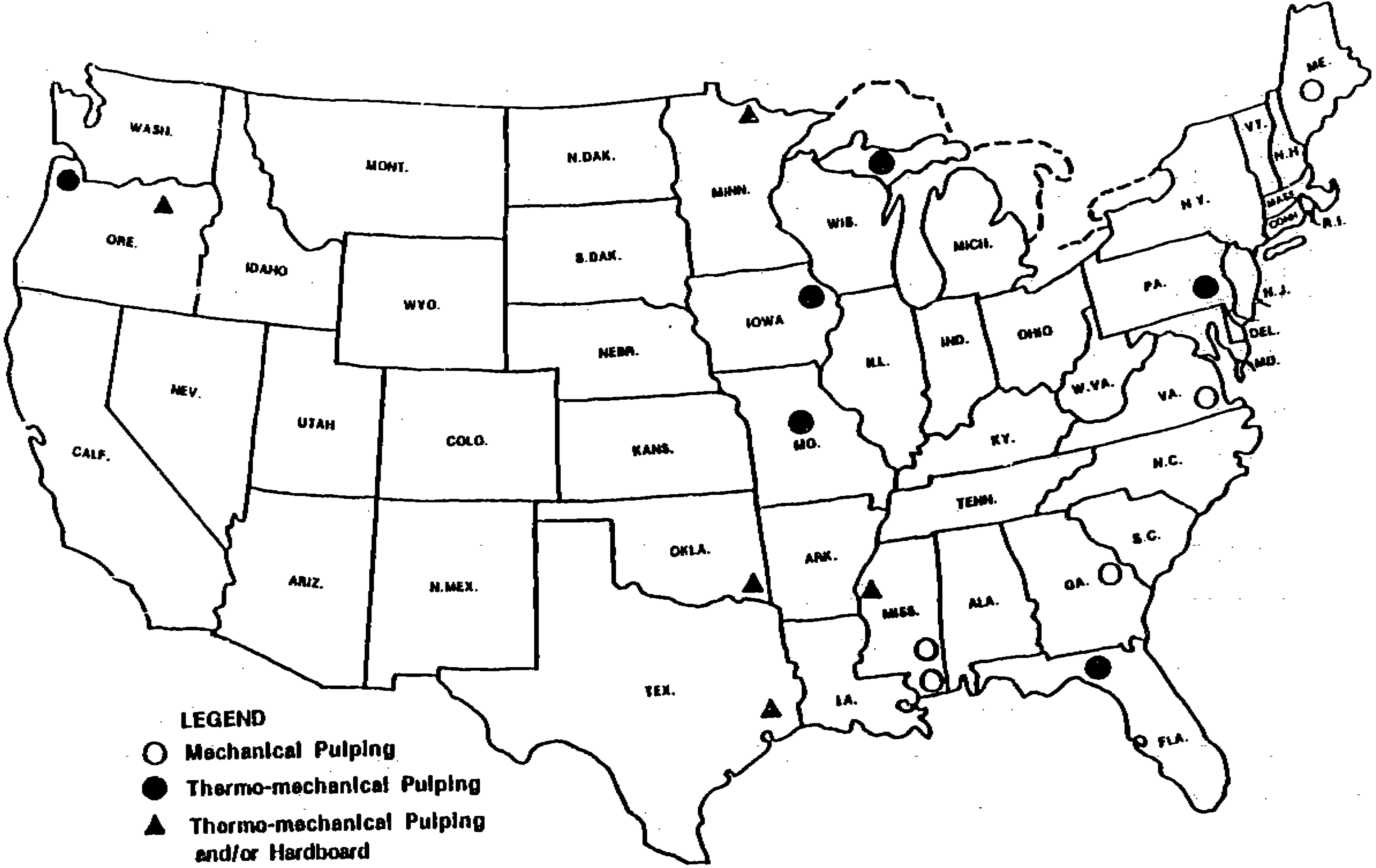


Figure 9. Geographical distribution of hardwood manufacturing facilities in the United States. (6)

Summary of Wood Products Industries

Wood products industries have a number of subcategories as shown in Table 1. The approximate number of plants and typical production capacities for each subcategory are also noted. Descriptions of industries follow.

PRODUCTION TRENDS

Pulp, Paper and Paperboard

Pulp, paper, and paperboard production capacity have exhibited moderate but steady growth in recent years. This pattern is illustrated in Tables 2 and 3, for 1975 through 1981.(3)

Other Wood Products

Other wood products industry production patterns are shown in Tables 4 through 9.(4,5,6) Lumber production has fluctuated with no trend in recent years. Particleboard production peaked in 1973 and then began declining. Hardwood plywood production steadily declined, while prefinished hardwood plywood made from purchased pulp increased dramatically over the past decade. Softwood plywood production experienced steady gains over the same period (Tables 7, 8, 9).

POLLUTION ABATEMENT COSTS

According to an advance report from the U.S. Department of Commerce, Bureau of the Census, United States manufacturing establishments spent $3.586 billion on pollution control in 1977.(7) This total represents a 2 percent increase over 1976 capital expenditures. Operating costs for pollution abatement totaled $5.485 billion in 1977, representing a 21 percent increase over the 1976 total of $4.539 billion. Costs incurred by the lumber and wood products industry (SIC 24) and the paper and allied products industry (SIC 26) are summarized in Table 10.

Table 10 shows there was a slight reduction in capital expenditures for pollution control by the paper and allied products industry in 1977. This indicates that many mills have already completed the construction of required environmental control systems. Pollution control operating costs rose by 28 percent for the paper and allied products industry from 1976 to 1977. Most of the costs incurred relate to air and water pollution control efforts.

TABLE 1. WOOD PRODUCTS INDUSTRY SUBCATEGORIES PROFILE

Subcategory*	Number of plants	Typical Mill production (tons/day)	Products
Pulp, Paper and Paperboard Industry			
Dissolving kraft	3	1,000	Pulp
Market bleached kraft	12	600	Pulp
BCT bleached kraft**	9	800	BCT paper
Alkaline fine	20	900	Printing paper
Unbleached kraft (linerboard)	20	1,000	Linerboard
Unbleached kraft (bag)	8	1,000	Bag
Semi-chemical	20	425	Corrugating medium
Alkaline unbleached and semi-chemical	10	1,500	Linerboard corrugating medium
Dissolving sulfite	6	600	Pulp
Papergrade sulfite	15	450	Tissue & writing paper
Groundwood thermo-mechanical pulp	4	300	Groundwood specialty
Groundwood CMN papers#	5	600	Newsprint
Groundwood fine papers	9	500	Printing paper
Deink (fine)	5	180	Fine paper
Deink (newsprint)	6	400	Newsprint
Deink (tissue)	15	180	Tissue paper
Tissue from wastepaper	23	40	Industrial tissue
Paperboard from Wastepaper	159	160	Wastepaper board
Wastepaper molded products	18	50	Molded products
Builders' paper and roofing felt	66	100	Roofing & construction
Nonintegrated fine	45	215	Printing paper
Nonintegrated tissue	28	180	Sanitary tissue
Nonintegrated lightweight	18	60	Lightweight & thin paper
Nonintegrated filter & nonwoven	14	20	Filter paper
Nonintegrated paperboard	16	40	Board & coarse paper

TABLE 1 (Continued)

Subcategory*	Number of plants	Typical Mill production (tons/day)	Products
Other Wood Products Industries			
Veneer/plywood	593	55	Veneer/plywood
Particleboard	75	60	Particleboard
Millwork	35†	630	Windows/doors
Structural members	678	10	Structural members
Wood furniture & fixture	N.D.	340,000§	Furniture & fixtures
Gum & wood chemicals	130	500§	
Char & Charcoal Briquets	77		Char & Charcoal briquets
Gum Rosin & Turpentine	7		Gum rosin & turpentine
Wood Rosin, Turpentine & Pine Oil	5		Wood rosin & turpentine
Tall Oil Rosin, Fatty Acids, & Pitch	12		Tall oil rosin
Essential Oils	9		Cedarwood oil
Rosin Derivatives	13		Rosin derivatives
Sulfate Turpentine	7		Turpentine
Wood preserving	300	--	Treated lumber
Waterbourne or Non-Pressure			
Steam			
Boultonizing			
Insulation Board	16	334	Insulation board
Hardboard	33	--	Interior wall paneling, furniture
Dry process	17		
Wet process (S1S)	9		
Wet process (S2S)	7		

*Note: Pulp, paper, and paperboard industry profile was derived from mill survey data collected through ongoing effluent guidelines development. Other wood products profile information was obtained from Battelle Columbus Laboratory's study effort; wood preserving industry data were obtained from reference 2.

**BCT = Paperboard, coarse, tissue.

#CMN = Course, molded and news.

†Major producers of molding only.

§Total production for this industry.

TABLE 2. PULP, PAPER AND PAPERBOARD INDUSTRY WOODPULP PRODUCTION CAPACITY: 1977-1981

	Amount produced in thousands of short tons				
Grades	1977	1978	1979	1980	1981*
Total Wood Pulp#	51,849	52,998	54,150	55,613	56,963
Dissolving	1,648	1,639	1,613	1,611	1,611
Sulphite paper grades	2,252	2,096	2,066	2,000	2,000
Sulphate and soda paper grades	36,922	38,016	38,909	39,893	40,911
Bleached	15,822	16,678	17,267	18,114	18,438
Semi-bleached	1,547	1,538	1,552	1,552	1,552
Unbleached	19,552	19,801	20,090	20,227	20,921
Semichemical	4,514	4,602	4,691	4,795	4,845
Mechanical#	6,442	6,573	6,801	7,242	7,524
For paper & paperboard	4,502	4,623	4,827	5,267	5,549
For other paper and board#	1,939	1,949	1,974	1,975	1,975
Screenings	71	71	71	71	71
Total machine dried wood pulp	7,975	8,280	8,707	8,972	9,171
Dissolving	1,648	1,639	1,613	1,611	1,611
Bleached sulphite	638	578	563	496	496
Bleached sulphate	5,311	5,720	6,198	6,528	6,724
Unbleached sulphate	178	130	126	126	126
All other	200	213	207	211	214

*Capacity additions presented here for 1981 include only presently known commitments and do not necessarily represent final expansion plans of the industry for that year.

#Excludes 2.5 million tons of defibrated pulp capacity used to produce furnish for hard pressed board.

Source: American Paper Institute(3)

TABLE 3. PAPER AND PAPERBOARD PRODUCTION CAPACITY: 1977-1981

Grades	Amount produced in thousands of short tons 1977	1978	1979	1980	1981*
Total, all grades paper and paperboard#	66,459	67,505	69,355	71,233	72,579
Total paper	29,831	30,389	31,059	32,417	32,964
Newsprint	4,069	4,115	4,259	4,742	4,973
Printing, writing & related	14,975	15,401	15,684	16,340	16,561
Uncoated groundwood	1,367	1,367	1,378	1,360	1,361
Coated groundwood	2,408	2,429	2,461	2,653	2,788
Coated free sheet	1,989	2,056	2,125	2,169	2,224
Uncoated free sheet	7,464	7,775	7,924	8,350	8,380
Cotton fiber	133	131	131	131	131
Thin papers	402	416	424	431	432
Solid bleached bristols	1,213	1,226	1,240	1,245	1,245
Packaging and industrial converting†	6,242	6,220	6,246	6,246	6,271
Unbleached kraft†	4,317	4,372	4,397	4,400	4,431
Bleached packaging & industrial converting	1,069	973	964	965	961
Special industrial	856	875	884	881	879
Tissue	4,545	4.654	4,871	5,088	5,159
TOTAL PAPERBOARD	32,173	32,644	33,796	34,321	35,119
Unbleached kraft	14,793	15,081	15,659	15,827	16,535
	13,586	13,846	14,398	14,398	15,097
Solid bleached	4,020	4,154	4,289	4,362	4,396
Semichemical	4,661	4,762	5,057	5,155	5,158
Recycled	8,699	8,647	8,792	8,977	9,029
Total Construction Paper and Board and Other§	4,455	4,472	4,500	4,495	4,496

*Capacity additions presented here for 1981 include only presently known commitments and do not necessarily represent final expansion plans of the industry for that year.

#Excludes hard pressed board capacity; includes 170,000 tons of capacity for unbleached kraft paper facilities that have been shut down.

†Includes 170,000 tons of capacity for unbleached kraft paper facilities that have been shut down.

§Excludes hard pressed board capacity.

Source: American Paper Institute(3)

TABLE 4. TRENDS IN LUMBER AND PARTICLEBOARD PRODUCTION CAPACITY*

Year	Lumber (board-ftx10^6)	Particleboard (3/4-inch, ft^{2}x10^6)
1970	34,668	1,763
1971	36,998	2,394
1972	37,745	3,116
1973	38,595	3,493
1974	34,608	3,103
1975	32,619	2,367
1976	36,905	N.A.

*Source: U.S. Department of Commerce, Bureau(4)
N.A. = Not available

TABLE 5. HARDWOOD PLYWOOD AND PREFINISHED HARDWOOD PLYWOOD PRODUCTION: 1966-1977

		Hardwood plywood quantity ($ft^2 \times 10^6$ surface measure)			Prefinished hardwood plywood made from purchased plywood#	
Year	Total	Shipped as unfinished	Shipped as prefinished*	Value (in millions)	Quantity ($ft^2 \times 10^6$ surface measure)	Value (in millions)
1977	1,339.1	859.4	479.7	$468.2	2,190.2	$335.9
1976	1,250.8†	734.2†	516.6†	416.5†	2,091.0†	293.6
1975	1,148.3	649.2	499.1	347.2	1,861.7	242.1
1974	1,447.8	726.9	720.9	393.6	2,051.2	263.4
1973	1,810.2	864.1	946.1	409.4	2,453.3	313.9
1972	1,954.3	782.7	1,171.6	371.8	2,996.1	299.5
1971	1,813.7	913.5	895.2	326.7	2,202.4	214.7
1970	1,615.4	811.0	804.4	309.7	1,930.1	177.1
1969	1,644.8	857.6	791.2	347.0	1,811.9	180.2
1968	1,786.3	863.1	918.2	353.9	1,413.7	143.7
1967	1,693.3	934.5	758.8	327.7	902.9	98.0
1966	1,776.2	1,037.4	738.8	355.9	676.0	81.6

*"Shipped as prefinished" reflects hardwood plywood produced and prefinished at the same location.

#Data for "prefinishers" is not directly comparable with information published prior to 1972. In 1972, 16 establishments accounting for approximately 10 to 15 percent of the shipments value were added to the survey. Information for prior periods is not available.

†Revised by 5 percent or more.

Source: U.S. Department of Commerce(4)

TABLE 6. SOFTWOOD PLYWOOD PRODUCTION: 1967-1976*

Period Covered	Total Produced†		Amount produced by type			
			Interior		Exterior	
	Quantity±	Value (in millions)	Quantity±	Value (in millions)	Quantity±	Value (in millions)
1976	18,033.0	$2,541.9	5,264.6	$639.2	12,768.4	$1,902.7
1975	15,708.1	1,725.6	4,665.0	481.7	11,043.1	1,243.9
1974	15,507.9	1,625.8	4,730.3	463.9	10,777.6	1,161.9
1973	17,897.6	1,927.5	5,979.3	593.1	11,918.3	1,334.4
1972	17,974.6	1,665.8	6,343.0	545.2	11,631.6	1,120.6
1971	16,408.1	1,243.8	6,452.6	454.6	9,955.5	789.2
1970	14,126.7	958.4	5,870.8	371.0	8,255.9	587.4
1969	13,405.5	1,086.0	6,004.1	446.6	7,401.4	639.4
1968	14,516.4	1,069.5	7,141.0	479.8	7,375.4	589.7
1967	12,914.8	776.9	6,919.0	387.3	5,995.8	389.6

†Details do not add to total because of independent rounding.

*Source: U.S. Department of Commerce(4)

±Quantity in million square feet, 3/8 inch basis

TABLE 7. GUM AND WOOD CHEMICALS PRODUCTION, 1975

Item	Production Volume	Weight (tons)
Rosin:		
Gum	69,600 drums	17,991
Steam distilled (wood)	328,480 drums	85,404
Tall oil	612,350 drums	159,211
Total	1,010,430 drums	262,606
Turpentine:		
Gum	20,240 50-gal bbl	3,632
Steam distilled (wood)	38,260 50-gal bbl	6,866
Sulfate	370,970 50-gal bbl	66,572
Total	429,470 50-gal bbl	77,070
Tall oil	--	614,224*
Tall oil fatty acids	--	146,638#

*Production in 1973 was 793,150 tons, and 726,475 tons in 1974.

#Production in 1974 was 181,608 tons.

Sources: Naval stores, U.S. Department of Agriculture Monthly Reports. 1975. Pulp Chemicals Association. New York, New York. January 23, 1976. Pulp Chemicals Association. New York, New York. April 16, 1976.

TABLE 8. MILLWORK AND STRUCTURAL WOOD MEMBERS PRODUCTION

	Production (in thousands of tons)	
Material consumed*	Millwork	Structural wood members
Rough lumber	1,687.0	226.5
Dressed lumber	2,469.4	1,043.4
Softwood plywood	48.8	23.5
Thermosetting resins	--	4.3
Hardwood veneer#	298.8	--
Hardwood plywood#	116.4	--
Particleboard	124.6	
Hardboard	70.2	
Other materials	3,267.9	955.3
Total	8,083.1	2,253.0

*Excludes builders hardware.

#Assumes that reported surface areas are 1/4-in. thick.

Source: U.S. Department of Commerce(5)

TABLE 9. PRESERVED WOOD PRODUCT PRODUCTION, 1969-1973

Material	Amount produced (in thousands of m^3)				
	1969	1970	1971	1972	1973
Cross-ties	2,020	2,248	2,465	2,432	1,915
Switch-ties	180	223	176	169	142
Piling	417	428	388	406	368
Poles	2,107	2,174	2,106	2,111	2,135
Cross-arms	91.9	97.8	87.1	70.4	73.4
Lumber & timbers	1,689	1,577	1,695	1,811	1,950
Fence posts	443	428	472	515	430
Other	231	195	218	205	194
Total*	7,178.9	7,370.8	7,607.1	7,719.4	7,207.4

*Components may not add due to rounding.

Source: Environmental Science and Engineering, Inc.(6)

TABLE 10. POLLUTION ABATEMENT CAPITAL EXPENDITURES AND OPERATING COSTS, 1977 AND 1976 ($1,000,000)

Industry	Year	Pollution abatement capital expenditures (PACE)				Pollution abatement gross annual costs (PAGAC)			Percent change		
		Air	Water	Solid Waste	Total	Air	Water	Solid Waste	PACE	GAC	Total
Lumber and wood products	1977	34	19	7	60	20	19	34	+15	-11	73
	1976	30	9	13	52	27	21	34			81
Paper and allied products	1977	136	261	31	428	134	324	92	-12	+28	550
	1976	181	279	27	487	124	239	67			430

Source: U.S. Department of Commerce(7)

SECTION 4

AIR POLLUTION CONTROL

AIR QUALITY REGULATIONS

Background

The Clean Air Act in its present form has its origin in the Clean Air Act Amendments of 1970. At that time Congress established the basic programs and philosophies under which we operate today. These programs can generally be broken down into three areas: 1) the attainment and maintenance of National Ambient Air Quality Standards (NAAQS); 2) limitations on the emissions of certain pollutants from stationary and mobile sources; and 3) a permit program for new sources. In conjunction with these programs, Congress established some statutory deadlines for such things as attainment of the NAAQS and emission levels for new automobiles.

The primary responsibility for implementing these and most other requirements of the Clean Air Act belongs to the individual states. The strategy and mechanism for accomplishing this is the State Implementation Plan (SIP), containing regulations and procedures developed by each state and approved by EPA for implementing the Act. Most states had approved SIP's in effect by 1972. State ambient air quality standards are shown in Table 52; stationary source emission standards for kraft and sulfite mills are listed in Table 53.

By 1976 it was evident that many deadlines had already been missed and that others were very likely to be missed. Congress recognized that something had to be done, and began an extensive revision of the Act, not only to relieve the deadlines, but also to deal with the many problems and deficiencies which had been identified during the six years since the last major revision.

National Ambient Air Quality Standards

To date, EPA has established NAAQS for six pollutants: sulfur dioxide (SO_2); total suspended particulates (TSP); carbon monoxide (CO); nitrogen oxides (NO_x); photochemical oxidants (O_x); and hydrocarbons (HC). Under the 1970 Act, all areas of the country were required to attain the NAAQS by July 1975. Many areas of the country (primarily urban) have not yet attained the standards. Recognizing this, the 1977 Amendments require that each state identify those areas which have not yet attained the standards and develop

TABLE 52. STATE AIR QUALITY STANDARDS

State	Sulfur dioxide Primary µg/cu m	Sulfur dioxide Secondary µg/cu m	Carbon monoxide Primary mg/cu m	Carbon monoxide Secondary mg/cu m	Nitrogen dioxide Annual arithmetic mean (AAM) µg/cu m	Photochemical oxidants µg/cu m max/1 hr
Alabama	80-AAM 365-24hr	1300-3hr	10-8 hr 40-1 hr		100	160
Alaska	80-Annual arithmetic mean (AAM) 365-24 hr 1300-3 hr		10-8 hr 40-1 hr		100	160
Arizona	80-AAM 365-24 hr 1300-3 hr		10-8 hr 40-1 hr		100	160
Arkansas	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
California	80-AAM 131-24 hr		10-8 hr 46-1 hr 11-12 hr		100	200
Colorado	Category I II III AAM 2 10 15 24 hr max 5 50 100 3 hr max 25 300 700		9 ppm-8 hr 35 ppm-1 hr		0.05 ppm	0.08 ppm
Connecticut	80-AAM 365-24 hr	60-AAM 260-24 hr	10-8 hr 40-1 hr		100	160
Delaware	80-AAM 340-24 hr	60-AAM 260-24 hr 1300-3 hr	13.8-8 hr 40-1 hr		100	160

(continued)

TABLE 52. (Continued)

State	Sulfur dioxide Primary µg/cu m	Sulfur dioxide Secondary µg/cu m	Carbon monoxide Primary mg/cu m	Carbon monoxide Secondary mg/cu m	Nitrogen dioxide Annual arithmetic mean (AAM) µg/cu m	Photochemical oxidants µg/cu m max/1 hr
Florida	60-AAM 1300-3 hr		10-8 hr		100	160
Georgia	43-AAM 229-24 hr 715-1 hr		10-8 hr 40-1 hr		100-AAM 300-24 hr	98
Hawaii	20-AAM 80-24 hr		5-8 hr 10-1 hr		70-AAM 150-24 hr	100
Idaho	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Illinois	0.03 ppm-AAM 0.14 ppm-24 hr	0.50 ppm-3 hr	9 ppm-8 hr 35 ppm-1 hr		0.05 ppm-AAM	0.08 ppm
Indiana	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Iowa	80-AAM 365-24 hr	1300-3 hr	9 ppm-8 hr 35 ppm-1 hr		100	160
Kansas	None. A standing interpretation by the Kansas Attorney General has precluded the adoption of even Federal Standards on the basis they would allow deterioration.					
Kentucky	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Louisiana	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160

(continued)

TABLE 52. (Continued)

State	Sulfur dioxide Primary μg/cu m	Sulfur dioxide Secondary μg/cu m	Carbon monoxide Primary mg/cu m	Carbon monoxide Secondary mg/cu m	Nitrogen dioxide Annual arithmetic mean (AAM) μg/cu m	Photochemical oxidants μg/cu m max/1 hr
Maine	57-AAM 230-24 hr 1150-3 hr		10-8 hr 40-1 hr		100	160
Maryland	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Massachusetts	0.03 ppm	0.03 ppm	9 ppm		0.05 ppm	0.08 ppm
Michigan	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Minnesota	0.02 ppm-AAM 0.10 ppm-24 hr 0.25 ppm-3 hr		9 ppm-8 hr 30 ppm-1 hr		0.05 ppm	0.07 ppm
Mississippi	80-AAM 365-24 hr	60-AAM 260-24 hr 1300-3 hr	9 ppm-8 hr 35 ppm-1 hr		100	160
Missouri	53-AAM 365-24 hr 1300-3 hr		9 ppm-8 hr 35 ppm-1 hr		100	160
Montana	0.02 ppm-AAM 0.10 ppm-24 hr 0.25 ppm-1 hr					
Nebraska	80-AAM 365-24 hr	1300-3 hr	9 ppm-8 hr 35 ppm-1 hr		100	160

(continued)

TABLE 52. (Continued)

State	Sulfur dioxide Primary μg/cu m	Sulfur dioxide Secondary μg/cu m	Carbon monoxide Primary mg/cu m	Carbon monoxide Secondary mg/cu m	Nitrogen dioxide Annual arithmetic mean (AAM) μg/cu m	Photochemical oxidants μg/cu m max/1 hr
Nevada	60-AAM 260-24 hr 1300-3 hr		10,000 μg/m3-8 hr <5000 ft m.s.l. 6670 μg/m3-3 hr >5000 ft m.s.l. 40000 μg/m3-1 hr all elevations		100	160
New Hampshire	60-AAM		9 ppm-8 hr 35 ppm-1 hr		100	0.08 ppm
New Jersey	80-AAM 365-24 hr	60-AAM 260-24 hr 1300-3 hr	10-8 hr 40-1 hr		100	160
New Mexico	0.02 ppm-AAM 0.10 ppm-24 hr		8.7 ppm-8 hr 13.1 ppm-1 hr		0.05 ppm-AAM 0.10 ppm-24 hr	0.06 ppm
New York	0.03 ppm-AAM 0.14 ppm-24 hr 0.05 ppm-3 hr		9 ppm-8 hr 35 ppm-1 hr		0.05 ppm	0.08 ppm
North Carolina	80-AAM		10-8 hr 40-1 hr		100	160
North Dakota	60-AAM 260-24 hr 715-1 hr		10-8 hr 40-1 hr		100-AAM 200-1 hr, 1% of 3 months	160
Ohio	60-AAM 260-24 hr		10-8 hr		100	119-1 hr 79-4 hr 40-24 hr

(Continued)

TABLE 52. (Continued)

State	Sulfur dioxide		Carbon monoxide		Nitrogen dioxide	Photochemical oxidants
	Primary µg/cu m	Secondary µg/cu m	Primary mg/cu m	Secondary mg/cu m	Annual arithmetic mean (AAM) µg/cu m	µg/cu m max/1 hr
Oklahoma	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Oregon	60-AAM 260-24 hr 1300-3 hr		10-8 hr 40-1 hr		100	160
Pennsylvania	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Rhode Island	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
South Carolina	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
South Dakota	80-AAM 365-24 hr		10-8 hr 40-1 hr		100-AAM 250-24 hr	160
Tennesee	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Texas	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Utah	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160

(Continued)

TABLE 52. (Continued)

Particulates		
Primary mg/cu m	Secondary mg/cu m	µg/c
l geometric n (AGM) 0-24 hr	60-AGM 150-24 hr	
60-AGM 150-24 hr		Reduced sul 50µg/cu m-3
75-AGM 150-24 hr		
5-AGM 60-24 hr	60-AGM 150-24 hr	
0-AGM 00-24 hr	60-AGM 150-24 hr	Hydrogen su 42µg/cu m-1
Nondesignated areas 150-24 hr Designated areas 180-24 hr		
5-AGM 60-24 hr	60-AGM 150-24 hr	
0-AGM 00-24 hr 00-1 hr	60-AGM 150-24 hr	Hydrogen sul 0.06 ppm-3 0.03 ppm-1 h

TABLE 52. (Continued)

State	Sulfur dioxide Primary µg/cu m	Sulfur dioxide Secondary µg/cu m	Carbon monoxide Primary mg/cu m	Carbon monoxide Secondary mg/cu m	Nitrogen dioxide Annual arithmetic mean (AAM) µg/cu m	Photochemical oxidants µg/cu m max/1 hr
Oklahoma	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Oregon	60-AAM 260-24 hr 1300-3 hr		10-8 hr 40-1 hr		100	160
Pennsylvania	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Rhode Island	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
South Carolina	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
South Dakota	80-AAM 365-24 hr		10-8 hr 40-1 hr		100-AAM 250-24 hr	160
Tennesee	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Texas	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160
Utah	80-AAM 365-24 hr	1300-3 hr	10-8 hr 40-1 hr		100	160

(Continued)

TABLE 52. (Continued)

State	Nonmethane hydrocarbons µg/cu m max/3hr (6-9 a.m.)	Particulates		Others	
		Primary µg/cu m	Secondary µg/m3		
Florida	160	60-AGM 150-24 hr			
Georgia	98	60-AGM 150-24 hr			
Hawaii	100	55-AGM 100-24 hr			
Idaho	160	75-AGM 260-24 hr	60-AGM 150-24 hr 1300-3 hr	Sulfuric acid mist 12µg/cu m-24 hr 30µg/cu m-1 hr	Beryllium 0.01µg/cu m-24 hr
Illinois	0.24 ppm	75-AGM 260-24 hr	60-AGM 150-24 hr		
Indiana	160	75-AGM 260-24 hr	150-24 hr		
Iowa	160	75-AGM 260-24 hr	60-AGM 150-24 hr		
Kansas					
Kentucky	160	75-AGM 260-24 hr	60-AGM 150-24 hr		
Louisiana	160	75-AGM 260-24 hr	60-AGM 150-24 hr		

(Continued)

TABLE 52. (Continued)

State	Nonmethane hydrocarbons μg/cu m max/3hr (6-9 a.m.)	Particulates Primary μg/cu m	Particulates Secondary μg/m3	Others
Maine	160	50-AGM 100-24 hr		
Maryland	160	75-AGM 260-24 hr	150-24 hr	
Massachusetts		75-AGM	60-AGM	
Michigan	160	75-AGM 260-24 hr	60-AGM 150-24 hr	
Minnesota	0.24 ppm	75-AGM 260-24 hr	60-AGM 150-24 hr	Hydrogen sulfide 0.05 ppm-1/2 hr,twice per year 0.03 ppm-1/2 hr,twice every 5 days
Mississippi	160	75-AGM 260-24 hr	60-AGM 150-24 hr	
Missouri		60-AGM 150-24 hr		Sulfuric acid: 10μg/cu m-24 hr 30μg/cu m-1 hr Hydrogen sulfide: 70μg/cu m-1/2 hr,twice per year 42μg/cu m-1/2 hr,twice every 5 days
Montana		75-AGM 200-1% of days per year		Sulfuric acid: 4μg/cu m-annual average 12μg/cu m-1% of days 30μg/cu m-1 hr, 1% of days Hydrogen sulfide: 0.03 ppm-1/2 hr twice every 5 days 0.05 ppm-1/2 hr twice per year
Nebraska	160	75-AGM 260-24 hr	60-AGM 150-24 hr	

(continued)

TABLE 52. (Continued)

State	Nonmethane hydrocarbons µg/cu m max/3hr (6-9 a.m.)	Particulates Primary µg/cu m	 Secondary µg/m3	Others
Nevada	160	60-AGM 150-24 hr		
New Hampshire	160	60-AGM		
New Jersey	160	75-AGM 260-24 hr	60-AGM 150-24 hr	
New Mexico	0.19 ppm	60-AGM 150-24 hr		Hydrogen sulfide 0.003 ppm
New York	0.24 ppm	75-AGM 250-24 hr		
North Carolina	160	60-AGM 150-24 hr		
North Dakota	160	60-AGM 150-24 hr		Hydrogen sulfide 45µg/cu m-1/2 hr, twice every 5 days 75µg/cu m-1/2 hr,twice per year Sulfuric acid mist 4µg/cu m-AAM 12µg/cu m-24 hr,1% of time 30µg/cu m-1 hr,1% of time
Ohio	126	60-AGM 150-24 hr		

(continued)

TABLE 52. (Continued)

State	Nonmethane hydrocarbons μg/cu m max/3hr (6-9 a.m.)	Particulates Primary μg/cu m	Particulates Secondary μg/m3	Others	
Oklahoma	160	75-AGM 260-24 hr	60-AGM 150-24 hr 1300-3 hr		
Oregon	160	60-AGM 150-24 hr	15% of samples >100μg/m3 in 1 month	Lead 3.0μg/cu m- 1 month	Calcium oxide 20μg/cu m as TSP 0.35 gm/month as fallout
Pennsylvania	160	75-AGM 260-24 hr	60-AGM 150-24 hr 1300-3 hr		
Rhode Island	160	75-AGM 260-24 hr	60-AGM 150-24 hr 1300-3 hr		
South Carolina	160	75-AGM 250-24 hr	150-24 hr	Gaseous fluorides (HF) μg/sq cm 12 hr avg-3.7 1 month avg-0.8 24 hr avg-2.9 1 wk avg-1.6	
South Dakota	160	60-AGM 150-24 hr			
Tennesee	160	75-AGM 260-24 hr	60-AGM 150-24 hr		
Texas	160	75-AGM 260-24 hr	60-AGM 150-24 hr 1300-3 hr		

(continued)

TABLE 53. STATE STATIONARY SOURCE EMISSION STANDARDS

State	Sources and pollutants (All measurements in kg/kkg of pulp, unless otherwise specified)							
	Kraft pulp mills					Sulfite pulp mills		
	Particulates					Particulates		
	Recovery furnace	Smelt dissolving tank	Lime kiln	Total reduced sulfur (TRS)	sulfur oxides	100 kg/hr process weight	1,000,000 kg/hr process weight	sulfur compounds
Alabama	2.0	0.25	0.5	0.6	--	--	--	--
Arizona	--	--	--	--	--	--	--	4.5
Connecticut	--	--	--	--	--	--	--	4.5
Florida	3.0kg/3,000 kg black liquor feed	--	--	0.5 kg/3,000 kg black liquor feed	--	--	--	--
Idaho	2.0	0.25	0.5	1.0	--	--	--	--
Kentucky	--	--	--	0.25 (17.5 mg/l)	--	--	--	4.5
Louisiana	2.0	0.25	0.5	--	--	--	--	--
Maine	2.0	0.25	0.5	--	--	--	--	20
Mississippi	2.05	0.25	0.5	1.0	--	--	--	--
Montana	--	--	--	0.087 kg 1,000 kg black liquor (17.5 mg/l)	--	--	--	--
New Hampshire	2.0	0.25	0.5	--	--	0.25 kg/hr	31 kg/hr	--
New Mexico	2.0	--	--	0.05	--	--	--	--
North Carolina	1.5	0.3	0.25	--	--	--	--	--
North Dakota	--	--	--	--	--	--	--	4.5
Oklahoma	--	--	--	--	--	--	--	9.0

(continued)

TABLE 53 (Continued)

Sources and Pollutants
(All measurements in kg/kkg of pulp, unless otherwise specified)

	Kraft pulp mills					Sulfite pulp mills		
	Particulates					Particulates		
State	Recovery furnace	Smelt dissolving tank	Lime kiln	Total reduced sulfur (TRS)	sulfur oxides	100 kg/hr process weight	1,000,000 kg/hr process weight	Sulfur compounds
Oregon	2.0	0.25	0.5	0.15 (10 mg/l)	200 mg/l	--	--	10
South Carolina	1.4	0.5	0.5	--	--	--	--	--
Tennesee	1.5	0.37	0.5	0.6	--	--	--	--
West Virginia	--	--	--	--	--	--	--	4.5
Wisconsin	--	--	0.25	--	--	--	--	--

Source: Battelle Columbus Laboratories. Multi-Media Pollution Assessment In Pulp, Paper and Other Wood Products Industry, 1976.

strategies that will ensure the attainment and maintenance of the primary standards by December 31, 1982, and the secondary standards as soon as possible. Congress has established strong sanctions for those areas for which SIP revisions are not approved by July 1979. Examples of these sanctions include not permitting new sources emitting pollutants which are especially hazardous to human health. Currently there are standards for sources of asbestos, mercury, beryllium, and vinyl chloride. Standards for benzene are impending. These standards apply to both existing and new sources, and new sources must obtain a permit prior to construction.

The fourth and final portion of the New Source Review program is the Prevention of Significant Deterioration, (PSD) which is likely to be the most restrictive requirement for new sources. The PSD section has two requirements: 1) that any new source install and operate the best available control technology (BACT) for reducing emissions; and 2) that all sources locating in any given area, together, not degrade air quality more than a specified increment. The increments, shown in Table 54, vary from very little degradation in Class I areas (currently National Parks and Wildernesses, National Memorial Parks and International Parks) to the greatest allowable degradation in Class III areas (there are currently no Class III areas). In no case will the air be allowed to degrade beyond the NAAQS. All major stationary sources which have the potential to emit over 250 tons per year of any pollutant will need a PSD permit before constructing. It should be noted that a source locating in or near a nonattainment area may have to satisfy both the offset and PSD provisions.

There is an increased emphasis on New Source Review, especially the PSD and offsets programs. It is evident that the air quality considerations in obtaining a permit to construct a new source or modify or expand an existing source have become more stringent. Industrial growth in or near nonattainment areas and near Class I areas will require the best control technologies. There will likely be some impact on the forest products industry because the resource (the forests), and hence the industrial development, is almost always in the vicinity of Class I areas. Air quality considerations will be an important, and perhaps a deciding, factor in future land management decisions.

One portion of the PSD program, the new national visibility goal, has the potential to impact the forest products industry, particularly with respect to prescribed burning. Congress has created a national goal to remedy existing and prevent future impairment of visibility in the mandatory Class I areas. The implementation of a strategy to accomplish this goal will be twofold: 1) a requirement that any major stationary source which may reasonably be anticipated to contribute to impairment of visibility, install the Best Available Retrofit Technology (BART) if it was built between 1962 and 1977; and 2) that the states develop a long-term strategy to accomplish the national goal. This portion of the Act may have an impact on such sources as pulp mills and hogged fuel boilers, as well as prescribed burning practices.

TABLE 54. PREVENTION OF SIGNIFICANT DETERIORATION AREA CLASSIFICATIONS AND ALLOWABLE INCREASES

Pollutant	g/cu m	National ambient air quality standards	
		primary	secondary
Class I#			
Particulate matter:			
Annual geometric mean	5	75	60
Twenty-four hour maximum	10	260	150
Sulfur dioxide:			
Annual arithmetic mean	2	80	-
Twenty-four hour maximum	5	365	-
Three-hour maximum	25	-	1300
Class II			
Particulate matter:			
Annual geometric mean	19	75	60
Twenty-four hour maximum	37	260	150
Sulfur dioxide:			
Annual arithmetic mean	20	80	-
Twenty-four hour maximum	91	365	-
Three-hour maximum	521	-	1300
Class III†			
Particulate matter:			
Annual geometric mean	37	75	60
Twenty-four hour maximum	75	260	150
Sulfur dioxide:			
Annual arithmetic mean	40	80	-
Twenty-four hour maximum	182	365	-
Three-hour maximum	700	-	1300

*Maximum allowable increase in micrograms per cu m (but not to exceed NAAQS).

#Initially included most national parks, national wilderness areas, national memorial parks, and international parks.

†Currently, there are no Class III areas.

NOTE: Presently, there are numerical increments only for total suspended particulates and sulfur dioxide. EPA is, however, required to study and promulgate numerical increments for other criteria pollutants by August 1979.

Source: (164)

Standards of Performance for Kraft Pulp Mills

On February 23, 1978, after receiving and reviewing comments for standards proposed on September 24, 1976, revised emission standards were established for the major emitting process units in new, modified, and reconstructed kraft pulp mills. New standards were published in the Federal Register Vol. 43, No. 37 FR on pages 7568-7598(186). These final rules require "best available control technology for new mills and establish limits for both particulate and total reduced sulfur (TRS) emissions. Process equipment with designated particulate limits include the recovery furnace, smelt tank, and lime kiln. Items with TRS limits are digester, evaporators, brownstock washers, black liquor oxidation system, condensate stripping systems, lime kiln, and smelt tanks.

Control strategies (BACT) include caustic scrubbing towers, adequate lime mud washing, "overdesign" of components such as brownstock washers, recovery furnaces, and evaporators. These new mill standards in many cases impose tighter restrictions than the maintenance of ambient air standards or present state (SIP) plans would require. The standards contained in the February 23, 1978 final rules are shown below:

Source	
	Particulates
recovery furnace	0.1 gram/cu meter (9/dscm) at 8 percent oxygen
dry black liquor solids - smelt tank	0.1 g/kg
lime kilns - gas-fired	0.15 g/dscm at 10 percent oxygen
oil-fired	0.30 g/dscm at 10 percent oxygen
	Total Reduced Sulfur
digester	5 ppm by vol. at 10% oxygen
multi effect evaporator	5 ppm by vol. at 10% oxygen
brownstock washer vents	5 ppm by vol. at 10% oxygen
condensate strippers	5 ppm by vol. at 10% oxygen
black liquor oxidation system	5 ppm by vol. at 10% oxygen
lime kiln	8 ppm by vol. at 10% oxygen
kraft recovery furnace	5 ppm by vol. at 8% oxygen
kraft-NSSC recovery furnace	25 ppm by vol. at 8% oxygen
black liquor solids - smelt tank vent	0.0084 g/kg

emission; local terrain, and prevalent atmospheric conditions. For example, mills located in valleys with poor dispersion characteristics may create a greater impact with a given emission mass loading.

The following paragraphs address the character and potential environmental impacts associated with each pollutant.

Particulates

Particulates emitted from kraft pulping processes range from up to 30 micrometers (um) in diameter (e.g. wood char from hogged fuel boilers) to less than 1 um (e.g. sodium sulfate, sodium carbonate, sodium chloride).

The health concern associated with particulates is their ability to penetrate and cause direct tissue damage to the alveoli of the human lungs. Another concern is the ability to be taken up by the phagocytes and transported by the blood to the lymph stream.(153) The ultimate effects of these phenomena on human health are not well documented.

There is also a health concern over sodium sulfate and sodium carbonate aerosols emitted by recovery boilers. This mixture is slightly alkaline and its exact effect on health is not well understood.

Fine particles emitted from the lime kiln include alkaline calcium oxide, and inert calcium carbonate. The tolerance level for continuous exposure to calcium oxide is given by the American Council of Government Industrial Hygienists (ACGIH), as 5,000 ug/cu m. Studies have shown ambient concentrations in the vicinity of pulp mills to be well below this level.

Particulates can have an impact when they settle out of the atmosphere by gravity. Most fallout occurs within two miles of a mill.(154) Larger particles can cause soiling, while chemical salts can cause corrosion in the affected area.

Fine particle emissions also tend to create an atmospheric haze in the vicinity of the discharge. This, coupled with water vapor emissions, can create a fog-like plume through condensation of the water vapor on the particulates. This plume can persist for several miles, especially in coastal regions where it is enhanced by sodium chloride.

Wood preserving with creosote solutions and oilborne preservatives can result in atmospheric emissions exceeding opacities and concentrations permitted under current air pollution regulations.

Sulfur Dioxide

Sulfur dioxide (SO_2) is emitted primarily from kraft pulp mills. Vegetation can be damaged by continuous exposure of SO_2 in concentrations on the order of 300 ug/l or higher.(155) Typically the SO_2 concentration in kraft mill stacks is 50-200 mg/l. There is some evidence to indicate that at low levels SO_2 can be beneficial to plants. Thus the impact, if any, would depend largely on local conditions including dispersion.

SO_2 can also be a strong irritant perceptable by odor and taste. The maximum concentration allowed by OSHA is 4 mg/l, with 13 ug/l for a maximum time weighted average.

Total Reduced Sulfur Compounds (TRS)

The major environmental impact of reduced sulfur compounds is their noxious odor and extremely low detectability. The compounds of concern and their detectability by the human nose are shown below.(155)

Reduced sulfur compound	Lower detectable limit (ppb)
Hydrogen sulfide	8-20
Methyl mercaptan	2.4
Dimethyl sulfide	1.2
Dimethyl disulfide	15.5

Chlorine Compounds

The chlorine compounds used in pulp bleaching and wood preserving are extremely corrosive to metals and/or hazardous to human health.

AIR EMISSION SOURCES IN THE PULP, PAPER, AND PAPERBOARD INDUSTRY

The pulp and paper segment of the wood products industry is the most significant source of air emissions. The emissions of this segment are best discussed by breaking down the division into four subcategories, three of which make up the bulk of the discharge.

Kraft Pulping

The kraft (sulfate) subcategory is the major offender, with emissions of various sulfur compounds and particulates. Within this process the digester - blow tank portion, where the wood is cooked, is a main source of gaseous emissions. The reduced sulfur compounds of dimethyl sulfide and dimethyl disulfide are the most important of those. Very little gaseous emission occurs when the cooked wood (pulp) is washed in the stock washing process.

Black liquor oxidation, a process more widely applied in the kraft process, has as a main purpose of chemical recovery. It also facilitates the removal of odorous sulfur compounds by oxidation. However, improper operation can increase the discharge of dimethyl disulfide and produce an extremely noxious odor by the release of methyl mercaptan.

Two main evaporation systems are wood in the kraft process to bring the black liquor to a concentration at which it can efficiently be burned: multiple-effect evaporators and direct contact evaporators. When used in conjunction with black liquor oxidation, emissions from the evaporators can be further reduced. Compounds typically emitted from multiple-effect evaporators are hydrogen sulfide and mercaptan. Direct contact evaporators are bigger offenders. In addition to greater discharges of hydrogen sulfide and mercaptan, particulates are released in significant quantities by direct contact evaporators.

The kraft process uses a recovery boiler in order to recover cooking chemicals from the spent cooking liquor, and as a means of steam generation. The extent of emissions from the recovery boiler hinges upon its manner of operation. Hydrogen sulfide, sulfur dioxide and particulates are the major pollutants discharged. Furnace flue gases can be discharged to the evaporators for further heat recovery, or can be incinerated (e.g. in the lime kiln) to further reduce emissions.

The smelt dissolving tank produces a low level of emissions, but the vigorous reaction that occurs there can entrain particulates in the gases (which include reduced sulfur compounds) that are discharged. A vigorous reaction can also occur in the slaker-causticizer, where particulates are also carried out in the steam that is generated in lime slaking.

Particulates are the primary emission of concern from the lime kiln, where calcium oxide is recovered after slaking. Reduced sulfur compounds are also emitted.

Table 55 lists air emissions which are typical of kraft pulping with and without black liquor oxidation.

Sulfite Pulping

Within the sulfite subcategory, there are four main chemicals, upon which the cooking process is based: calcium, magnesium, sodium, and ammonia. Recovery of the spent cooking liquors ranges from good with magnesium to poor with calcium. The following discussion of the sulfite process is directed toward the magnesium based sulfite process.

Absorption towers are used to produce sulfite solutions by absorbing sulfur dioxide gas in alkaline carbonate solutions. The primary emission from these towers is sulfur dioxide gas which is not absorbed.

The digester - blow tank segment of the process can be a significant source of sulfur dioxide discharges. Depending on the greater discharge method, the sulfur dioxide released varies significantly.

Neutral Sulfite Semichemical (NSSC)

Wood chips are cooked in a mild chemical solution in the NSSC process; the resulting pulp is then handled as in other processes. There are fewer air emissions from the NSSC process. Methyl mercaptan and disulfite do not form during digestion and hydrogen sulfide is reduced because the sulfide is absent.

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Smelt tank

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TABLE 55. (Continued)

Pollutant operation	SH$_2$S (kg/kkg)	Reduced sulfur compounds (RS) Methyl mercaptan (kg/kkg)	Dimethyl sulfide (kg/kkg)	Dimethyl disulfide (kg/kkg)	Total RS (TRS) (kg/kkg)	SO$_2$ (kg/kkg)	Particulates (kg/kkg)
With black liquor oxidation*							
Black liquor oxidizer	TR-0.01	0.03-0.05	0.01-0.04	0.03-0.08	0.002-0.5 (0.17 avg)	TR-0.01	-
Multiple effect evaporator	0-3.0	0.001-0.15	0.0001-0.08	0.0002-0.08	0.0002-0.75	0.01	-
Direct contact evaporator with recovery furnace	0.5-1.0	0.30-0.13	0.01-0.05	0.01-0.10	0.6-1.4	1.0-4.0	1.1-37.6
Total: range	0.52-4.7	0.17-1.3	0.25-2.2	0.17-1.9	0.92-14.1	1.1-5.8	3.9-39.6
average	2.6	0.7	1.2	1.0	6.3	3.5	20.8

*Operations not listed in the "with black liquor oxidation" section have the same discharges as indicated in the "without black liquor oxidation" section.

#Total not reported.

Source: Battelle Columbus Laboratories. Multi-Media Pollution Assessment In Pulp, Paper and Other Wood Products Industry, 1976

Power Boilers

Power boilers are essential to the manufacture of pulp, paper, and paperboard due to the large quantities of steam required by the process. Fuel burned by the boilers are coal, gas, oil, or bark, in any combination or separately (except for bark). Significant sulfur dioxide is emitted from coal or oil fired boilers, with particulates emitted by all boilers.

Wood Waste Combustion

Wood waste, once just a nuisance in most forest products industry operations, is now considered a valuable energy resource. As a natural byproduct of the industry's resource utilization, wood waste is an attractive alternative to more expensive fossil fuels. The industry has for many years used wood-fired boilers to produce process steam and electricity, while at the same time solving a large-scale wood waste disposal problem. In the Pacific Northwest, for example, there are approximately 1,000 industrial wood-fired boilers in operation. Junge reports that annual use of wood fuels in Oregon alone is equivalent to more than 19 million barrels of oil.(156)

The combination of wood residues in hogged fuel boilers creates a particulate emission composed of fly ash, or the unburned remains of wood or bark fuel, including sand or dirt picked up during the logging operation. If not controlled, this fly ash can result in visible stack emissions. Most states regulate both the particulate emission rate and the visible emissions, or opacity, of stack effluents. Although the regulations vary from state to state, most requirements can be met with air pollution control devices presently available. The particles emitted from hogged fuel boilers are relatively large, and thus relatively easy to collect.

Wastewater Sludge Combustion

Due to rising landfill costs and scarcity of suitable disposal sites it is becoming more common for mills to burn wastewater treatment plant sludge to recover the heat value and reduce the volume of solids to landfill. Typically a low ash sludge dewatered to a solids content of ±30 percent will burn without need for auxiliary fuel except during startup.(157) This would apply to primary and biological sludges, however, the higher inorganic content of sludge from chemical clarification make the latter less suitable for incineration. In any case a higher solids content would improve the heat value.

In order to attain the required solids concentration conventional dewatering methods such as the vacuum filter and horizontal belt filter must be followed by the more expensive and sophisticated filter press. Additional research is needed on an industry wide basis to determine the feasibility and implications of this approach with respect to: 1) effect on combustion/boiler system 2) existing burning capacity; 3) air emissions; and 4) economics.

EMISSIONS FROM OTHER WOOD PRODUCTS INDUSTRIES

Six major categories make up the remainder of the wood products industry: converted paper products; veneer/plywood; particleboard; millwork, structural members, fabricated wood products; and gum and wood chemicals and wood preserving.

Within the gum and wood chemicals subcategory, the wood rosin, turpentine, and pine oil category obtains terpene as a distillation byproduct. Terpene is burned in a boiler, which may emit combustion byproducts. Residue from the distillation of wood chips to recover essential oils is burned to recover the heat value. Some pollutants may be discharged from this process.

The only significant air emissions occur within the veneer/plywood, particleboard, and wood preserving segments of other wood products industry. Major emissions from the veneer/plywood, particleboard, and gum and wood chemicals subcategories are summarized in Table 57. One of the areas of greatest concern is veneer dryer emissions, as discussed below. A discussion of air emissions from the wood preserving industry follows that for veneer dryers.

No significant air emissions are discharged from the converted paper products category. There are also no significant air emissions from the millwork, structural members, and fabricated wood products subcategory.

Veneer Dryer Emissions

At the point of discharge from the exhaust stack, veneer dryer emissions consist of hot air, a small amount of wood fiber, water vapor and gaseous organic compounds that have been distilled from the wood veneer. The character and quantity of these steam-distilled organics are related to the wood species, the drying temperature, the humidity in the dryer, and the type of dryer.

In the early 1970's, state and regional air pollution control agencies formed a committee to establish a source test procedure for the determination of particulate emissions from veneer dryers. This test procedure addressed only the distilled organic gases that condensed at standard temperature (70°F); these were classified as particulates. Subsequent tests on local veneer dryers demonstrated that, for the most part, veneer dryers met current emission standards for existing sources. Control of dryer emissions was subsequently directed toward reducing the visible blue-haze emissions to 10 to 20-percent opacity. The noncondensible fraction of these organic emissions was not addressed until recent studies showed that photochemical oxidants were exceeding air quality alert levels in many parts of the country.

Photochemical oxidants are formed by chemical reactions in the atmosphere between reactive hydrocarbons and oxides of nitrogen in the presence

TABLE 57. MAJOR EMISSIONS FROM OTHER WOOD PRODUCTS SUBCATEGORIES

Subcategory/pollutant operation	Hydrocarbons	Particulates	Miscellaneous
Veneer/plywood			
Veneer dryer	50 to 100 lb/1,000 cu ft product		Blue plume saturated w/water vapor emitted
Incineration		10 lb/ton wood waste burned	130 lb CO/ton wood waste burned
Panel press operation	Phenolic resins discharged		
Sander		33 to 99 tons/10^6 sq ft plywood	
Particleboard			
Drying, sanding, pressing	Some discharged	8 to 25 lb/1,000 sq ft	
Incinerator		2 to 8 lb/1,000 sq ft particleboard	
Material handling operation			Highly variable emissions
Gum and wood chemicals			
Char production			Products of volatile oxidation

Source: Batelle Columbus Laboratories. Multi-media Pollution Assessment In Pulp, Paper, and Other Wood Products Industry, 1976.

of sunlight. EPA's strategy for achieving air quality standards for photochemical oxidants is to reduce emissions of hydrocarbon precursors. According to the EPA strategy, reducing hydrocarbon emissions from industry sources and motor vehicles would limit the amount of hydrocarbons available for sunlight-induced reaction and thus reduce photochemical oxidants. However, a recent report by Radian Corporation (158) studied the relationship between anthropogenic hydrocarbon emissions and ambient ozone levels using data from five American cities. The results showed that in three cities (Cincinnati, Philadelphia, and San Francisco) reductions in hydrocarbon emissions were accompanied by increases in ozone levels. In the fourth city (Houston), reductions in hydrocarbon emissions were accompanied by no clear change in ozone levels. In the fifth city (San Diego), emissions of hydrocarbons and ambient ozone levels remained virtually unchanged.

Condensible hydrocarbon emissions in the wood products industry are produced almost exclusively by veneer dryers. The condensible organics average about 70 percent of the total organic emissions from veneer dryers. The lifetime of these primary particles is short; in the absence of chemical reactions, a major portion of the condensed organics quickly revaporizes. The fate of those veneer dryer emissions which remain permanently in particle form can be predicted, provided one knows the particle size distributions and the chemical reactivity of the particles. If the chemical reactivity is low, these particles can be treated as any other stable group of particles with a similar size distribution. Thus, their lifetime in the local atmosphere can be estimated and models can be used to determine their impact on total suspended particulate (TSP).

The volatile component and the revaporized primary particles have two possible fates. Some of them may follow the hydrocarbon-to-oxidant pathway, possibly increasing the oxidant concentration in the area; the rest may follow the hydrocarbon-to-particle pathway, producing secondary particles. These secondary particles are quite distinct from the primary particles evident in the veneer dryer plumes. They are produced slowly, over a period of hours to days, and over an entire airshed. They become visible and are associated with the characteristic aerosol haze in rural areas like the Smokey Mountains in North Carolina or the Blue Ridge Mountains of Virginia. They can also contribute to urban smog.

Of the possible fates, Cronn and Campbell (159) believe that the majority of veneer dryer emissions take the route to secondary particle formation. Campbell, working with related hydrocarbons, observed that more than 80 percent of the hydrocarbons were rapidly converted to secondary particles, leaving less than 20 percent available for oxidant production. Similar conclusions have been reached by Gay and Arnts.(160)

On the other hand, in a statement published in the Federal Register on July 8, 1977, titled, "Recommended Policy on Control of Volatile Organic Compounds," the EPA stated that in the analysis of available data, very few volatile organic compounds are of such low photochemical reactivity that they can be ignored in oxidant control programs. Reactivity scales are measures of the rate at which hydrocarbon compounds react in the ambient air. EPA has classified terpenoids as highly reactive. The classification specifically assumes that all of the hydrocarbon is consumed in producing ozone. There is evidence that this is not true for wood-related hydrocarbons, which actually consume oxidant by reacting directly with ozone in the atmosphere. In fact, Gay and Arnts were able to account for only a few percent of the heavy, wood-related hydrocarbons which they reacted with nitrogen oxides; the bulk of the hydrocarbons was apparently being converted into particles.

At the request of the American Plywood Association, the team at Washington State University submitted a research proposal (159) with the following goals and objectives:

Project A:	Physically and chemically characterize the gaseous and particulate emissions from four to five veneer dryers of varying types and/or feedstocks.
Project B:	Determine the lifetime of the primary particle plume above veneer dryers, and the fraction of it which is persistent.
Project C:	Determine the yields of particles and oxidant from a typical veneer dryer, during a 2-day period of residence of the emissions in the atmosphere.

In their summary, they felt the following data was needed to determine the significance of wood product hydrocarbon emissions in local air pollution.

1. Information is needed on the actual partition of wood hydrocarbons between particle and gas phases at the stack, using veneer dryers as a source. Older studies of this subject, with categorizations into condensible and non-condensible fractions, are probably misleading. The size distribution and chemical stability of the persistent primary particles need to be determined.

2. The ratio of gaseous hydrocarbons going respectively to oxidant formation and secondary particle formation is urgently needed. It is expected that almost all wood product hydrocarbon gases will end up as secondary particles. If this proves to be true, there may be differences of factors of several-fold in the air pollution significance of a given rate of veneer dryer emissions.

Wood Preserving Emissions

When creosote and oilborne (pentachlorophenol) preservative solutions are heated, lower boiling point organics vaporize to produce dense white emissions. When tram cars are pulled from the retort, the white plume from the freshly treated wood may exceed 60 percent opacity beyond the opaque water vapor breakoff point and continues to exceed 40 percent up to 20 minutes. Additional emissions are released from the open end of the retort during a few minutes required to remove a tram of treated wood and recharge the retort with a tram of virgin material. During that brief period, emissions occur which exceed 60 percent opacity beyond the opaque steam plume.(161)

High atmospheric particulate concentrations occur in the vacuum exhaust as well as in the exhaust during steam cleaning. Source tests at one mill revealed 2.2 g/cu m (0.95 grain/scf), or 1.6 kg/hr (3.6 lb/hr) in 12.5cu m/min (440 scfm) of gas from a vacuum pump venting one retort at the start of the vacuum cycle. Steam cleaning released 44 g/m^3 (19 grains/scf) or 34 kg/hr (75 lb/hr) in 13cu m/min (460 scfm).(162) Some mills may exceed these grain loadings.

Ammonical copper arsenite (ACA) wood preserving plants, in contrast to creosote plants, present a nuisance odor abatement problem and not an opacity problem. Ammonia vapors are released during vacuum cycles, gas purging of the retort, and from treated wood just after its removal from the retort. Other potential ammonia sources are the barometric hot well, and preservative mixing and storage tanks.

Wood treatment with fire retardants and other water soluble preservatives presents no known air pollution regulatory problems.

Pentachlorophenol and many components of water soluble preservatives are acutely toxic. They are chosen for their biocidal properties. Entirely aside from air pollution-oriented regulations, atmospheric releases of these chemicals must be avoided to prevent inhalation by employees. Non-automated mixing is a particularly likely source of toxic particulates release. Bourgeois has reported visible deposition of toxic inorganics on floors and soil at one mill.(163)

EMISSION CONTROL TECHNOLOGIES

A number of technologies are currently used to reduce air pollutant emissions. A brief description of the more common technologies and their applications is presented in the following paragraphs.

Scrubbers

Scrubbers are air pollution control units in which liquids are used to remove aerosols from gas streams. Particles can be wetted by contact with a liquid droplet; wet or dry particles may contact a collecting surface from which they are subsequently rinsed. The liquid can be fresh water, a specifically prepared solution, or a process stream. Scrubbers can be effective in removing particulates, reduced sulfur compounds, and organic non-sulfur compounds. Four main scrubber types, with variations, are in use in the pulp and paper industry. These four types, venturi, cyclone, impingement and packed tower are discussed in the following paragraphs.

Venturi scrubbers consist of a convergent section (throat) and divergent section. As gas enters the throat it increases in velocity. Liquid contacts the gas just before the divergent section, and the liquid becomes fine droplets. The droplets contact gas particulates which are entrapped, and the gas then exits the unit while the particles are contained, separated by centrifugal force (often by means of a cyclone separator).

Gas enters a cyclone scrubber at its base and spirals upward while liquid is sprayed on the gas as it passes through the unit. Gas particulates are trapped in the droplets which strike against the unit walls and fall to the bottom, where they are removed. Meanwhile the gas exits the top.

Impingement scrubbers consist of two main operations. Gas enters the bottom of the unit and is sprayed with liquid to remove large particles. Gas then passes through a series of perforated baffles where the scrubbing liquid is atomized and particulates are entrapped in the droplets. The droplets then fall to the bottom of the unit while the gas exits the top.

Packed tower scrubbers are cylindrical units packed with inert material of various shapes. Liquid scrubbing media enter from the top of the tower, while the gas to be scrubbed enters from the bottom. The inert packing material creates a large volume of surface contact area for the gas and scrubbing medium. Depending on the situation, either a gas stripper (such as air or steam) or liquid scrubber (such as white liquor) may serve as the medium. Pollutants removed by various media are shown in Table 58.

TABLE 58. POLLUTANTS REMOVED BY VARIOUS SCRUBBING AND STRIPPING MEDIA

Solution	Particulate	TRS	H_2S	SO_x	Cl_2	ClO_2
Alkaline solution	X	X	X	X	X	
Alkaline suspension of activated carbon	X	X	X			
Water & $FeCl_3$ solution	X		X			
Thin black liquor solution	X					
Steam/air stripping (in packed towers)		X				
H_2O_2						X
Cold water	X			X		

Source: (164)

Electrostatic Precipitators (ESP)

An ESP consists of discharging and charging electrodes, and a high-voltage power rectifier, which converts AC power to high-voltage direct current. The discharge electrodes negatively charge the particulates in the gas stream which then are attracted to the positively charged collecting electrodes. The collecting electrodes are grounded causing collected particles to lose their negative charge, and fall to a collecting surface. A rapping mechanism is used to dislodge the particles from the collecting surfaces. ESP can be effective in the removal of particulates and reduced sulfur compounds.

Cyclone Separators

Cyclone separators are inertial, or centrifugal, separators which separate particulate matter from a gas stream by transforming the inlet stream velocity into a double vortex contained within the cyclone. In the double vortex, the entering gas spirals downward at the outside and upward at the inside of the cyclone outlet. Because of their inertia, particulates tend to move toward the outside wall, from which they go to a collector.

Fabric Filtration

Gas enters the fabric filtration unit (baghouse) and particulates are captured and retained on the cloth. Once a mat of particles is accumulated, the particles themselves are also responsible for capturing additional particles. Cleaning is done regularly.

Mist Pads

Mist elimination pads consist of fine wire mesh screens, about 1 foot thick. Droplets condense from the gas and the pads are backwashed by water sprays. Most pads can be effective in the removal of particulates and reduced sulfur compounds.

Chlorination

Chlorination of various condensate stream is effective in the reduction of odor caused by reduced sulfur compounds, as these compounds have a high chlorine demand. Chlorination is expensive unless a chlorine source is readily available.

Black Liquor Oxidation

Black liquor oxidation is a kraft mill process operation carried out in order to recover process chemicals, as well as to control air pollution. Both strong and weak black liquors are oxidized in packed towers, bubble tray towers, and agitated or unagitated sparging units. Either air or molecular oxygen is used. This process controls the emission of reduced sulfur compounds, especially H_2S.

Incineration

Incineration of waste gases is often accomplished in the lime kiln, and can be done in the recovery furnace or power boiler. It is effective in the removal of reduced sulfur compounds and organic non-sulfur compounds.

Condensation

Condensation of gases from digesters and evaporators, allows heat recovery and the reduction of gaseous emissions of reduced sulfur compounds and organic non-sulfur compounds.

A summary of the applicable technologies and pollutants removed in certain areas of kraft and sulfite mills respectively is shown in Tables 59 and 60. Removal efficiencies, costs, applications and advantages, and disadvantages of various air pollution control technologies are summarized in Table 61.

Wood Preserving Air Emission Controls

The high particulate concentration from the vacuum and steam cleaning exhausts require a 96 percent removal to comply with emissions relations.(161) A venturi scrubber of this efficiency (capable of collecting suspended particulate in the micrometer size range) would need a 0.089 kg/sq cm (35 inches water) pressure drop across its throat.(162) Such a scrubber may have prohibitively high capital and operating costs.

An attractive alternative control technique to reduce particulate emissions during vacuum cycle and steam cleaning is incineration in an afterburner. Gas stream volumes may run 8.5 to 34 cu m/min (300 to 1200 scfm). To condense live steam and rough out the contaminant load, a surface condenser and knockout tank precede the afterburner.

To prevent fouling, naphthalene crystals must be removed periodically from the condenser. Duct velocities must exceed flame front velocities to avoid flashback from incinerators. Exit temperatures of 815°C and retention times exceeding 0.3 sec are adequate. 99 percent efficiencies are achieved, with exit grain loadings of 0.09 g/cu m (0.04 grain/scf). Afterburner waste heat should be recovered.(162)

IN-PLANT PROCESS CONTROLS TO REDUCE EMISSIONS

Pulp, Paper, and Paperboard Industry

Significant internal controls can be utilized by the pulp, paper, and paperboard industry to minimize air emissions. Some of these controls complement other processes in that control of emissions in one location may ease the problems in others.

TABLE 59. KRAFT MILL APPLICABLE AIR POLLUTION CONTROLS AND POLLUTANTS REMOVED

Source-pollutant	Digester			Evaporator			Washer		Recovery Boiler						Lime burning-dust handling				Smelt dissolving tank		Power boiler				Bleach plant		
Controls used	TRS	especially H_2S	organic non-S_2compounds	TRS	especially H_2S	organic non-S_2compounds	TRS	organic non-S compounds	TRS	especially H_2S	organic non-S_2compounds	particulates	NO_x	SO_x	TRS	particulates	NO_x	SO_x	TRS	particulates	Organic non-S compounds	particulates	NO_x	SO_x	SO_x	Cl_x	ClO_2
Scrubbers (unspecified)				X											X	X	X	X	X						X	X	X
Venturi												X		X		X			X	X		X					
Cyclone																X			X	X							
Impingement																X						X					
Absorption/packed tower	X	X		X	X				X	X		X							X	X					X		
Electrostatic precipitator (ESP)									X			X				X						X					
Cyclone separator																X						X					
Fabric filter (baghouse)																						X					
Mist pads																				X							
Chlorination	X			X																							
Combinations																											
ESP & scrubber											X								X	X							
Cyclone sep. & scrubber																X											
Mist pads & scrubber																			X	X							
Black liquor oxidation (BLO)				X	X																						
Incineration in lime kiln/rec. or power boiler	X		X	X		X	X	X																			
Condensation	X		X																								
Internal controls											X		X									X	X	X			
Venturi & packed tower									X			X	X														

Source: U.S. Environmental Protection Agency (164)

TABLE 60. SULFITE MILL APPLICABLE AIR POLLUTION CONTROLS AND POLLUTANTS REMOVED

Source pollutant Controls used	Digester	Evaporator	Washer	Recovery boiler				Power boilers			
	SO_x	SO_x	SO_x	SO_x	NO_x	H_2S	Particulates	SO_x	NO_x	Particulates	Organic non-S compounds
Scrubbers (unspecified)	X	X	X	X							
Venturi				X						X	
Absorption/packed tower	X	X					X				
Electrostatic precipitator (ESP)							X				
Cyclone separator							X			X	
Fabric filter										X	
ESP & scribber							X				
Internal controls	X	X			X			X	X		X

Source: U.S. Environmental Protection Agency (164)

TABLE 61. SUMMARY OF AIR POLLUTION CONTROL TECHNOLOGIES

Device	%* Efficiency (pollutants)	Cost#		Advantages/disadvantages	Usage†
		Capital	O&M (date)		
Venturi scrubber	95-99+	\$22-27/TPD \$0.6-4/CFM	\$6-10/TPD/Yr (10/76)	Required less ground space than most particulate controllers, has few internal parts to maintain. Cost of op'n=50-60%>ESP	Used in many lime kilns; limited use in recovery boilers & smelt dissolving tanks
Cyclone scrubber	65-96	0.5-2.1/CFM	-	-	Normally used in conjunction with mist pads in lime kiln
Impingement scrubber	92-97	\$29-32/TPD	\$3-6/TPD/Yr	Efficient on coarse particulates (>10μ)	Used in a few lime kilns, & in wood burning power boilers
Absorption/ packed tower	80-909TRS) 85-98(particulates) 98-99(H_2S) 90-97(SO_2)	\$2-8/CFM plus installation	-	Subject to plugging and channeling	Widespread usage not common

(continued)

TABLE 61. (Continued)

Device	%* Efficiency (pollutants)	Cost#		Advantages/disadvantages	Usage†
		Capital	O&M (date)		
Electrostatic precipitator	91-99+	$0.4-2.3 x 106 $0.9-4.2/CFM	$0.05-0.7/CFM/Yr (1971)	Economical w/simple, low cost operation. High initial cost, large space requirements, can't be efficiently used on explosive gases; may foul with SO_2 sensitive to flow variation.	Widespread usage in recovery and power boilers; sometimes used in lime kilns
Cyclone separator	65-99+	$0.59-1.0/CFM plus installation		Efficient on coarse particulates & high concentration. Excellent as a primary collection system.	Typical in lime kilns; also found in coal and wood fired power boilers, and some recovery furnaces
Fabric filter	99+	$0.91-4/CFM	0.12-0.32/CFM/Yr (1971)	Useful on gases of low humidity, volume, and temperature, and to trap particulates which are economical to recover.	No extensive use in any process
Black liquor oxidation(BLO)	50-100(TRS) 95-99(H_2S) 50-100(TRS)	$350-1000/TPD	$10-200/TPD/Yr (11/73)	Can provide better performance in recovery boiler, for chemical recovery.	Frequently used
(continued)					

TABLE 61. (Continued)

Device	%* Efficiency (pollutants)	Cost#		Advantages/disadvantages	Usage†
		Capital	O&M (date)		
Mist pads	70-90	-	-	-	Used for some smelt dissolving tanks
Incineration	-	$108-162/TPD	$0.01-0.05/TPD/Yr (10/76)	-	Lime kiln incineration relatively widespread

*Unless otherwise specified, efficiency is based on particulates.

#Cost figures based on TPD (tons of product per day) and cfm (cubic feet of gas treated per minute). O&M (operation and maintenance) costs do not include any credits (such as any chemical or heat recovery).

†Usage is based on total industry capacity.

To minimize odors from this area, adequate condensation of these gases must be provided. This requires that sufficient capacity be provided to handle peak gas flow, and that the heat recovery system is adequate. The heat recovery system should have proper controls and instrumentation and heat exchanger surfaces should be clean. If possible, the discharge (blow) of the digesters should be controlled so no surge of gases occurs; this can be accomplished by decreasing the blow pressures.

In the pulping of softwoods, turpentine can be recovered from the blow gases. If the condensate outlet temperature can be decreased, the odor from the turpentine recovery system can be decreased. Gases can also be incinerated.

By evaporation, black liquor (spent cooling liquor) may be concentrated to combustion strength. Two methods of evaporation are currently in use: direct contact evaporation with hot flue gases from the recovery boiler; and indirect evaporation with stream. The former method can lead to odor problems when the black liquor is burned in the recovery furnace. Bringing the sulfide concentration down to near zero will greatly decrease the odor caused by hydrogen sulfide. This can be accomplished by oxidizing the weak black liquor with air or oxygen before evaporation.

The use of rotary drum filter pulp washers instead of diffusion washers also decreases the odor at the evaporators by some oxidation of the liquor, but this transfers the problem to the washers, as more odor will be noticed there.

In the oxidation of black liquor, sufficient oxygen transfer from the air must occur to ensure efficient oxidation. It is also important to increase the capacity for black liquor oxidation when the pulping capacity increases. Proper liquor and air flow rates, and sodium sulfide (the compound to be oxidized) loadings must be maintained depending on the type of oxidation system employed.

As in any combustion process, the burning of spent cooking liquor in a recovery boiler should have an optimum amount of air for complete combustion. If any auxiliary fuel is required, as may be the case in the sulfite process, this quantity too should be constantly checked to ensure that fuel is not being wasted and causing an increase in air emissions. Nitrogen oxides are a major pollutant in the burning of spent liquor from the magnesium based sulfite process. These discharges can be minimized by evaporation of the spent liquor to a minimum solids content necessary to support combustion, and by operating the boiler at a relatively low firing rate to minimize heat release.

After cooking chemicals are reclaimed through the oxidation process and new liquor is made up through lime addition, the lime sludge containing calcium carbonate obtained after adding lime (calcium oxide) is burned to recover calcium oxide. Various sulfur compounds are emitted in this process; however, TRS discharges can be minimized by maintaining excess oxygen levels of at least 4 percent by volume. A high temperature and long retention time of lime sludge in the kiln also decreases the amount of reduced sulfur compounds discharged. The handling of lime dust does cause emission of particulates, but these can be decreased by containing the sources of the emission, and by wetting the lime dust to prevent it from becoming airborne. Care must be taken not to overwet the lime dust, as this can create a very wet sludge which would then have to be handled.

Gases can be incinerated at various points in the mill. Preventive maintenance is also important and an effective way to control atmospheric discharges. Systems should be constantly checked for leaks, and any fouled parts should be cleaned.

The increased use of wood waste as a fuel source has led to a need for research into the combustion characteristics and emissions from hogged fuel boilers. Particulate emissions from hogged fuel boilers can be reduced through proper fuel characteristics and careful combustion control. Research in these areas has been recently conducted at Oregon State University leading to the following conclusions:(165)

- There is a significant interaction effect on combustion efficiency between fuel size, fuel moisture content, levels of excess air, and location of the inlet air for combustion.
- The effect of fuel size on combustion efficiency is limited. Test data indicates that fuel size fractions less than 1/4 inch have generally lower emissions of unburned solid carbon than larger size fractions.
- Fuel moisture effects are minimal on combustion efficiency for some modes of operation, but may be highly significant for small size fractions coupled with air fed principally as undergrate air. The effects of moisture are negligible when the undergrate air flow is limited to low levels and the majority of the combustion air flow is provided as overfire air.
- The carryover of unburned carbon from the combustion zone is roughly linearly related to fuel feed rates (heat release rates) when air is supplied as undergrate air. For normal operation of spreader-stoker combustion systems, one can expect carryover concentrations from the combustion zone of 3 grains/scf at heat release rates of 0.52 million BTU's per square foot of grate area. The concentration may approach 5 grains/scf at heat release rates of 0.72 million BTU's per square foot of grate area.
- Wood fuels are roughly 80 percent volatile on a dry basis. It is predicted in theory and now shown in practice that combustion efficiency and stack gas opacity can be improved by taking advantage of this characteristic of the fuel by burning it in two-stage combustion; that is, by strictly limiting the flow of undergrate air to levels approaching 10 percent of the total air flow and making up the remainder of the combustion air by overfire

air. Thus, the solid carbon portion of the fuel is allowed to burn to CO_2 on the grate with very low vertical gas velocities. The volatile portion of the fuel is burned above the grate at the level of the overfire air inlet ports. This mode of operation permits combustion at relatively low levels of excess air. This finding is perhaps the most significant of the research effort to date.

Wood Preserving Industry

Production controls can also be employed in the wood preserving industry to reduce air emissions.

An enclosing hood or building could be used to collect vaporized organic emissions from creosote and oilborne preservatives. The hood would need to cover the entire end of the retort, a section of track and switches, and a complete tram or trams. Such a structure, perhaps exceeding 60 meters in length, would require enormous gas exhaust rates to supply work-place ventilation needs, and the associated emission control devices would also be very large. Particularly in retrofit at older mills, such hooding and ventilation systems could be economically unfeasible. Alternatives exist, however, as are discussed below.

Low boiling point organics may be controlled by reducing the temperature of the freshly treated wood from 82 to 45°C. A header containing spray nozzles may be mounted a few centimeters from the open end of the retort, so placed as to blanket the entire opening and emerging tram loads with water sprayed at about 1 cu m/min. A switch engine slowly moves the emerging tram cars from the retort through the spray blanket. Speeds no faster than 5 m/min are recommended.(162) In effect, the air pollution problem becomes a water pollution problem. Spray water must be collected, skimmed to remove insolubles, and cooled prior to recycling. Following skimming, creosote concentration is about 2 ppm. Spray water is heated several degrees during each use cycle, unless the final vacuum period is extended to an hour or more, a spray tower or pond is employed, or a large capacity water system is used.

Odor emissions from the Ammonical Copper Arsenate (ACA) preserving process can effectively be controlled from the retort. A final hour at 0.7 kg/sq cm (gage) is adequate.(162) Ammonia emissions from the barometric hot well and preservative mixing tanks may be controlled by sealing and/or venting equipment.

Flow rates at ACA wood preserving plants must be as low as possible, to maximize scrubber efficiency and reduce odor. A packed tower of 46 cm diameter packed with 0.2 cu m of 2.54 cm Raschig rings has been used at one mill.(162) Recirculating water concentrations should not exceed 1.5 percent NH_3 by weight.

Workplace safety procedures including automatic mixing of preservatives can minimize the potential for inhalation of toxic materials.

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APPENDIX A.

PRODUCTION PROCESS DESCRIPTIONS

INTRODUCTION

The following process descriptions for the pulp, paper, and other wood products industries have been taken directly from referenced documents in order to present an overview of production practices as they affect the industries' pollution control requirements.

PULPING PROCESSES (1, 2)

Unbleached Kraft

Wood, the fiber raw material of unbleached kraft pulp, arrives at the pulp mill as logs or as chips. Barked logs can be chipped directly for use. Bark is removed from unbarked logs in a wet or dry process and the logs are then chipped for conveyance to the digester, a large steel pressure vessel heated with steam to approximately 150°C. Here the chips are cooked in either a batch or continuous operation to dissolve lignin and separate the cellulosic fibers. The cooking liquor contains a mixture of caustic soda and sodium sulfide, which necessitate, because of high chemical costs and high liquor concentrations, a chemical recovery system which is integral to the process. This system and its role in the preparation of cooking liquor are described in ensuing paragraphs.

The unbleached kraft process is described as a full-cook process, since cooking is completed to the point at which the wood will be fiberized upon being blown from the digester. In modern practice, the pulp is ejected to a blowtank.

The pulp, along with the spent cooking liquor is then transferred to a brown-stock chest, or tank, and thence to vacuum drum washers or continuous diffusers where the spent cooking liquor is separated by counter-current washing. In older mills, the pulp is blown directly to the diffusers from the digester.

Chemical recovery necessitates a high degree of liquor separation with as little dilution as is possible to minimize heat requirements of evaporation. Three stages of washing, which may employ blow tank condensate reuse are common but, in some cases, four are used. In some newer installations a combination of vacuum washers and diffusers is employed. Some continuous digesters contain liquor separation and diffusion washing zones within the digester body, and in many kraft mills, the pulp is screened and/or refined prior to brown-stock washing to effect certain economies in washing and improvements in pulp quality.

After washing, the pulp is diluted and then screened to remove knots, uncooked chips, pitch particles, etc., and is ready for production of unbleached paper and paperboard or thickening to a high consistency for further processing, storage, or lapping for shipment.

The kraft pulping process is illustrated in Figure 10.

Weak black liquor comes from the washing operation and contains about 10 to 16 percent solids. In addition to the inorganic cooking chemicals, it contains organic wood constituents separated in the pulping process. The weak black liquor is concentrated to about 45 to 50 percent solids in long-tube multiple-effect evaporators and the resulting viscous mass is called strong black liquor. This is then concentrated further to a consistency of 60 to 65 percent solids in the recovery furnace contact evaporator or in a concentrator.

Cooking chemicals lost in pulping and washing are replaced with a make-up chemical, usually sodium sulfate, or a residue with a high content of this salt. Acid sludge from oil treatment, raffinate from by-product production, NSSC waste liquor, and ash from incineration of NSSC liquor are examples of such residues. Salts captured from the recovery furnace stack gases are also reintroduced into the system Sulfur and caustic soda are sometimes used to adjust the sulfidity.

The strong black liquor is then burned and the heat recovered in a specially designed boiler. During burning, the organic sodium compounds are converted to soda ash and sulfates reduced to sulfides on the floor or reducing section of the furnace. The molten smelt of salts is dissolved in water to form green liquor. This is clarified by sedimentation and then causticized with lime to convert the soda ash to caustic soda. After causticizing, the combined Na_2S - NaOH solution is known as white liquor. This is settled and sometimes filtered through pressure filters, adjusted to the desired strength or concentration for cooking with weak black liquor, and stored for use in the pulping process.

The lime mud (calcium carbonate) obtained on settling this white liquor is washed and dewatered on rotary vacuum filters or centrifuges and burned in rotary or fluidized kilns to form quick lime. This is hydrated with green liquor in slakers for reintroduction to the recovery cycle.

Bleached Kraft

Prior to bleaching, the processing steps used in producing bleached kraft pulps are identical to those used in producing unbleached pulp with one exception.

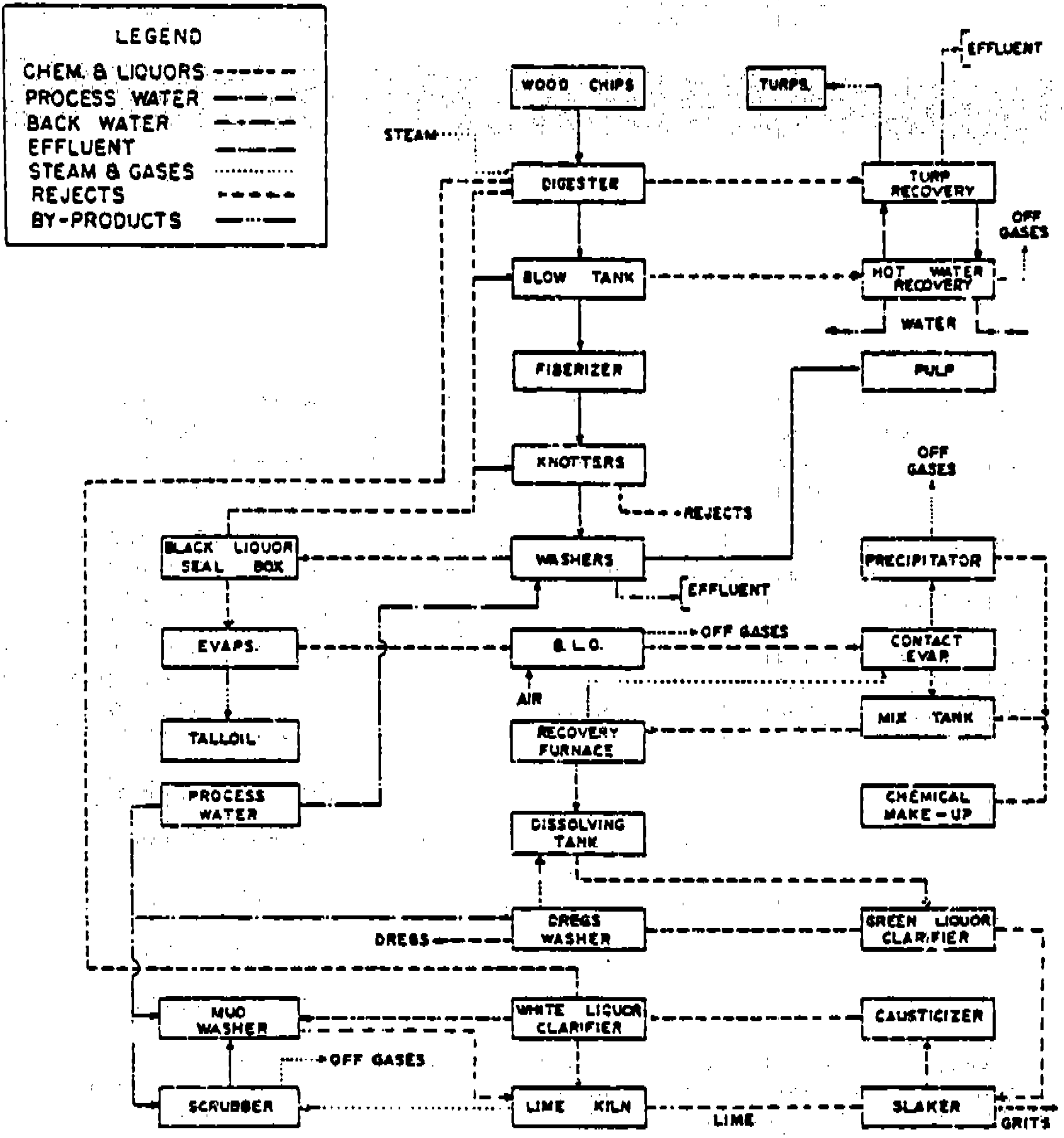

FIGURE 10 KRAFT PULPING PROCESS DIAGRAM[1]

The NSSC pulping process is illustrated in Figure 11.

Recovery or Burning of Cooking Chemicals--

Chemical recovery in the sodium base NSSC process is considerably more difficult than in the kraft process. The spent liquor is low in solids with a relatively high proportion of inorganic to organic constituents, and, thus, does not burn easily. Other factors which complicate recovery are a relatively high liquor viscosity and relatively low sodium to sulfur ratio.

Because of these factors many mills simply evaporate and burn the spent liquor without recovery. Evaporation is commonly accomplished in multiple-effect evaporators. The concentrated liquor is burned for disposal or recovery in a fluidized bed reactor or a specially designed furnace. In sodium base mills, the fluidized bed combustion units produce sodium sulfate which is suitable for use in kraft mill liquor systems.

Recovery of sodium base NSSC liquor alone is presently limited to a few large mills. Three have chemical recovery systems. Three others incinerate the liquor and two discharge to city sewers. For sodium base NSSC mills, the simplest recovery practice, which is called cross recovery, is to send the liquor to a nearby kraft recovery system.

No successful system has been developed for chemical recovery in ammonia base NSSC mills. In the two mills utilizing this base, the spent liquor is incinerated. The combustion products are gaseous with a negligible residue of inorganic ash.

Kraft-NSSC (Cross Recovery)

A substantial number of kraft pulp mills have an accessory sodium base neutral sulfite semi-chemical pulp mill. In most instances, these are kraft linerboard mills employing pine as a raw material from forest areas where appreciable hardwood species grow as well. These mixed hardwoods are harvested separately but simultaneously with the pine, cooked by the sodium base NSSC process, and manufactured into corrugating board. This product is compatible with linerboard since both are required to produce container board. Such combined pulp production also provides the simplest and most economic means for disposing of the sodium base NSSC spent liquor since it can be introduced into the kraft recovery system at one point or another to provide make-up chemicals to the kraft liquor, sodium and sulfur, to produce white liquor, the kraft cooking agent.

Kraft recovery systems can absorb spent liquor from an NSSC mill producing about one-third the tonnage of the kraft operation assuming that adequate evaporator capacity is provided to accept the NSSC brown liquor which is generally more dilute and lower in heat value than the kraft black liquor. One mill has been able to increase this ratio through a process employing crystalization of soda ash from the green liquor for use in preparing NSSC cooking liquor. This limitation has also been overcome by cooking the hardwood with green liquor, although the pulp produced has less

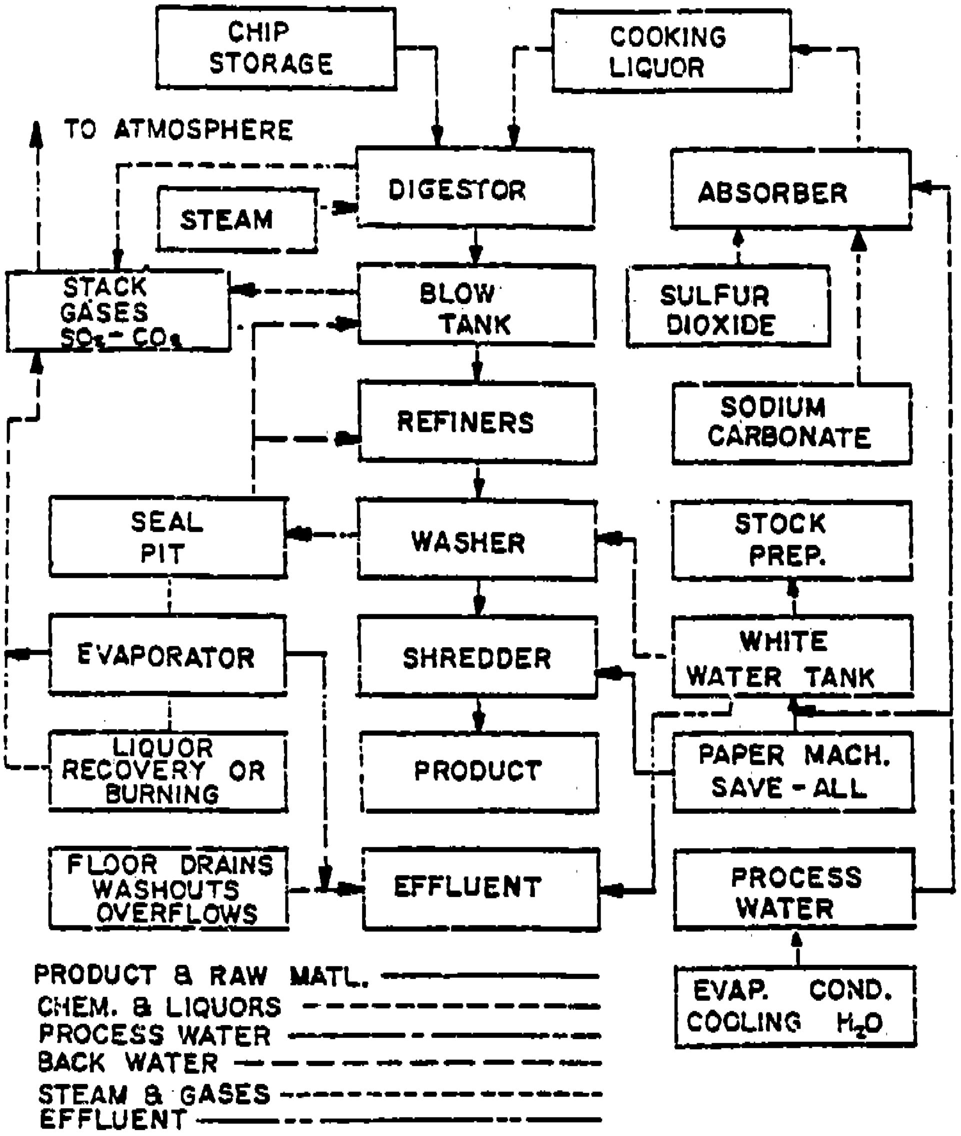

FIGURE 11 NEUTRAL SULFITE SEMI-CHEMICAL PULP PROCESS DIAGRAM (1)

desirable characteristics than NSSC. While limitations of 1:3 on the basis of NSSC to kraft pulping may appear severe, this is not usually the case because the large size of modern linerboard mills still allows an economic size NSSC operation.

Acid Sulfite

The acid sulfite process is used to make two distinctly different types of pulp: papermaking grades and dissolving grades. The basic process is the same for both, although there are significant differences in cooking temperatures, strength of chemical application, and bleaching practices. The following discussion of sulfite pulping is generally applicable to both. The major differences in its application to dissolving pulp are noted at the end of this discussion.

In the acid sulfite process, wood chips are cooked with solutions of the bisulfite of calcium, magnesium, ammonia, or sodium containing an excess of free sulfur dioxide. The cooking liquor is manufactured at the mill from purchased and recovered chemicals.

Sulfurous acid is prepared by absorbing sulfur dioxide in water. Sulfur dioxide is made at the mill by burning sulfur or is purchased in liquid form either of which is supplemented by that returned to process from the sulfur dioxide recovery system.

In calcium base mills, calcium is supplied either in the form of calcium carbonate or calcium oxide; the base is reacted with sulfurous acid and is not usually recovered from the spent liquor. In ammonia base mills, aqua ammonia is reacted with sulfurous acid. If the chemical is purchased in the anhydrous form, it is first put into solution. Ammonia, too, is not recovered. Magnesium oxide and caustic soda are purchased as make-up base for the magnesium and sodium base recovery systems which retain about 90 percent of the base in the system through recovery.

When ammonia, magnesium, or sodium base cooking is completed, the pulp is blown into a blow tank. It is then delivered to multi-stage vacuum washers on which countercurrent washing separates the spent liquor from the pulp. In the case of calcium base pulp and some ammonia base pulps, blow pits rather than tanks are generally employed where the pulp is washed by diffusion of wash water through the pulp mass. It is possible to recover 95 percent of the liquor solids by vacuum washing, but the limit is about 85 percent from displacement washing in blow pits. A 15-percent liquor concentration is obtainable by vacuum washing while the highest solids concentration attainable by blow-pit washing is about 10 percent. Off-gases are passed to an absorption system for recovery of their sulfur dioxide content. After washing, the pulp is diluted, screened, centrifugally cleaned, and deckered to the desired stock chest consistency for bleaching. A process diagram is presented in Figure 12.

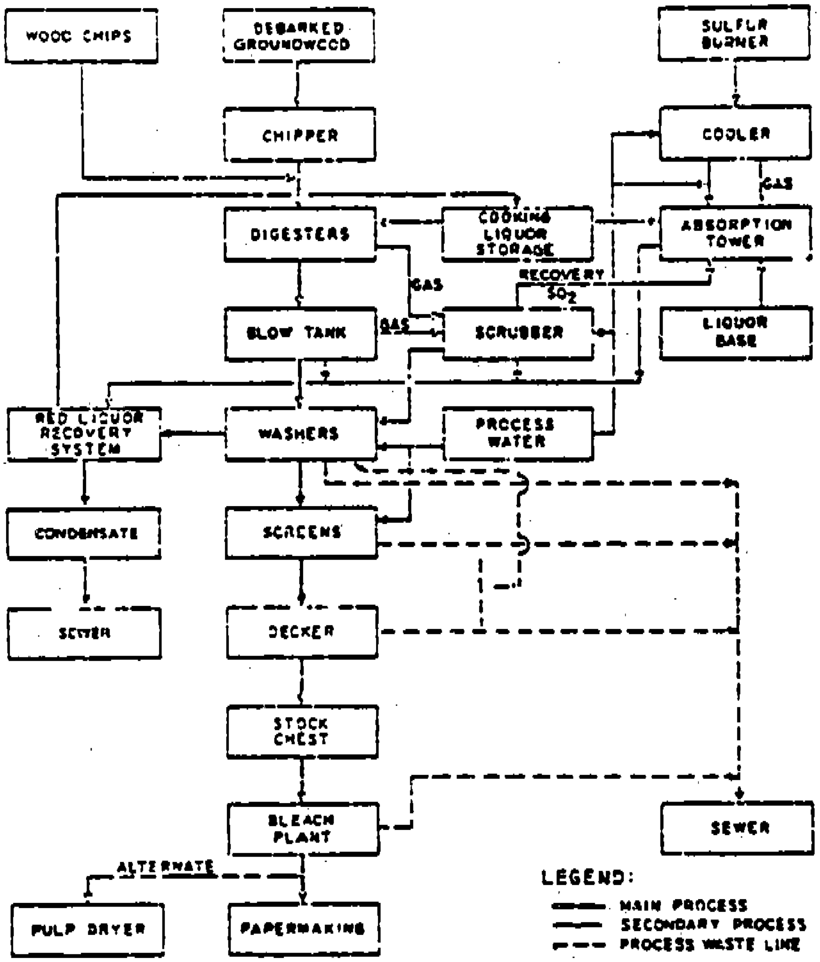

FIGURE 12 SULFITE PULP MILL PROCESS FLOW DIAGRAM (2)

The weak red liquor separated from the pulp is evaporated in multiple effect long tube evaporators and recovery furnace contact units to a consistency of about 60 percent solids which is suitable for burning. Because of scaling problems, special evaporation units of the switching type are required for calcium base liquor. Also, forced feed evaporators must be used for ammonia base liquor because of its high viscosity.

In the magnesium base process, the ash produced on burning the liquor is magnesium oxide which is recovered in cyclones and returned to the liquor manufacturing section on the mill. The smelt obtained on burning sodium base liquor is solidified and redissolved under controlled conditions so that the soda ash and sodium sulfide present can be separated by differential solubility. The sodium sulfide is reacted with carbonic acid to form hydrogen sulfide which is burned to produce sulfur dioxide. The latter is reacted with the soda ash obtained from the smelt to form sodium bisulfite cooking liquor, and the carbon dioxide produced is employed in the sodium sulfide reaction. Ammonia base liquor is burned either in a typical recovery furnace or a fluidized bed unit and sulfur dioxide is stripped from the off-gases for use in the liquor preparation unit. A process flow diagram of a magnesium base sulfite recovery system is presented in Figure 13.

In the preparation of sulfite dissolving pulps, the wood is cooked at a higher than standard temperature. Cooking is continued until most of the lignin and part of the cellulose are dissolved whereas in papermaking pulps only a portion of the lignin is dissolved. The resulting spent liquor thus has a higher solids content and a much higher heat content when burned. In addition to screening to remove bark and wood particles after the pulp is washed, it is sent through special "side-hill" screens for thickening and to separate resinous materials.

Soda

The only major difference today between the soda and kraft processes and their recovery systems is that sulfur is present in kraft liquor and because of this black liquor oxidation is practiced at a number of kraft mills. All the recovery systems of both are designed to burn all the organic matter present in the black liquor rather than producing black ash as in the old soda process.

In the soda process wood chips are cooked in a solution of caustic soda containing 6.1 to 6.6 pounds of active alkali per cubic foot of liquor. When pulping is complete the contents of the digester are blown into a tank. Exhaust steam passes through a cyclone to remove entrained black liquor which is sent to the recovery plant. This steam and that contained in the relief gases is condensed in a heat exchanger used for heating process water before entering the atmosphere. Knots are removed from the pulp which is then washed on countercurrent drum washers generally in three stages. The pulp is then diluted, screened, and deckered to stock chest consistency.

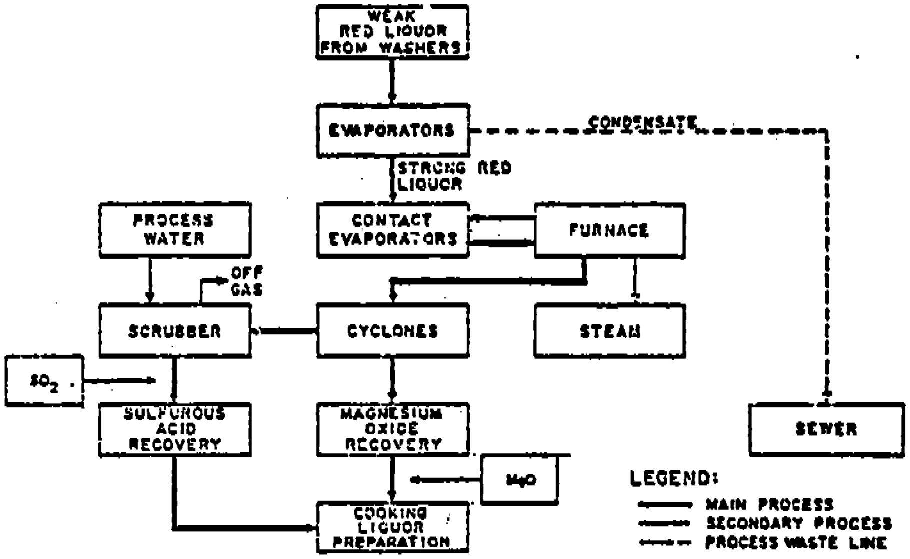

FIGURE 13 MAGNESIUM BASE SULFITE RECOVERY SYSTEM PROCESS FLOW DIAGRAM(2)

The weak black liquor from the washers is concentrated to 40 percent solids content in long tube multiple effect evaporators and then to about 65 percent in a recovery furnace stack evaporator. The liquor is then burned in the recovery boiler. The molten ash, which consists almost entirely of sodium carbonate, is dissolved in weak wash water and the make-up chemical -- purchased and recovered soda ash -- is added to form green liquor. Also, the make-up chemical can be sodium hydroxide to the white liquor rather than sodium carbonate to the green liquor. The green liquor is clarified and causticized here with lime to convert the sodium carbonate to sodium hydroxide. The lime mud is settled and filtered from the solution which is now designated a white liquor. This is filtered through a pressure filter and stored for use in the digesters. Lime mud is dried and burned to calcium oxide which is slaked and used again for causticizing. The kiln is equipped with a venturi scrubber for dust collection which generally utilizes weak wash from the causticizing system. This is returned to the process carrying recovered lime and some soda.

The soda pulping process is identical to that of kraft pulping illustrated in Figure 10.

Mechanical Pulping

The energy used in producing conventional groundwood pulp -- stone or refiner -- is mechanical. Modified groundwood processes such as the cold soda (chemi-mechanical) and chemi-groundwood methods employ a mild chemical treatment ahead of mechanical fiberizing. The latter processes are considered here as mechanical pulping, however, because the chemical pretreatment is much milder and the mechanical action more drastic than is the case in semichemical pulping. In thermo-mechanical pulping, an off-shoot of refiner groundwood, the pretreatment is accomplished with heat and pressure. The cold soda and chemi-groundwood pulps are produced and used as a direct substitute for groundwood or as supplements to special furnishes. All mechanical pulps contain practically all of the wood substance and yields are generally 35 to 90 percent of the bone dry weight of the wood processed while semichemical pulps fall within the 60 to 80 percent yield range.

The type of wood economically available is a factor in selection of the groundwood process applied. Softwood does not necessarily require pretreatment and has thus been the traditional raw material of the stone groundwood process, and more recently of the refiner method. The high energy requirements of grinding untreated hardwood are overcome by the processes which incorporate pretreatment. Thus, their development made possible the use of large stands of hardwood for mechanical pulping. Sawmill wastes are another source of raw material for the mechanical processes which utilize wood chips.

Stone Groundwood--

In this process, billets are fed to the grinders by hand or automatically from a belt or chain conveyor and are forced hydraulically against the large rotating grindstone, specifically designed for the purpose. The pocket-type grinder is most common although the magazine, ring, and continuous or chain types are being installed in new mills. The grinding occurs in the presence of a large quantity of water which acts as both a coolant and a carrier to sluice the pulp from the body of the grinder. The pulp slurry is diluted to a consistency of from 0.6 to 0.8 percent and is passed through coarse and fine screens and a centricleaner to remove dirt and slivers. Over-sized rejects may be passed through a disc refiner and returned to the system ahead of the fine screens. The pulp slurry is then thickened on a decker to between 10 and 15 percent consistency and discharged to a stock chest for mill use, bleached, or thickened further for transport to other mills either in the form of wet lap at about 25-percent consistency or nodules containing 50 percent fiber. A diagram of the stone groundwood process is presented in Figure 14.

Refiner Groundwood--

The availability of saw mill chips as a low-cost wood source led to the development and exploitation of the refiner groundwood process which has the additional advantage of using less power than stone grinding. The chips are first washed and two stages of refining are generally employed in the pulp mill, the fiber receiving a third refining in the papermill. Disc type refiners are used which contain one fixed and one rotary disc between which the wood passes together with a stream of water. A double-disc type unit is used mainly for refining rejects. The pulp is discharged from the refiners at a consistency of about eight percent and move by a high-density pump to the secondary units. Here it is diluted to low consistency and subsequently fine screened and freed of dirt in centri-cleaners. Screen rejects are refined and returned to process ahead of the screens. After cleaning the pulp is handled in the same manner as stone groundwood as shown in the process flow diagram in Figure 15.

Cold Soda--

In the production of cold soda pulp, chips are soaked either at atmospheric pressure for two hours or under forced pressure for shorter periods of time in liquor containing 20 to 40 mg/l of caustic soda. The caustic expended varies from two to 10 percent of the weight of the wood depending on the wood species used and the pulp quality desired. The liquor is recycled after fortification. Subsequent separation of chips and liquor may be accomplished by gravity or screw or roll presses may be employed. The treated chips are then handled in a manner similar to that used in manufacturing refiner groundwood.

Chemi-Groundwood--

The liquor used in chemi-groundwood pulping contains from 60 to 180 mg/l of sodium sulfite buffered with one-sixth to a third that amount of soda ash. Hardwood billets are first impregnated with the liquor and then cooked for periods ranging from a half an hour to six hours at a maximum temperature of 135° to 150°C. (278-201°F.). This is followed by grinding on stones under operating conditions very similar to those of stone groundwood. This pulp is stronger than conventional groundwood.

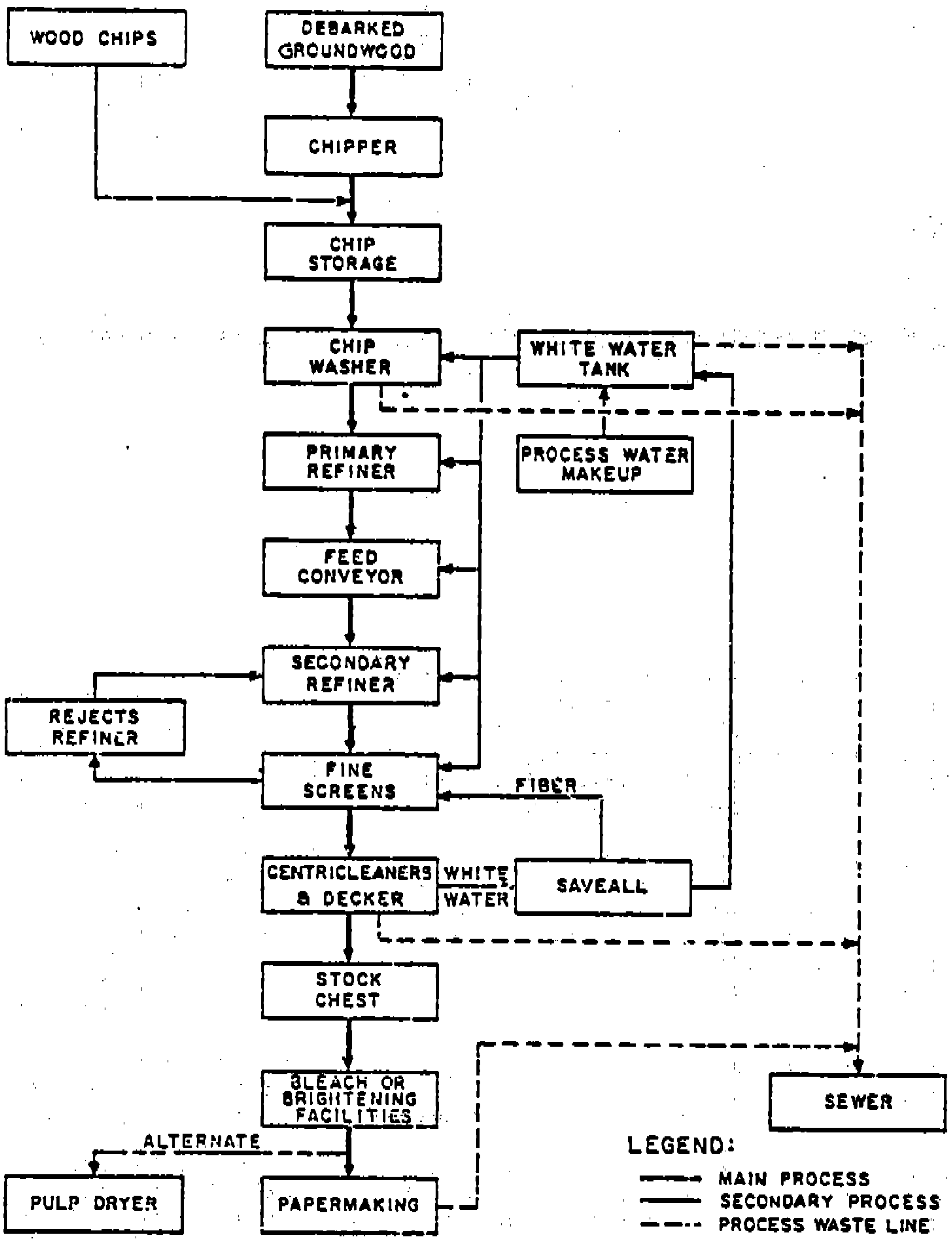

FIGURE 15 REFINER GROUNDWOOD PULP MILL PROCESS FLOW DIAGRAM (2)

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screened at about one to two percent consistency, after which it is ready for cleaning. This is accomplished by passing the stock at about 0.5 percent consistency through centricleaners and fine screens. Generally countercurrent washing is employed on washers of various types. Some mills employ flotation for separating the fiber from the undesirable materials and others use various kinds of deckering or thickening equipment. Fiber leaves the washers and is delivered to a stock chest at six to 15 percent.

Deinking practices in a tissue or molded pulp mill do not vary appreciably from the above. However, cooking temperatures for papers high in groundwood content are generally lower -- 38° to 71°C (100° to 160°F.) with a pH below 10. In addition, sodium peroxide is frequently adding to the cooking liquor since its bleaching action tends to prevent browning of the pulp.

A considerable shrinkage of the raw stock occurs in deinking because of the filler and coating materials washed from it along with large quantities of fiber fines when appreciable groundwood is present.

Newsprint is deinked by a proprietary process employing a special detergent. The pulp produced is suitable for conversion on high-speed newsprint paper machines with the addition of little, if any, long fiber stock and may not require bleaching. Shrinkage is reported to run around 15 percent.

In some nondeinking operations considerable quantities of books, envelope cuttings and flyleaf shavings, and similar unprinted scrap is repulped and washed free of fillers, adhesives, and sizing materials. Although ink removal is not involved, shrinkage and attendant sewer losses from such operations are similar to those from deinking.

At some paper mills relatively small amounts of selected kinds of waste paper are deinked from time to time for use in furnishes employed in the production of particular specialties. In some cases, almost the entire operation, including bleaching, is carried out in Hollander beaters. This may be the case also with the reclamation of fiber for use as liner in board mills.

Paperboard From Waste Paper

To convert waste paper to secondary fiber waste paper, sufficient water to provide desired consistency of four to six percent, and chemicals are charged at a controlled rate to a pulper along with steam. In this operation, the paper follows water circulating in a large open vat and is repeatedly exposed to rotating impeller blades. Over a period of time, it is ripped, shredded, and finally defibered. The pulper operation may be batch, continuous, or a combination of both. A junker is usually attached which, through centrifugal action, collects and removed extraneous solid materials and papers not suitable for use.

The stock is then passed to centrifugal cleaners, and finally to a thickener which may be preceded by pressure screens. Reject material is dewatered for disposal, and the stock is stored for use or goes directly to the refiners which serve the paper machines.

The removal of modern contaminants found in waste paper, including plastic containers, polystyrene packing materials, and other plastic coatings and laminants has required some refinements to the basic process. Some mills also have systems for dispersing the bituminous asphalt found in some reclaimed laminated kraft bags. This type system subjects the fiber to a heat and pressure environment in a press and digester.

The paper forming section of the board machine, or wet end, employed depends on the type of product made. Both fourdrinier and cylinder machines and some special devices as well are used. Variations and exceptions occur throughout the industry, although in general, a fourdrinier is used to make a single stock sheet and a cylinder machine a multi-ply sheet or heavy board. During recent years, cylinder machines have been replaced by variations of the dry-vat principle in order to produce a multi-stock sheet at higher speeds.

A process flow diagram of a typical paperboard from waste paper mill is shown in Figure 16.

BLEACHING METHODS

Bleaching of Chemical Pulp

The chemicals most commonly employed for bleaching chemical pulps are chlorine, calcium or sodium hypochlorite, and chlorine dioxide. Alkalies such as caustic soda and calcium hydroxide are used for extracting chlorinated reaction products from treated pulp. In some instances, hydrogen peroxide or sodium peroxide or peroxyacetic acid are used in the finishing stages of bleaching. Sulfur dioxide or sodium sulfite can be used as neutralizing and anti-chlor reagents and in some instances to stabilize pulp brightness. However, the chlorine compounds and alkalies are the most commonly applied chemicals.

Chlorine and caustic soda are either purchased in liquid form or, in rare cases, manufactured at the mill by electrolysis of sodium chloride. Hypochlorites are generally manufactured on site by treatment of milk of lime or caustic soda with chlorine. Strengths produced vary with intended use since this chemical is used not only for bleaching, but, in the case of dissolving pulps, to control rate of extraction of materials from the pulp and the ultimate viscosity of it.

Chlorine dioxide, because of its instability, is manufactured at mills which use it by one of four methods. These are the Mathieson process, a modification thereof, the R-2 process; and the Solvay process. They all employ sodium chlorate and sulfuric acid. Sulfur dioxide is also used in both the Mathieson processes, and sodium chloride is added in the modified Mathieson method and R-2 technique. Methanol is substituted for sulfur dioxide in the Solvay process.

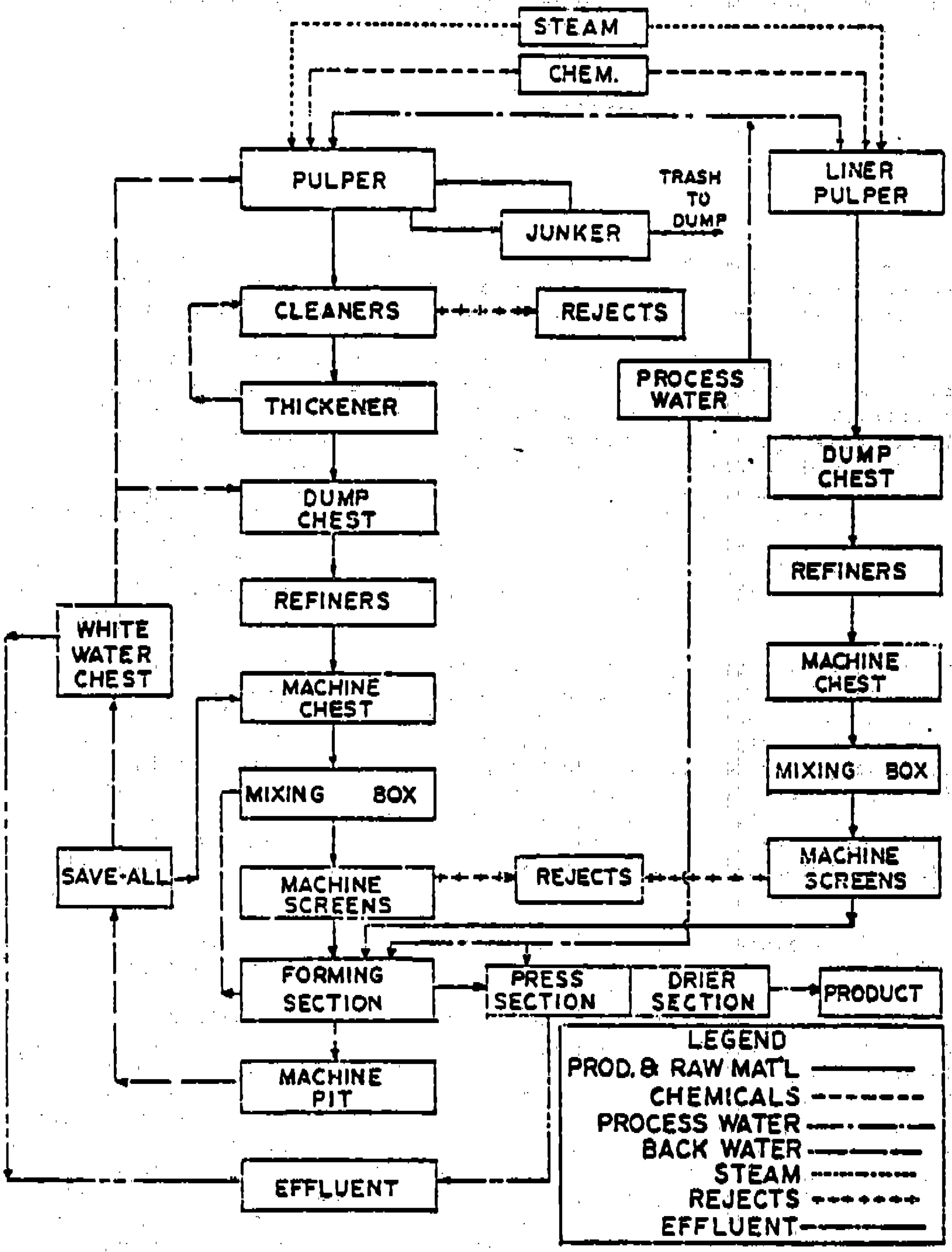

FIGURE 16 WASTE PAPER BOARD MILL PROCESS DIAGRAM (2)

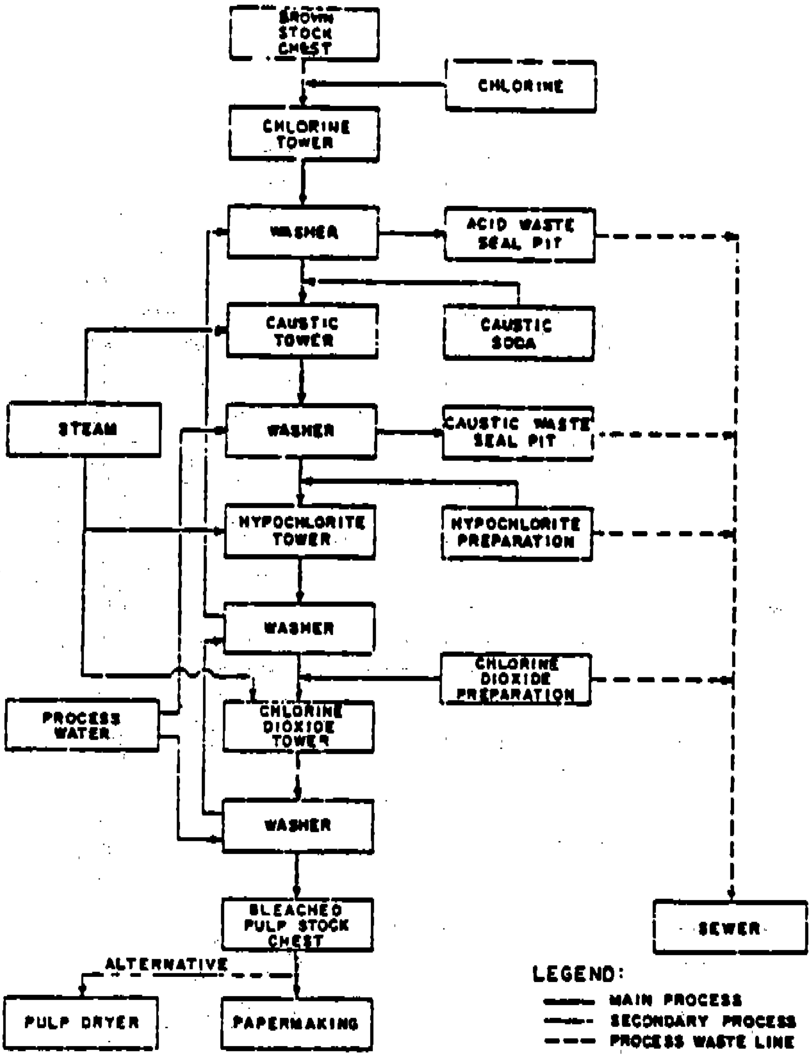

FIGURE 17 FOUR STAGE KRAFT PULP BLEACH PLANT PROCESS FLOW DIAGRAM (2)

The actual bleaching for both sulfite and prehydrolysis-kraft is accomplished by standard procedures as described in the previous section. CEHD is used by some sulfite dissolving mills, although others employ a five-stage process which may or may not include a chlorine dioxide stage. The use of this chemical, however, is indispensable for the production of dissolving grades from kraft pulp.

The purpose of the caustic extraction stage in bleaching dissolving sulfite pulps is somewhat different from its function in bleaching sulfite paper grade pulps. In the latter, this stage is utilized to remove partially bleached material solubilized in the chlorination stage. In the manufacture of dissolving pulp, the extraction stage is much more drastic in terms of caustic concentrations and degree of heat in order to dissolve a specific fraction of the cellulose itself which is not suited to the manufacture of rayon. Over 45 kg (100 lb) of caustic may be added per kkg (ton) of pulp and reaction temperatures exceed the boiling point while only about 14 kg (30 lb) of caustic under warm conditions are required for paper grade pulp. In dissolving pulp bleaching, this step dissolves approximately 10-16 percent of the pulp, depending on the grade of cellulose desired.

The final bleaching steps in sulfite dissolving also serve a different purpose from the last stage in bleaching paper pulp. In the latter case, the bleaching agent is usually used to achieve high brightness with minimum effect on the cellulose itself. In bleaching dissolving pulp, high brightness is only an incidental requirement and actual modification of the cellulose molecule itself is desired. Thus, the dissolving sequence usually ends with a relatively harsh bleaching agent such as sodium hypochlorite.

For kraft dissolving grades, the unbleached pulp is purified in the bleach plant to remove all traces of lignin and hemicellulose. This is done by means of a five to eight stage process, typically consisting of chlorination, caustic extraction, hypochlorite bleaching, chlorine dioxide bleaching, further caustic extraction followed by more chlorine dioxide and hypochlorite. Lignin is removed by chlorine and chlorine dioxide and hemicellulose by caustic extraction. The extreme hot alkaline extraction conditions designed for sulfite dissolving, described above, are not useful for the kraft dissolving process in which the alpha cellulose level is determined largely by cooking procedures.

Bleaching of Mechanical Pulp

Stone and Refiner Groundwood--

While these purely mechanical pulps have many desirable qualities for the manufacture of low-cost papers, they are not naturally sufficiently bright for the better grades. The brightness varies with the characteristics of the wood raw material. For example, northeastern spruce and balsam will generally produce a groundwood pulp in the brightness range of 57 to 65 units while the pulps from west coast species such as western hemlock range in the low 50's Thus, bleaching is undertaken when necessary to satisfy the demands of various end products.

The most common bleaching agents used for stone and refiner groundwood are hydrosulfites and peroxides, and, in some cases, both are used sequentially as shown in Figure 19. Hydrosulfite systems can improve brightness by as much as eight to 12 standard brightness units in single stage operation and up to 15 to 20 units in a two stage operation with peroxide. Peroxide alone has capabilities in the range of eight to 12 or more units.

In peroxide bleaching, hydrogen peroxide is generally used although sodium peroxide is sometimes employed. A solution of from 0.5 to 1.5 percent hydrogen peroxide or its oxygen equivalent of sodium peroxide is applied to the pulp. Frequently a small amount of magnesium sulfate -- 0.24 to 0.48 mg/l (1 to 2 lb/500 gal) of bleach solution - is used for stabilization purposes. The pH of the pulp is first adjusted to 10.5 with caustic soda which requires from 1.0 to 3.0 percent NaOH. Sodium silicate or sulfamic acid sometimes replaces the caustic soda since they are capable of sequestering metallic ions which catalyze peroxide decomposition or discolor the product. Groundwood pulp is generally bleached with peroxide at between 38 and 49°C (100 to 120°F). Consistencies of bleaching range from four to 35 percent. The pulp is usually subsequently neutralized with sulfur dioxide to prevent reversion.

In some instances, refiner groundwood is subjected to refiner bleaching (e.g., a solution of peroxide is added to the disc refiner employed for fiberizing). The bleaching reaction thus begins while the pulp is refined and is subsequently completed after discharge by maintaining the pulp at discharge temperature, 77 to 93°C (170 to 200°F), for approximately 15 minutes.

Some mills mix nodulated (pressed and shredded) pulp with sodium silicate and hydrogen peroxide in tank cars or truck tankers utilizing the tankage in transit as a reaction vessel for the bleaching operation.

Peroxide solutions are prepared at the mill by batch or continuous methods, and may contain either hydrogen or sodium peroxide or both. Epsom salts, sodium silicate, sodium and/or hydrogen peroxide is replaced by caustic soda. In the case of a sodium peroxide solution, sulfuric acid is used to replace the hydrogen peroxide.

When sodium or zinc hydrosulfite is used to bleach or brighten groundwood pulp, the chemical is frequently added directly to the secondary refiner or grinder sinks, canals, or stock chests since heat is important to the reaction. From 0.2 to 2.0 percent of the chemical is used depending upon the species of wood from which the pulp was derived and desired brightness; a temperature of 49 to 50°C (120 to 130°F) is most desirable at a consistency of 15 percent or greater. Sodium hydrosulfite is now preferred because of zinc discharge limitations.

Hydrosulfite solutions are prepared from purchased hydrosulfite or from chemicals manufactured at the mill. In one method, zinc hydrosulfite is made by reacting zinc dust with aqueous sulfur dioxide. In another, the

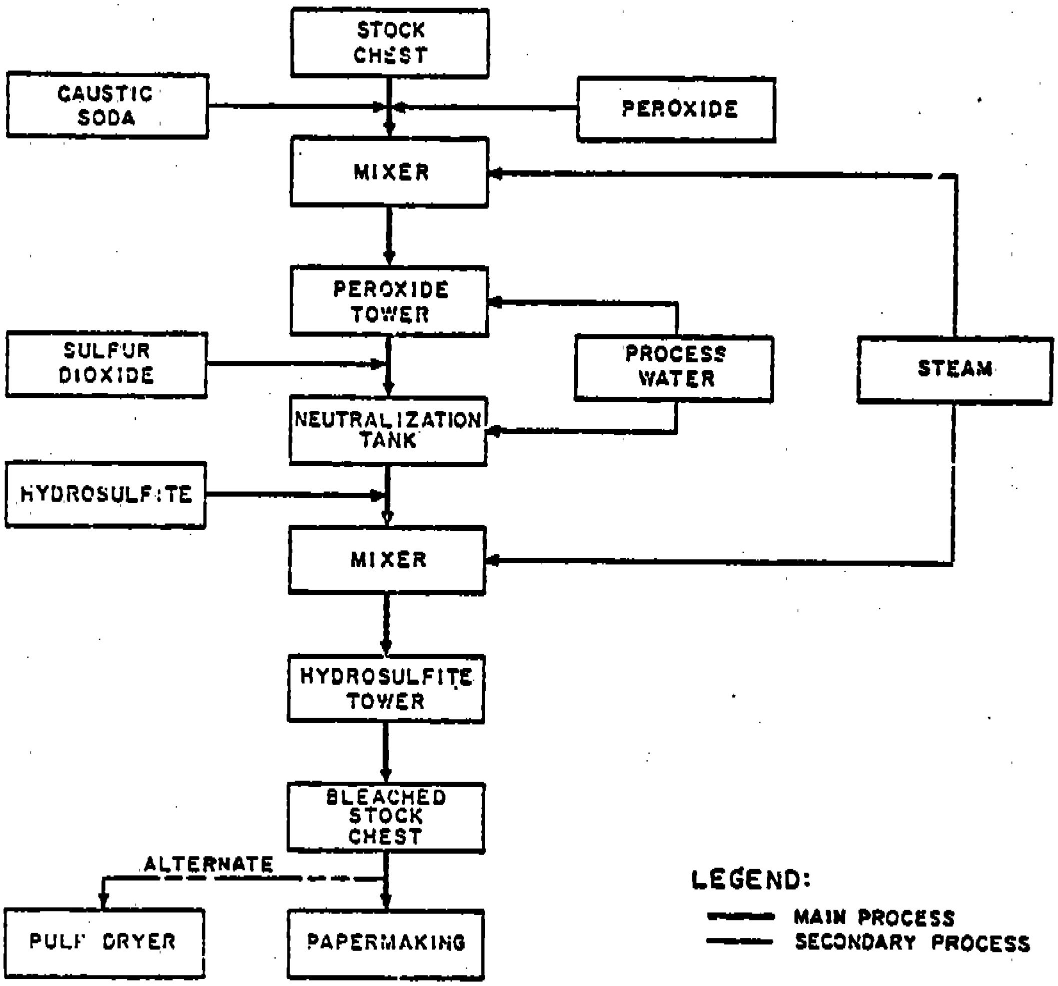

FIGURE 19 BRIGHTENING AND BLEACHING GROUNDWOOD AND COLD SODA PULPS PROCESS FLOW DIAGRAM (2)

zinc dust is mixed with pulp and the sulfur dioxide is introduced in aqueous solution or as a gas. Hydrosulfite can also be added dry at lower consistencies. Sodium and potassium borohydride, which also inhibits reversion following bleaching are sometimes used for brightening groundwood pulps, but, because of the chemical costs involved, the use of these chemicals has not become established practice in this country. The cost of peracetic acid has similarly precluded its use for groundwood bleaching.

Bleaching of Deinked Pulp

Deinked fibers consisting primarily of bleached chemical pulp are bleached in one stage with chlorine or calcium or sodium hypochlorite. From two to five percent of available chlorine is commonly used. Consistencies of the pulp bleached range from three to as high as 12 percent; tower type bleaching is used for the higher consistencies. When pulps containing considerable lignin are bleached after deinking, the three stage CED process commonly applied to kraft and sulfite pulps is employed. In this process, three percent of chlorine is applied to a dilute slurry of the pulp at ambient temperature. The pulp is then thickened and treated with caustic soda at 38°C (100°F) which is followed by washing and treatment with hypochlorite. A variety of equipment and variations of this process are in use. Pulps high in groundwood are bleached by the methods employed for groundwood alone and variations thereof employing caustic soda, peroxides, and hydrosulfites. Bleaching decreases the yield in the range of from 2.9 to five percent.

A process flow diagram of a deinking operation with single stage bleaching is presented in Figure 20.

PAPERMAKING

In stock preparation, pulp, either purchased or produced onsite, is resuspended in water to a consistency of four to six percent. The stock is mechanically treated in beaters or continuous refiners to brush or fray the individual fibers to obtain the necessary matting which produces the desired strength in the paper. This process also cuts the fibers to some extent. In cases where good formation is desired, such as fine papers, the stock is also pumped through a jordan which further cuts the fibers, with a minimum of brushing, to the necessary length. The amount of brushing and cutting varies with the type of pulp and the end product requirements. In a few cases, no mechanical treatment is needed.

Chemical additives may be added either before or after stock preparation. The most common additives are alum and rosin used for sizing, which prevents blotting of ink. Fillers such as clay, calcium carbonate, and titanium dioxide are added where opacity and brightness of the paper are important. A wide variety of other additives such as wet strength resins, dyestuffs, and starches may be used, depending on end-use requirements.

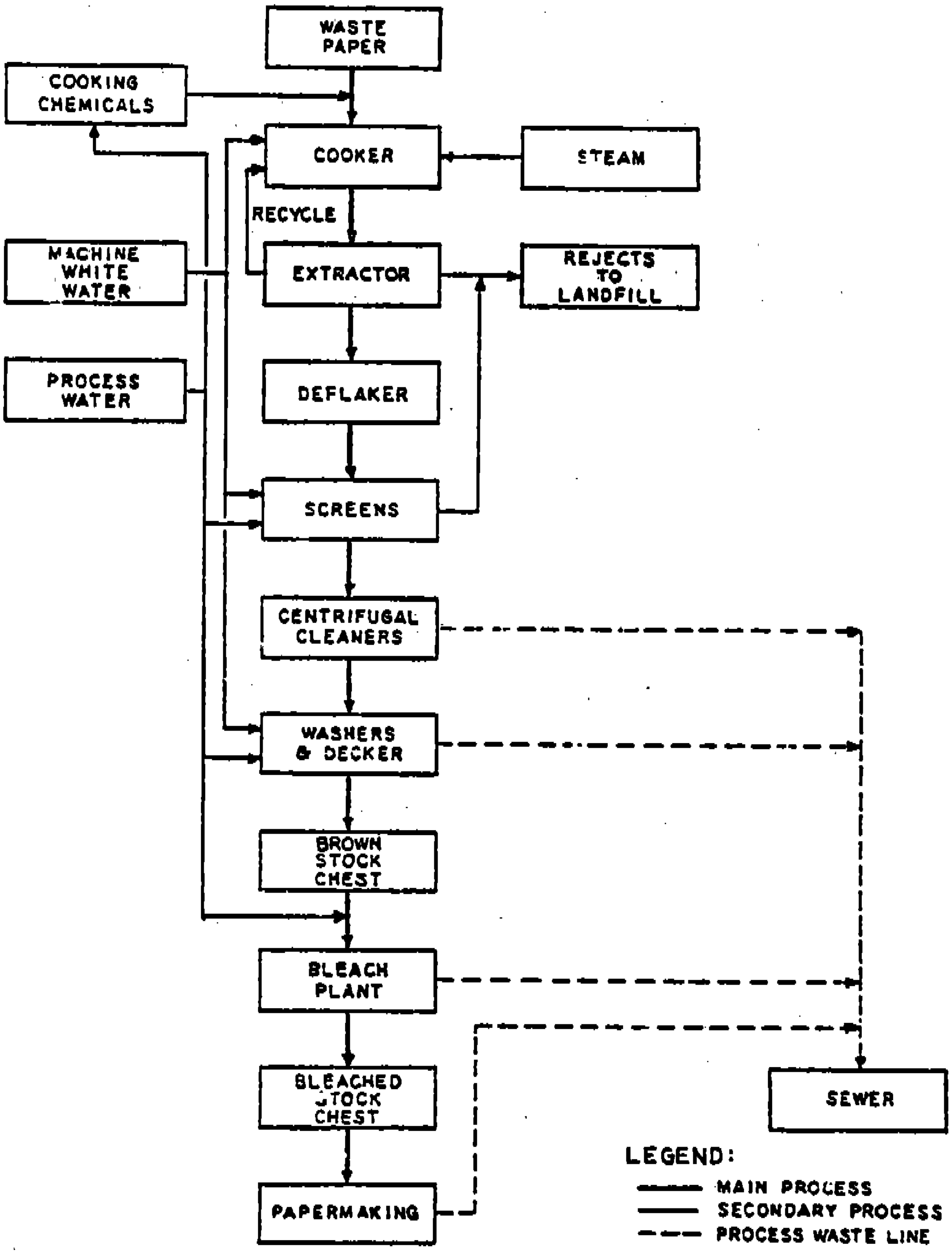

FIGURE 20 DEINKING PLANT PROCESS FLOW DIAGRAM [2]

Either a fourdrinier or cylinder forming machine may be used to make paper/board. The primary operational difference between the two types is the flat sheet-forming surface of the fourdrinier and the cylindrical-shaped mold of the cylinder machine. The type of machine used has little bearing on the raw waste load.

In the fourdrinier operation, dilute pulp, about 0.5 percent consistency, flows from the headbox onto the endless wire screen where the sheet is formed and through which the water drains. A suction pick-up roll transfers the sheet from the wire to two or more presses which enhance density and smoothness and remove additional water. It then leaves the wet end of the machine at about 35 to 40 percent consistency and goes through dryers, heated hollow iron, or steel cylinders, in the dry end.

In the cylinder operation, a revolving wire-mesh cylinder rotates in a vat of dilute pulp picking up fibers and depositing them on a moving belt. The pressing and drying operations are the same as described above. The cylinder machine has the capacity to make multi-layered sheets, which accounts for its principal use in the manufacture of paperboard.

Because of its higher speed and greater versatility, the fourdrinier is in more common use than the cylinder machine. In either case, coatings may be applied in the dry end or on separate coating machines. After initial drying on the papermachine, the sheets may be treated in a size press, and then further dried on the machine. Calender stacks and breaker stacks may be employed to provide a smoother finish, either after drying or while the sheet is still partially wet.

A flow sheet of the fourdrinier operation is presented in Figure 21.

PAPERBOARD MANUFACTURING (3)

Paperboard may be made on both a cylinder and fourdrinier papermachine. The fourdrinier is used to make a single stock sheet while a cylinder machine is used to make a multi-ply board. Paperboard is often made from a waste paper although virgin fiber may be used wholly as a top and/or bottom liner to improve printability and appearance. Virgin fiber is also used where sanitary considerations are important. A typical cylinder machine process for converting waste paper to paperboard is described below.

Waste paper and water are added to the pulper at four to six percent solids. Steam and various chemicals are introduced to aid in fiberization of the waste stock. The waste paper is repeatedly exposed to rotating impeller blades which act to rip, shred, and finally disperse the waste paper.

A junker may be attached to the pulper to collect and remove extraneous solid materials not suitable for use. Such contaminants might include plastics of all types, water-insoluble adhesives, etc. The junker utilizes centrifugal force to accomplish removal of contaminants.

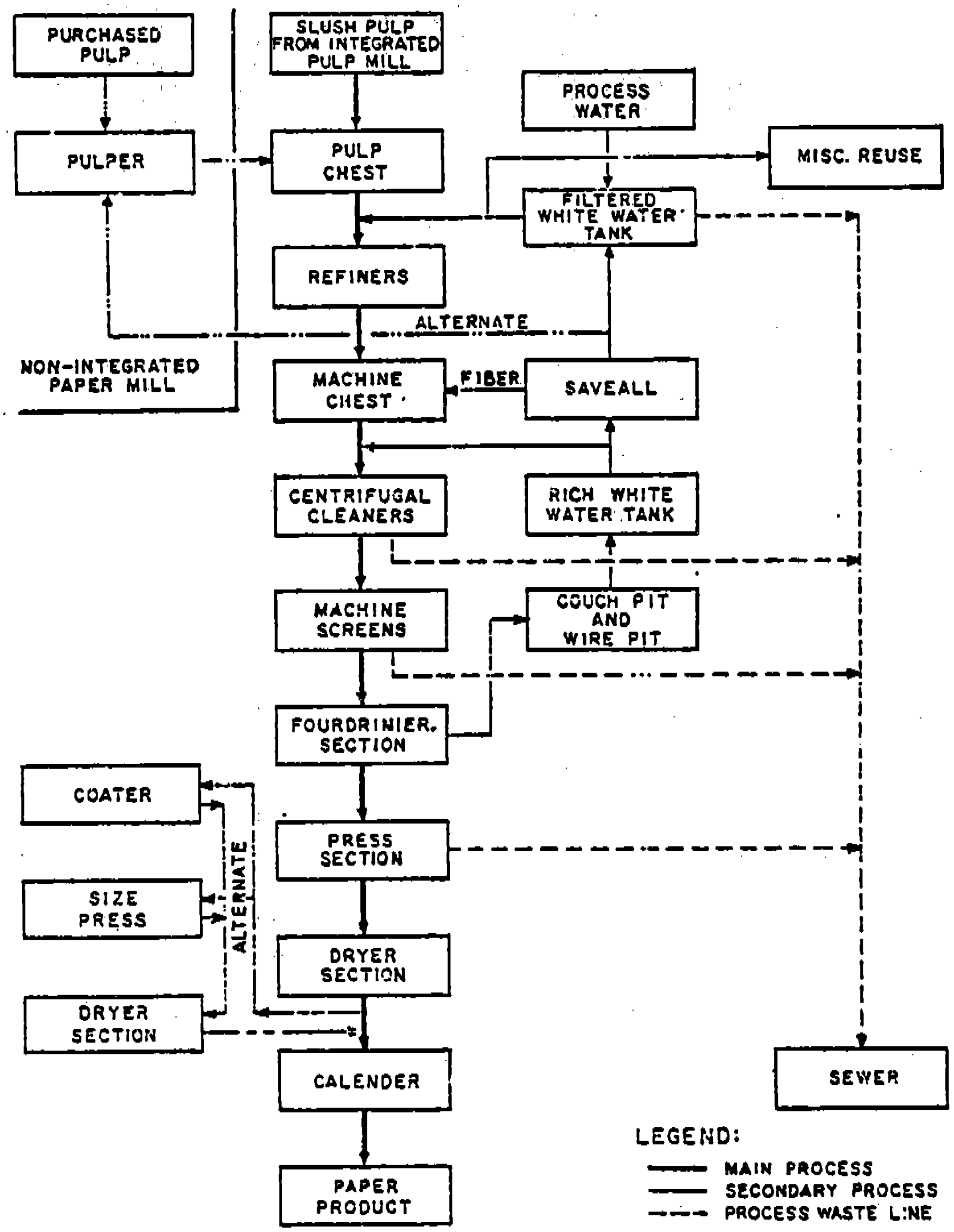

FIGURE 21 PAPER MANUFACTURING PROCESS FLOW DIAGRAM (2)

The stock is passed through centrifugal cleaners or pressure screens to remove contaminants not eliminated in the junker, and is then processed through a thickener which increases the solids concentration of the pulp slurry. From the thickeners the pulp is sent to a dump chest for temporary storage prior to refiners.

The pulp is refined using a conical or disc refiner to impart the desired characteristics to the individual fibers. The pulp is then sent to the machine chest prior to paperboard manufacture where it is temporarily stored prior to final processing and papermaking.

The pulp is diluted to the desired consistency in a mixing box using some of the whitewater obtained from the cylinder machine forming unit. A machine screen, the final cleaning step, removes contaminants from the pulp.

The cylinder machine forming section actually is composed of a number of successive forming units which consist of wire covered cylinders partially immersed in the pulp slurry. Fibers are deposited on the wire while whitewater passes through the screen. The whitewater is collected and sent to a saveall. The paper so formed is removed from the top of the screen through the use of a felt. Papers or plies so formed are joined to produce a layered product which is pressed and dried to form paperboard.

The saveall collects the fiber fines and solid material from the whitewater. These solids are returned to the machine chest. The saveall effluent is reused in the pulper, or is sewered. After leaving the forming section, the board is pressed to reduce the moisture content of the board from approximately 75 percent to 60 percent. After pressing, the paperboard enters the dryer section of the machine. The drying section of the cylinder machine consists of a series of steam heated, rotating drums around which the continuous web of paperboard is conveyed. The purpose of this section is to dry the paperboard to approximately 6 percent moisture.

One optional process is a size press operation. The size press would be located within the dryer section. The general purpose of a size press is to surface treat the board. After the dryer section, the board may be processed through the calender stack. The purpose of the calender stack is to densify the board and smooth or polish its surface.

FABRICATED PAPER PRODUCTS (3)

Paper Coating and Glazing

Most paper coating and glazing operations of interest to these guidelines fall into three major subdivisions, including aqueous-base, solvent-base, and hot-melt coatings.

The constituents of aqueous-base coatings include the following:

Water - acts as the carrier for the dispersed or dissolved components.

Adhesives - provide a liquid vehicle to suspend the pigment during the coating process, to fill the voids between particles of pigment, and to bind them to each other and to the paper. Examples include such natural adhesives as animal glue, casein, and starch, as well as synthetic adhesives such as styrene-butadiene latex.

Pigments - provide the color and opacity. These include white, luminescent, colored, and metallic pigments.

Additives - impart various desired qualities. Some examples include foam controllers, lubricants, preservatives, flow modifiers, and insolubilizers.

Solvent-base coatings are in general, more expensive than aqueous-base coatings, but they offer the advantages of shorter drying times often affording greater production, better water and vapor resistance, and better mechanical properties. From the standpoint of controlling water use within a plant, they also can be readily recovered. The primary ingredients include:

Organic solvent - as with the aqueous-base coatings, these serve as carriers for the dispersed or dissolved components. Numerous organic solvents are utilized, but the largest numbers are esters, alcohols, ketones, and aliphatic and aromatic compounds.

Primary film formers - make up the principal binding portion of the film. These are polymers of high molecular weights. A few examples include nitrocellulose, cellulose acetate, ethyl cellulose, polyethylene, and cyclized rubber.

Secondary film formers - resins used to modify the properties of primary film formers.

Plasticizers - added to improve flexibility, reduce shrinkage, and lessen the tendency of paper to curl.

Pigments and dyes - used to produce desired color.

Fillers - used to extend pigment, increase solids, reduce tackiness, or reduce gloss.

Bronze powders - made from aluminum, copper, and copper-zinc alloys to produce metallic effects.

Hot-melt coatings are ones in which the solid materials that might be in solvent-base formulation are used, but made sufficiently fluid for coating machine application by heat rather than a solvent. The hot-melt coatings utilized include various resins and resinous materials (natural and synthetic), crystalline and amorphous waxes, cellulose derivatives and plasticizers.

Five unit processes are necessary for most coating operations.

1. Preparation and Blending of the Coating Mixture--
Coating mixtures are prepared in batch operations. The ingredients mentioned previously are mechanically mixed in a variety of vessels to prepare them for use.

2. Application of the Coating to the Paper--
A variety of techniques including dip, knife (blade), cast, roll, brush, air-knife, spray, print, extrusion, and strip are used to apply the coatings. However, all application techniques involve the application or transfer of coating to the substrate, metering to regulate coating weights and smoothing or leveling to obtain a plane surface. Aqueous-base coatings are generally applied with a brush coater or an air brush. Knife coaters and roll coaters are used for some applications. Solvent-base coatings, on the other hand, are generally applied either by one of several modifications of doctor knife or by means of some type of roll coater. Hot melts are applied by methods such as gravure, roller, sheet, cast, dip, and equilizer coating.

3. Drying of Paper Web--
Following the application of the coating, the paper web must be dried to enable final processing into rolls, skids, etc. The driers utilized must incorporate two essential processes - the transfer of heat to evaporate the carrier (water or solvent) and mass transfer of the evaporated liquid in vapor form. Production driers utilized are varied in nature and may accomplish heat transfer by convection, conduction, radiation, or a combination of the above.

4. Calendering or Finishing the Surface--
Immediately following the drying process, the paper web is given its final finishing. Often this includes the use of metal rolls to calender or "iron out" the surface of the paper to its desired texture, or the application of embossing rolls which impress a desired design.

5. Cutting or Rewinding, Inspecting, Packing, and Shipping--
Once coated, dried, and finished, the paper web is processed for delivery to the customer. Generally the final products is in the roll form, but sometimes may be cut into sheets, depending on the customer's specifications.

Envelopes

Paper is brought into the plant in roll form and cut into sheets, which are die cut in an envelope press. The envelopes are either printed or left plain, with window punching optional. The envelopes go through a folding and gluing operation, after which they are packaged and shipped.

Bags, Except Textile

Bag plant operations employ one of two major production processes. In one process, roll paper is printed, glued and subjected to shrink-over operations (plastic covering, packaging). In another process, rolls of paper are passed through a bag machine (open-mouth tuber which cuts to tube lengths), glued and sewn, followed by optional shrink-oven operations prior to shipment.

Die-Cut Paper and Paperboard and Cardboard

In making tabulating cards and special forms, roll paper is slit, printed (letterpress or offset) and die cut to form standards cards. They are then packaged (which requires some gluing) and shipped. Special forms require some assembling and gluing before they are packaged. To make single-ply business forms, roll paper is slit, printed, folded, or rewound, and packaged. For multiple plies, the forms are collated (carbon insertion and gluing) before they are packaged.

Pressed and Molded Pulp Goods

As previously mentioned, pressed and molded pulp goods include products molded from a wet pulp; these guidelines will cover only articles that are pressed from a dry paper stock. The products in this category are numerous but, in general, paper stock is printed (if necessary), pressed and cut, finished (lined, coated, etc.), and packaged.

Sanitary Paper Products

Different types of paper are purchased in the form of jumbo rolls. They are unwound, embossed (towels and napkins), and printed, if necessary. Paper stock for towels and bathroom tissue is perforated, rewound and packaged, which requires some gluing. Napkins, tissues, and industrial wipes are cut and folded after the printing operation and then packaged. For sanitary napkins and diapers, the process is essentially a gluing operation to adhere the fluffy pulp layer to the liners.

Stationary, Tablets, and Related Products

In making these items, roll paper is ruled (tablets) or printed (stationary), followed by cutting. All types of printing are utilized, including some photography. Covers are added, and the items are bound by stitching, gluing, or sewing. For plain stationary, roll paper is simply cut and packaged.

Folding Paperboard Boxes

In the folding carton production, large rolls of paperboard are printed then cut, creased, folded, glued and shipped. A varnish or coating may be put on after printing to protect the surface. Printing is usually rotogravure, offset or letter press. Although water-base inks are found in some folding carton plants, they are not common in this type of operation since they do not give as good a quality of color as oil-base inks. Gluing (usually water-base) in a folding carton plant generally refers to a side seam or cellophane window.

Set-up Paperboard Boxes

Rigid boxes are made from four basic materials: paperboard, corner stays, adhesive and covering material. First, flat sheets of boxboard are cut and scored to size. Individual blanks are separated from the sheet and the corners are cut out. Next, the sides of the blank are folded at right angles to the base to form the sides of a tray. The corners of the tray are stayed (sealed and reinforced) by adhering paper, cloth, or metal reinforcements to the corners. The same process is repeated for the cover. Decorative coverings (wrappers) are adhered last. Letterpress and offset are the processes most used in printing wraps.

Corrugated and Solid Fiber Boxes

Corrugated boxes are made by feeding roll paper into a corrugator to form corrugated sheets which are then creased, cut and slit according to box specifications. The blanks are then printed and sometimes coated. The flat box is folded and the side seam is either taped, stitched or glued. Some plants purchase the corrugated sheets rather than form them.

In the corrugating machine, the fluted medium is made on a die and adhered to a kraft liner at the single facer with an adhesive solution of cornstarch, caustic, and borax. The single-faced sheet is then processed through the double backer which applies the second facing, forming a single wall. This process can continue to form double and triple walls. Depending on its size, a corrugator can have several single facers.

Solid fiber boxes are made in a similar fashion, but a different based adhesive (usually polyvinyl acetate) is used and there is no fluting. The solid fiber sheets are finished in the same manner as the corrugated sheets. All types of printing are found in the industry.

Sanitary Food Containers

To make paper cups and plates, roll paper is slit to the desired width, moistened and printed, usually with water-base inks. The paper is then cut and formed into a plate, cup or container (cups and other containers require seam gluing). Plates, cold cups and some food containers go through different degrees of waxing, and are cooled with either air or contact water. The containers are then stacked, wrapped, packaged, and shipped.

Milk cartons and other food containers are made from a polyethylene coated paperboard, which is printed and cut into forms. There is no waxing since the board is already coated when purchased. The side seam is adhered by melting the polyethylene between the layers, so there is no gluing operation. The cartons are then stacked, packaged and shipped.

Fiber Cans, Tubes and Drums

To make these items, large rolls of stock paper are slit to the desired width of the product. An adhesive is then applied to one side of the paper as it is wound to the specified thickness and cut. The units can be left plain, painted, or silk screened, according to customer specifications. Cans and drums may be lined to accommodate the material they will be carrying. For certain items, metal covers and parts are assembled on the ends. Many plants have their own metal forming and finishing operations. These involve cutting fluids, oils, degreasers, varnishes, varnish removers, deburring solutions, and special cleaners and surface preparation solutions.

Blankbooks, Looseleaf Binders, and Devices

Stock paper is sheeted and ruled. The paper is cut to size and holes are punched for certain products. Covers are added and books are bound by either gluing, sewing, or wiring. The finished items are packaged and shipped. The binding process requires metal parts, which are usually made by the company. This includes the fabrication, finishing, and plating of metals.

GUM AND WOOD CHEMICALS MANUFACTURING (4)

This section includes generalized process flowsheets and descriptions for each of the product categories of the gum and wood chemicals industry.

Char and Charcoal Briquets

Char or charcoal is produced by the carbonation of wood, which is the thermal decomposition of the raw wood. The product yield and purity are a function of the kiln temperature. Above 270 C, exothermic reactions set in, and the process can be self-sustaining with the rate of carbonization normally controlled by limiting the air feed to the kiln. Higher temperature reactions produce a higher carbon content product but reduce the product yield. During the decomposition of the wood, distillates are formed and leave the kiln with the flue gases. The condensable distillates are collectively referred to as pyroligneous acid, which contains methanol, acetic acid, acetone, tars, oils, and water. These materials have steadily declined in economic importance because of cheaper methods of producing synthetic substitutes; therefore, most plants have discontinued recovery of the by-products from the pyroligneous acid. Instead, the distillate and other flue gases are fed to an afterburner for thermal destruction before the flue gases are exhausted to the atmosphere. The condensable distillates may also be recycled as fuel for the kiln or recycled in the vapor phase as a fuel supply supplement. The non-condensable gases contain CO_2, CO, CH_4, H_2 and some higher hydrocarbons. The composition of the gases depends on the distillation temperature.

A typical flow diagram for char and charcoal briquets manufacturing is illustrated in Figure 22. During this study, no facilities which recovered distillation by-products were known to exist in the United States. The kiln depicted in Figure 22 is loaded with a payloader. After the kiln is loaded the wood is set afire and allowed to burn under controlled conditions for approximately 72 hours. The air for oxidation is then cut off and water injected in the kiln for quenching. Approximately 18 hours is required for the material to cool down; afterward, it is removed by a payloader. Pine wood char is sold at this point in the process to fill specialized orders. Hardwood char is ground, then blended with starch binder and water for feed to the briqueting operation. The resulting briquets are dried and packaged in bags for sale.

The off gases from the furnaces contain compounds such as acetic acid, methanol, acetone, tars, and oils. These materials are presently oxidized in the afterburners. The natural gas fuel required for the afterburners is a significant operating cost. An alternative emission control is now under consideration, in which off gases from the furnace would be scrubbed to remove the condensables from the flue gases. The resulting scrubber liquor would be sent to a separator where the pyroligneous acid could be recovered. The water and soluble compounds would be reused in the scrubber system. The separated products can then be recovered for sale or used as an auxiliary fuel.

Gum Rosin and Turpentine

Figure 23 illustrates a process flow schematic for the manufacture of gum rosin and turpentine. The crude gum raw material is obtained by gum farmers who collect the gum from scarified longleaf and splash pine trees. The plant receives raw crude gum from the gum farmers in 435-lb. barrel shipments. These shipments contain some dirt, water, leaves, bark, and other miscellaneous trash. Gum is emptied into a vat by inverting the crude gum containers over a high-pressure steam jet. The melter liquifies the crude gum material, and recycled turpentine is added to reduce the viscosity. This mixture is filtered through a pressure filter and collected. The trash is periodically removed and hauled to a landfill. The filtered gum is then washed with water. Because iron and calcium causes gum rosin to discolor at high temperature, a small amount of oxalic acid may be added to the wash water to precipitate the iron and calcium as an insoluble acids and oxalite precipitate, and is then discharged for treatment. The prepared crude gum material is then distilled to separate the turpentine.

Non-contact shell-and-tube steam heating and sparging steam are used in the stills. Turpentine and water are distilled overhead and condensed with shell-and-tube condensers. The water is separated from the turpentine in the downstream receivers as shown in Figure 23. The turpentine product is

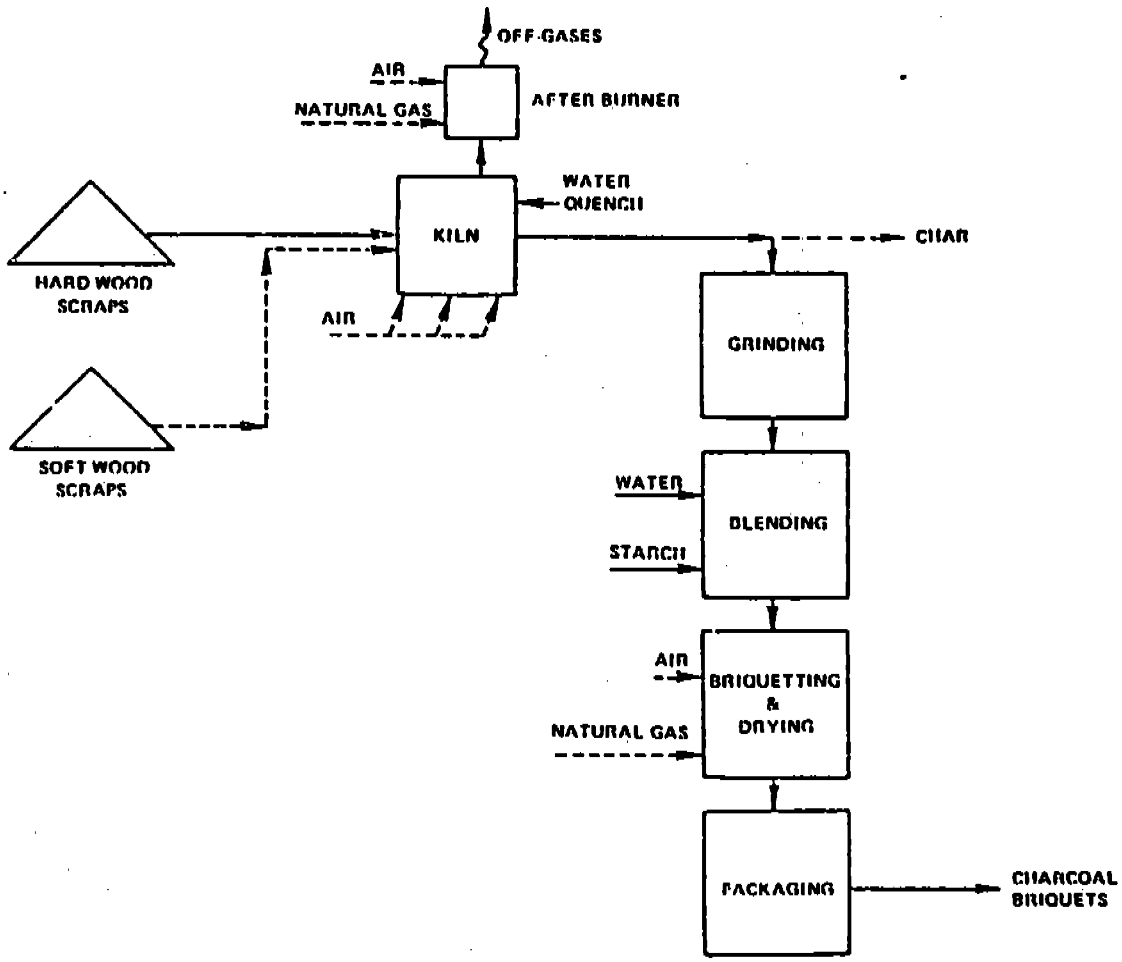

FIGURE 22   CHAR AND CHARCOAL BRIQUET MANUFACTURING (4)

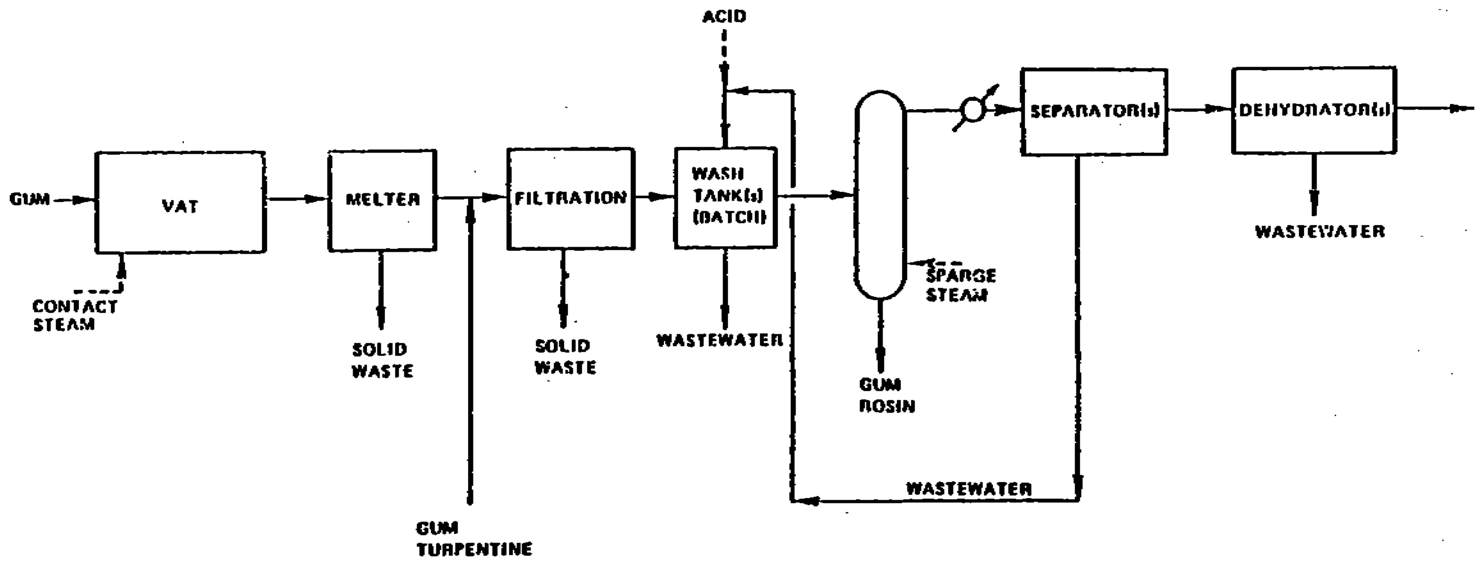

FIGURE 23 GUM ROSIN AND TURPENTINE PRODUCTION (4)

dried with a sodium chloride salt dehydrator, and the gum rosin is removed from the still after each batch distillation in a fluid state and packaged.

Wood Rosin, Turpentine, and Pine Oil

The raw material for this process is stumps obtained from the cut over pine forests of the southern United States. The stumps are uprooted by bulldozers and freighted to the extraction plant on railroad flat cars.

Figure 24 is a flow schematic diagram of the solvent extraction/steam distillation plant which was surveyed.

The pine stumps from 40- to 60-year old longleaf pine trees are brought into the plant. The stumps are placed on a conveyor and are washed with 1,000 gpm of water at a pressure of approximately 110 psi. The water and dirt flow to a settling pond where the dirt settles out and the water is recycled back to the washing operation. The accumulated dirt is periodically removed to landfill. Wood hogs, chippers, and shredders mechanically reduced the wood stumps in size in a sequence operation until they become chips approximately 2 inches in length and 1/16 inch thick. These chips are placed into intermediate storage. The wood chips are fed to a battery of retort extractors. The extraction process is accomplished in sequential steps as follows:

1. Water is removed from the chips by azeotrophic distillation with a water-immiscible solvent.

2. The resinous material is extracted from the wood chips with a water-immiscible solvent.

3. Residual solvent is removed from the spent wood chips by steaming.

After the final step, the spent wood chips are removed from the retort and sent to the boilers as fuel. During Steps 1 and 3, the steam solvent azeotrope from the retorts proceeds to an entrainment separator. Any entrained wood fines coming from the retorts are removed in the entrainment separator and are used in the furnace as fuel. The vapors from the entrainment separator are condensed and proceed to one or more separators where the solvent-water mixture separates. The solvent is recycled for use in the retorts.

The extract liquor leaving the retorts during Step 2 is placed into intermediate storage tanks prior to further processing. The contents of these tanks are sent to a distillation column to separate the solvent from the products. The column is operated under vacuum conditions maintained by a steam-jet ejector. The overhead from the column is condensed and enters a separator where a condensed solvent is removed and recycled to the retorts. The vapor phase from the separator, along with the steam from the ejector, is condensed in a shell-and-tube exchanger and enters a separator. Here the remaining solvent and the condensed steam from the ejector are separated. The solvent is sent to recycle and water to treatment.

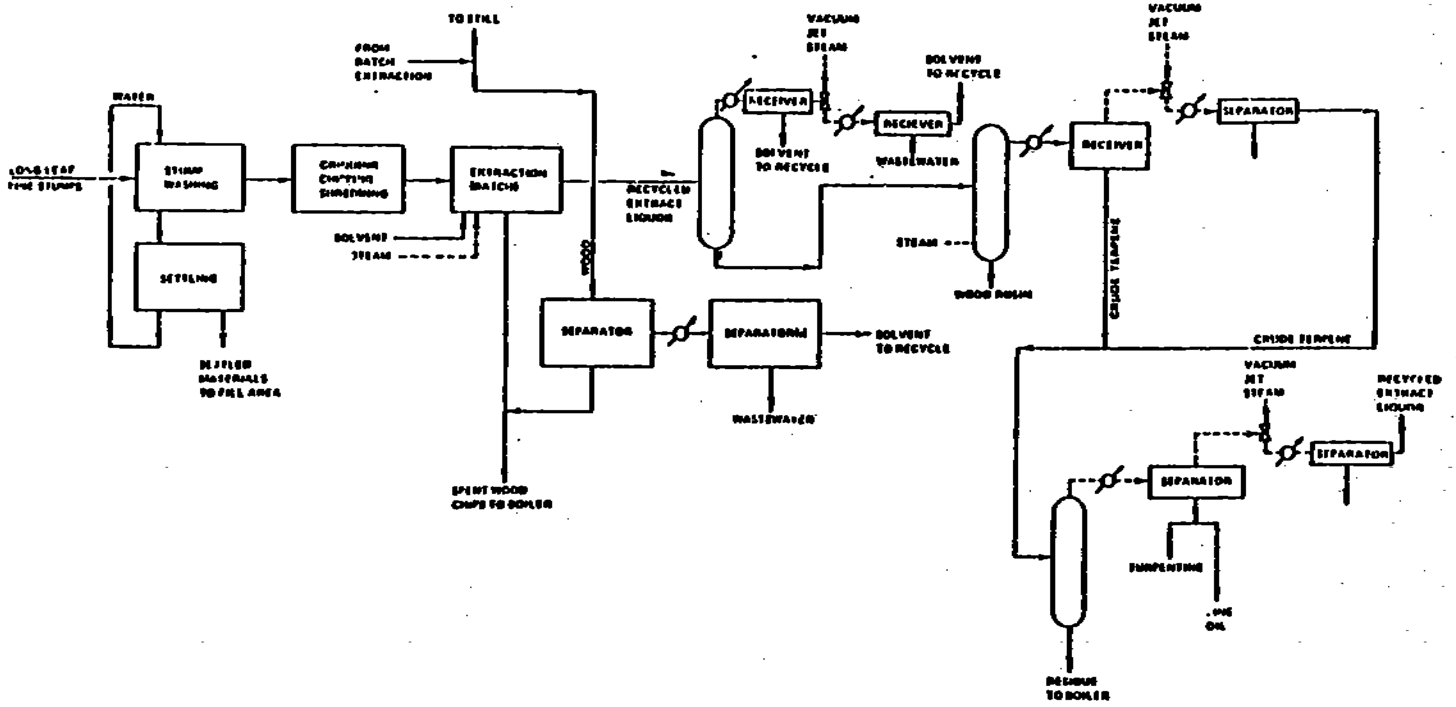

FIGURE 24 WOOD ROSIN, PINE OIL, TURPENTINE PRODUCTION VIA SOLVENT EXTRACTION (4)

The bottoms stream from the first distillation column enters a second distillation column, also operated under vacuum, as shown in Figure 16. Steam is introduced into the bottom of the tower to strip off the volatile compounds. This overhead stream enters a condenser and separator. A portion of the condensed liquor phase is refluxed back to the distillation column, while most of it is stored as crude terpene for further processing. The steam from the vacuum ejector and the vapor phase from the separator are condensed in a shell-and-tube exchanger and then sent to a separator. The non-aqueous phase from the separator is stored as crude terpene while the aqueous phase is removed as wastewater. The bottom stream from this second distillation column is the finished wood rosin product.

The crude terpene which has been removed in the second distillation column, is stored until a sufficient quantity has been accumulated, then this material is processed in a batch distillation column. The distillation column is charged with the crude terpene material, the overhead vapors are condensed in a shell-and-tube exchanger, and the condensed material enters a separator. The turpentine and pine oil products are removed from this separator while the vapors and the steam from the steam ejector enter a second shell-and-tube exchanger and proceed to a separator. The nonaqueous phase from the separator is recycled to the extract liquor storage while the aqueous phase is sent to wastewater treatment. The bottom from this batch distillation column is a residue containing high-boiling point materials, best described as pitch. This residue is used for fuel.

Tall Oil Rosin, Fatty Acids, and Pitch

Technology for the production of high-purity tall oil rosin and fatty acids is relatively recent compared to the age of the wood and gum rosin manufacture. The first commercial fractionation process was completed in 1949 by Arizona Chemical. The Arizona plant employed partial vacuum distillation techniques in the petroleum refinishing industry and adapted to protect the integrity of tall oil's heat-sensitive constituents.

Modern fractionation techniques yield fatty acids which contain less than two percent rosin and rosins which contain less than three percent fatty acids. Distillation techniques employed prior to the current fractionation technology employed steam distillation which produced rosin and fatty acid products with relatively high cross-product contamination.

The plant surveyed during this study employed modern fractionation distillation techniques. A schematic process flow diagram of this crude tall oil (CTO) fractionation process is presented in Figure 25. The plant fractionates CTO to produce approximately 20 percent pitch, 49 percent fatty acids, and 31 percent rosin. In addition, part of the plant's pitch and rosin production is used captively for the production of paper sizes.

The CTO is treated with dilute sulfuric acid to remove some residual lignins plus mercaptans, disulfides, and color materials. Acid wash water goes to the process sewer. The CTO then proceeds to the fractionation

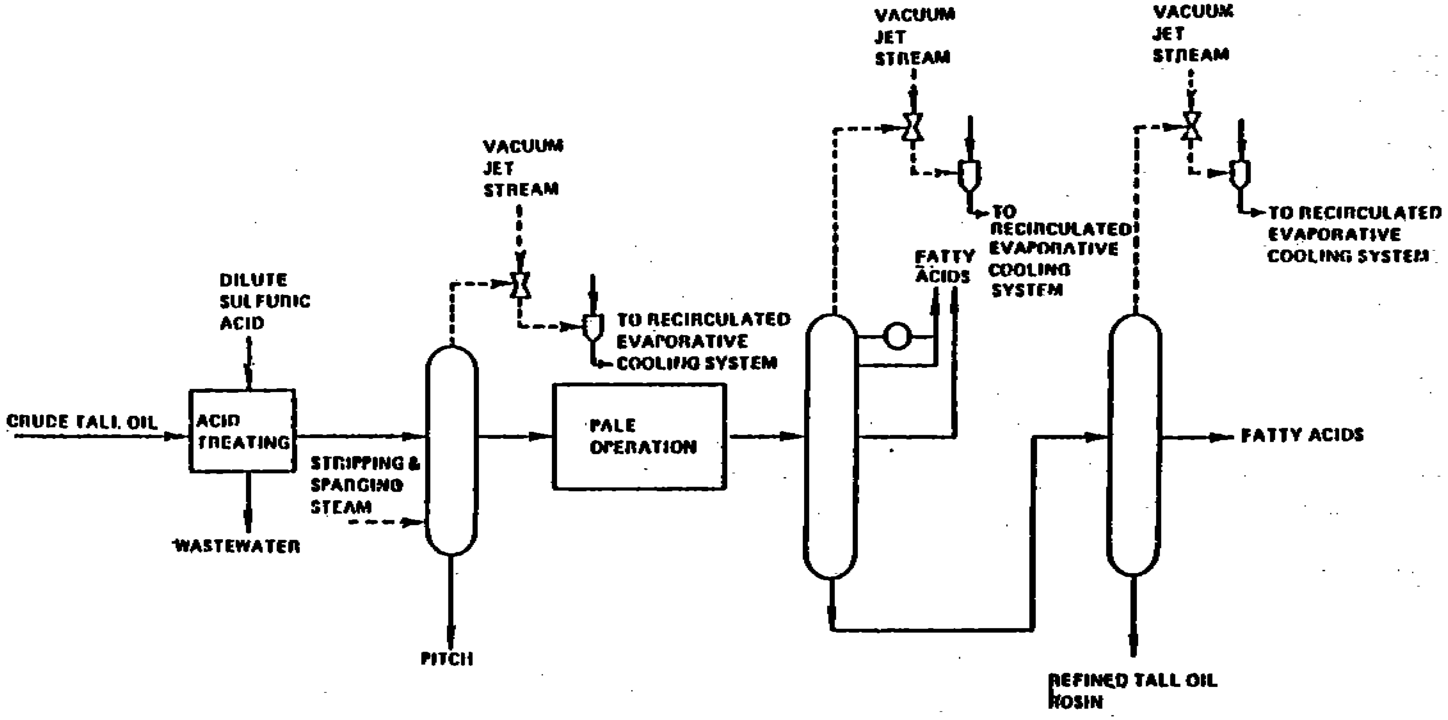

FIGURE 25 CRUDE TALL OIL FRACTIONATION AND REFINING (4)

process. In the first fractionation column, the pitch is removed from the bottoms and is either sold, saponified for production of size, or burned in boilers to recover its fuel value. The remaining fraction of the tall oil (rosin and fatty acid) then proceeds to the pale plant, where the quality of the raw material is improved through the removal of unwanted materials such as color bodies. The second column in Figure 25 separates low-boiling point fatty acid material while the third column completes the separation of fatty and rosin acids.

Barometric contact condensers are employed to condense the vacuum-jet steam. The recirculated barometric contact water is cooled by a holding reservoir, while light-separable organics are removed by means of an induced draft cooling tower. Once-through cooling water is used in non-contact column reflux and product heat exchangers.

Essential Oils

Figure 26 is a process flow schematic diagram for steam distillation of cedarwood oil from scrap wood fines of red cedar.

Raw dry dust from the planing mill and raw grain dust from the sawmill are mixed to obtain the desired blend and then fed pneumatically to mechanical cyclone separators which are located on top of the retorts. After loading, the extraction of oil of cedarwood is accomplished by injecting steam directly into the retort as shown in Figure 26. The steam diffuses through the cedarwood dust, extracting the oil of cedarwood, exits through the top of the retort, and is condensed to an oil/water mixture.

Following the steam extraction, the spent sawdust is allowed to cool for approximately two hours. The spent sawdust is then conveyed to storage from where it is eventually fed as fuel to the steam generators.

The primary product is a crude light oil which is separated by two oil/water separators immediately downstream of the condensers. The light oil is removed and mixed with clay. The clay lightens the product by removing color bodies and stabilizes the color of the product by inhibiting further oxidation. The clay/oil slurry is filtered through plate and frame pressure presses and the spent clay filter material is hauled to landfill for final disposal. The lightened oil product proceeds to bulk storage, blending, and is finally drummed for shipment.

The water phase, which is separated in the stillwells, contains a heavy red crude oil. This material is separated from the water phase in three settling tanks in series. The heavy red oil is periodically removed and drummed for sale as a co-product, while the underflow, or remaining water phase, is discharged as wastewater.

The cedarwood oil process has been described and the operation is representative of this category for production of other essential oil products.

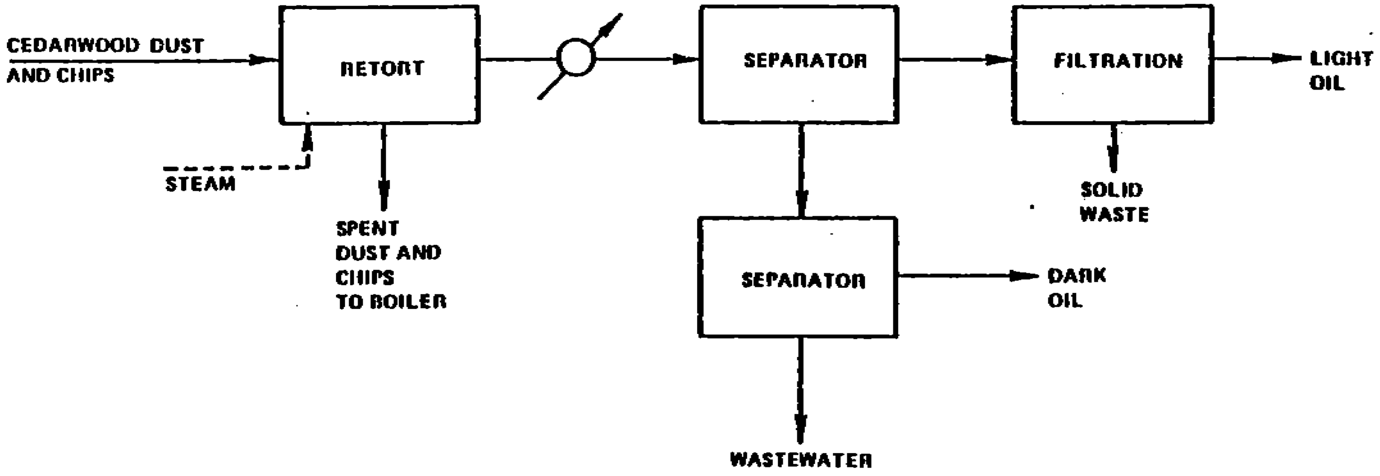

FIGURE 26 DISTILLATION AND REFINING OF ESSENTIAL OILS(4)

Rosin Derivatives

Most of the rosins produced in the United States are actually rosin derivatives. Prior to the development of rosin derivatives, rosin was used in the production of printing inks, linoleum, varnishes, electrical insulation, foundry core oils, leather, matches, adhesives, masonry, and solder fluxes. Rosins have some undesirable properties which include a tendency to crystallize from the solvents employed, oxidation of the unsaturated chemical bonds, and reaction with heavy metal salts. Rosin derivative manufacturing has modified the various rosins to eliminate these undesirable properties and to enhance their application in the foregoing areas of application and other new areas.

It should be noted that there are many rosin-derivative manufacturing processes including isomerization, oxidation, hydrogenation, dehydrogenation, polymerization, salt formation, and decarboxylation.

Process operating conditions in the reaction kettle are dependent on many variables, such as product specification and raw materials. For example, if a simple ester is produced from stump wood rosin (ww grade) and U.S.P. glycerin, and the esterification reaction takes place under high-temperature vacuum conditions. During the process, a steam sparge (lasting approximately two to three hours) is used to remove excess water of esterification, which allows completion of the reaction and removes fatty acid impurities for compliance with product specifications. The condensable impurities are condensed in a non-contact condenser on the vacuum leg and stored in a receiver. Non-condensables escape to the atmosphere through the reflux vent and steam vacuum jets. Phenol and maleic anhydried-modified tall oil rosin esters are also produced. The process operation is very similar to simple rosin ester production except that steam sparging is seldom if ever used, and other polyhydric alcohols may be used in the product formulation.

Rosin-based esters of maleic anhydride, fumaric acid, substituted phenolic, and other modified rosin-based esters, as well as a glycerol phthalate alkyd can be produced under modified conditions. Kettle cook times and pressure conditions vary with type of product. No contact sparge is used at the end of the cook to remove lights and odors. Unwanted materials, such as fatty acids, water of esterification, and sparge steam, are removed from the kettle by means of the vacuum leg. Condensable materials are condensed in a non-contact condenser and separated from the non-condensables in the receiver. Separable materials, such as fatty acids and reaction and reflux oils, are separated from the process wastewaters in the separator. Vacuum jet steam and most noncondensable materials are removed in a scrubber which uses a recirculated oil stream from the separator. The oils are recovered for a secondary market.

BUILDING PAPER AND ROOFING FELT (5)

Stock Preparation

Fibers are prepared for use by various methods which are determined by the fiber source. Wood chips are pulped mechanically in an attrition mill. This is a refiner containing fixed and rotating discs between which the chips pass on a stream of water. In some operations, this is preceded by cooking, or streaming, the chips with water for a short period in a digester, a large metal pressure vessel. This softens the chips and reduces the mechanical energy required. Chemicals are not generally utilized.

The pulp is discharged from the attrition operation as a slurry which goes to a stock chest for storage. It is then blended with other raw materials. Wood flour requires no pretreatment and enters the system in the blending chest.

After they are cut and shredded, rags are placed, along with fresh or process water, in a beater tank at about six percent consistency. Here a rotating cylindrical bladed element, which operates in conjunction with stationary blades, both impacts the fiber and causes its continuous circulation around the beater and back through the attrition zone. Thus, progressive fiberizing occurs. After a period of several hours, when the charge is sufficiently defibered, the pulp is diluted and removed to a dump chest.

Waste paper is similarly treated in beaters or pulpers. In the pulper operation, the paper follows the water circulation in a large open vat and is repeatedly exposed to rotating impeller blades. Over a period of time it is ripped, shredded, and finally defibered. Accessory equipment separates and removes metal and other contaminants.

After the stock is blended, it is subjected to refining and screening ahead of the forming process.

Some building papers are highly sized with resins and alum. Felts may be sized with bituminous materials or contain moldproofing or fungicidal materials.

Papermaking

These products are manufactured principally on single-cylinder paper machines from the raw materials reduced to fiber in the stock preparation area and transported to the machine in a dilute slurry. A rotating wire-covered cylinder retains the fibers which form a sheet on its surface and permits water to drain through. This sheet is then removed from the wire by a cloth felt which carries it through a press section where additional water is removed from the sheet. It is self-supporting as it leaves the press sections and passes through the steam-heated multi-drum drier section from which it is cut to width and rolled. At this stage it is considered a dry or unsaturated felt.

Asphalt Saturating Process

For some products, the paper is carried through one or two stations for asphalt saturation and application of a coat of talc on one side of the sheet. This requires the utilization of cooling water applied by spray nozzles after each saturation which represents the waste load sewered from the area. This process has the capability of making roofing shingles as well as roofing felts; therefore, a section for coating the saturated felt with a granular stone and/or mica is part of the operation.

A process flow diagram of a building paper and roofing felt mill is shown in Figure 27.

SAWMILLS AND PLANING MILLS (6)

The primary function of any sawmill is to reduce a log or cant to a usable end product. The process employed to accomplish this function consists of a combination of basic unit operations including the following:

- mill feed
- log washing
- debarking
- sawing
- resawing
- edging
- trimming
- lumber handling
- lumber finishing

It should be emphasized that several of the above operations may not be practiced at a specific plant. The following process description is a discussion of operations listed above including a discussion of some of the variations within each unit that are most common in the industry.

Mill Feed

The majority of mills utilizing land storage of logs as opposed to water storage are fed by using a variety of loading equipment, most commonly front-end loaders. The loader picks up the log and simply places it on a ramp or deck equipped with moving chains which transport the log into the mill. Some mills, however, utilize ponds or flumes for mill feeding purposes. Ponds may be used for sorting and washing prior to entering the mill. Ponds and other water bodies used for storage are also used for sorting purposes. Log flumes are utilized for mill feeding by relatively few sawmills. In those mills utilizing flumes, ponds or other water bodies for feeding, the logs are floated to the mill entrance where a chain belt or bull chain carries the logs out of the water and into the mill.

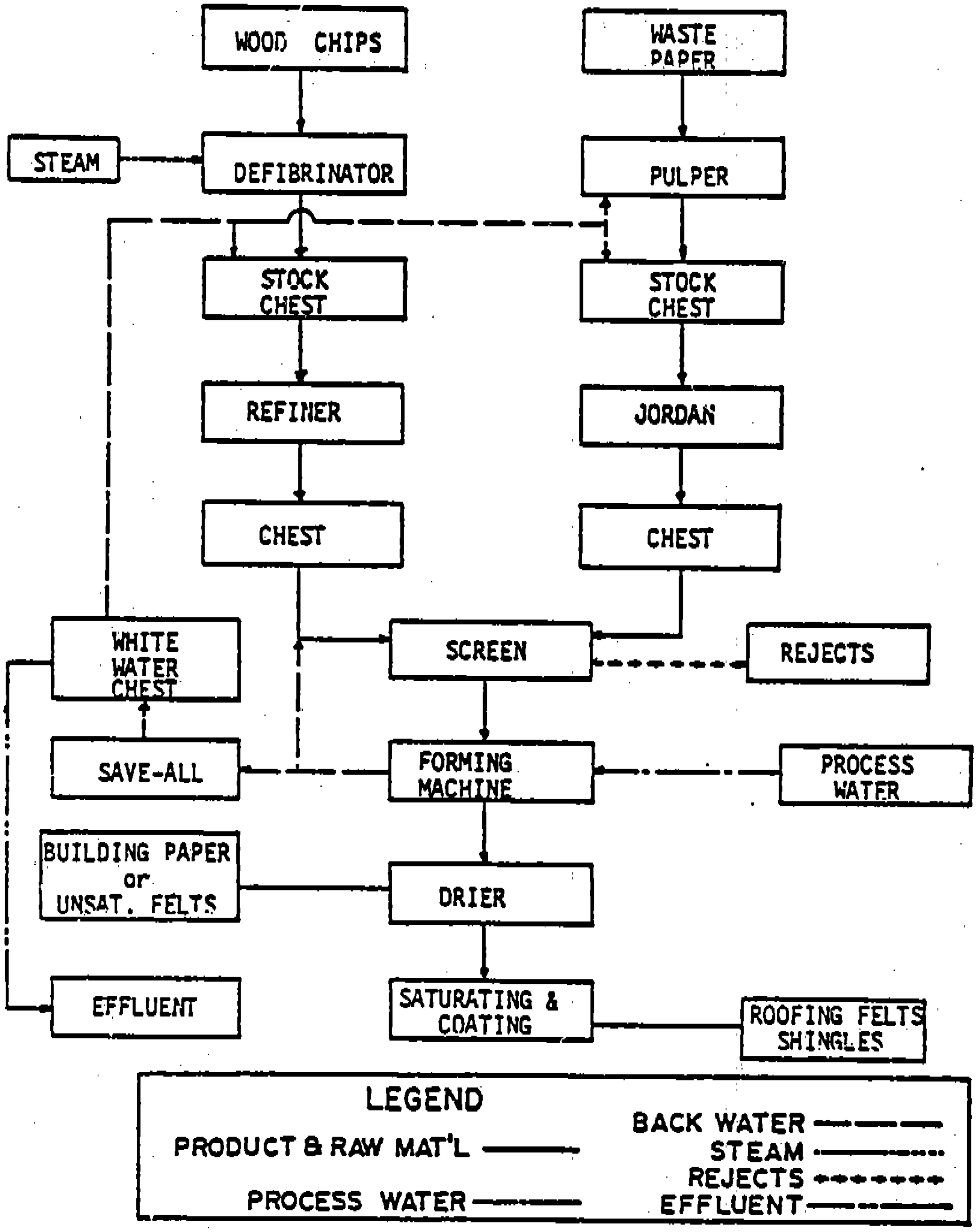

FIGURE 27 BUILDING PAPER AND ROOFING FELT PROCESS DIAGRAM (5)

Log Washing

Log washing may be practical prior to barking and/or sawing. While the desirability or necessity of this practice cannot be clearly established, some of the reasons for its use are as follows: (1) where bark is utilized as a fuel, log washing prior to barking reduces the amount of slag buildup on boiler grates and, consequently, reduces frequency of grate washdown. Also, if bark is used for other purposes, a minimal amount of grit is desirable; and (2) for mills not barking prior to sawing, log washing increases saw life.

Log washing is accomplished by spraying water on logs from fixed nozzles as the logs are transported into the mill. In practice, pressure and volume of water utilized vary from mill to mill, but pressures are on the order of 6.8 atmospheres (100 lb per inch^2) while the volume of water varies from less than 5 to 17 lps (80 to 265 gpm).

Headrig Operation

The term headrig is used by the industry to include all the machinery which is utilized to produce the initial breakdown of a log to boards, dimensions or cants. Thus, a headrig includes the feed works, the setworks, the carriage and shotgun, the headsaw, chipper or chipper saw, and all the controls associated with the above.

The basic headrig consists of a single diesel or electric powered circular saw and a log carriage. The carriage is a platform on wheels equipped with hydraulic or electric setworks which hold the log as the carriage moves parallel to the saw. The setworks, which are controlled by the sawyer, position the logs for sawing. The carriage is powered by a shotgun which may be air, hydraulic, or steam powered. The shotgun is a long, circular tube in which a ram is inserted. One end of the ram is attached to the carriage and the other is fitted with a piston head. A compressor or pump pressurizes the working fluid behind the piston and thus powers the carriage in one direction. By rotating a valve spool the sawyer can reverse the direction of the piston and the carriage. Figure 28 gives an equipment layout for a hydraulic shotgun.

Another type of single saw headrig utilizes a band saw. A typical band saw is 25 cm to 30 cm (10 to 12 inch) wide, 11 to 12 m (35 to 40 ft) long, and is mounted on two saw wheels, one above the other, each with a diameter of two to three m (six to ten ft). The band saw is tensioned and driven by the saw wheels and may be one-sided or two-sided. The log is placed on the carriage and sawn as it passes the saw which is moving vertically downward.

Ahead of either the band saw or the circular saw may be a chipper. The chipper is used to square the side of the log prior to sawing and thus eliminates the slab which would otherwise result from sawing.

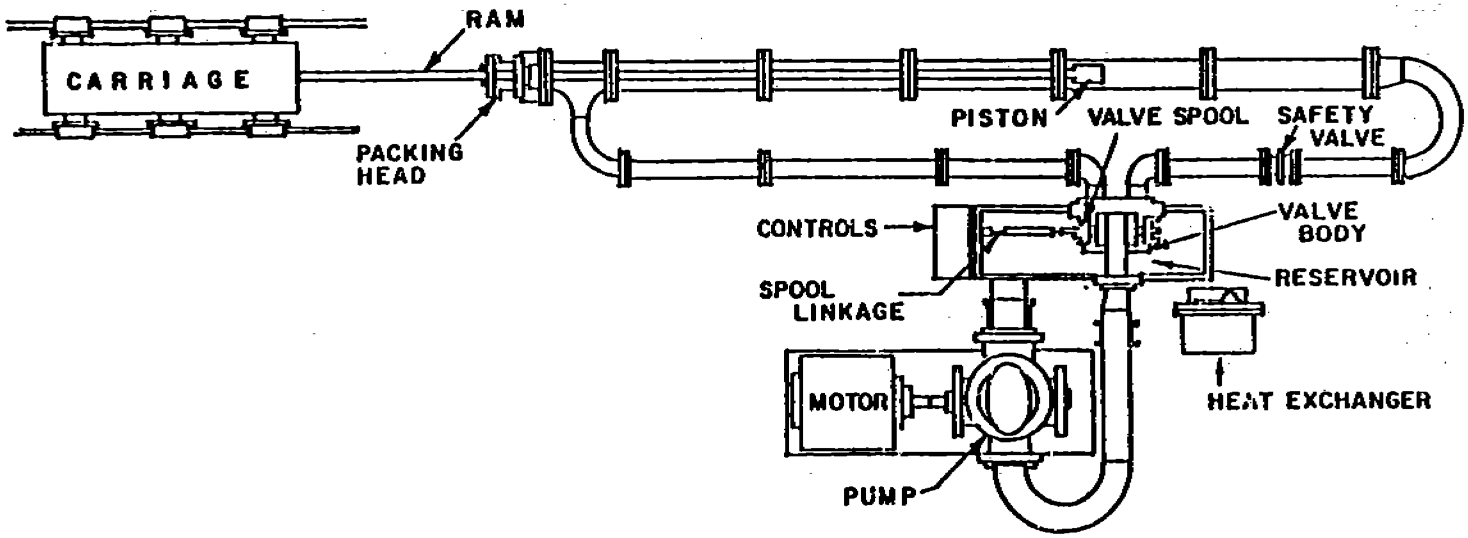

FIGURE 28 HYDRAULIC SHOTGUN (6)

The nature of subsequent sawing operations will depend on the degree of breakdown accomplished in the headrig and the desired end product from the mill. In general, the function of these operations is to reduce the width or thickness of the lumber or to square the edges or ends. The basic unit operations following the headrig are gang sawing, resawing, edging, and trimming. The gang saw may be the reciprocating type, or a set of circular saws usually of a movable, double arbor type. The gang saw reduces a cant to lumber of desired thickness. Resaws are usually vertical band saws and are used to saw thick boards into thinner ones. These may be single, double, or quad band resaws. Following resawing, or remanufacturing as it may be termed, the lumber enters the edger. Edgers vary widely in size and capacity but usually consist of one stationary circular saw and one or more circular saws that can be moved laterally on the arbor to permit ripping different widths. Trim saws are circular saws used to square the ends of the lumber and to remove serious defects.

Following edging and trimming, the rough green lumber is sorted and stacked. The lumber may first flow into a green chain and be graded, sorted, and stacked, or it may be graded and sorted by placing it in appropriate sorting troughs. If the lumber is to be marketed green, it may be passed through a preservative bath, usually pentachlorophenol, prior to stacking. The duration of the dip is usually less than one minute.

Dying of lumber is accomplished by either air seasoning or by kiln drying. Air seasoning is accomplished by segregating, coating, and piling. Segregation is done based upon green board weight so that a given pile will dry at the same rate. Prior to its being stacked, the lumber may be treated with chemicals by spraying, brushing, or dipping in order to prevent blue stain and other fungal attack. Various coatings may also be applied to the end of the lumber to retard checking. The most common of these is paraffin or other wax emulsions. The lumber is then stacked in such a manner as to provide adequate air circulation and left to dry for a period of time that may extend to several months.

Kiln drying is accomplished by placing green lumber into a humidity and temperature controlled kiln. The kiln is heated by steam or other means, generally by indirect radiation from coils. Air circulation is maintained by forced draft or by natural circulation. Humidity is controlled by steam sprays. The lumber is stacked mechanically or manually outside the kiln with sticks of wood used to separate the boards. The stacks are then moved into the kiln where they will remain until the desired moisture content is reached. Temperature, humidity, and drying time will vary with kiln type, wood species, initial moisture content, and various other factors. In general, however, kiln drying is accomplished in two to five days at dry-bulb temperatures ranging from 49 to 82°C (120 to 180°F). For some cases, high temperature drying, i.e., above 93°C (200°F) is also employed to reduce drying time.

Dried lumber is quite often planed to desired smoothness. The surfacing tools used are planer knives attached to rotating cutterhead. The quality of finish is a function of the number of knives, the rotations per minute of the cutterhead, the feed rate of lumber through the planer, and other factors. Lumber may be surfaced on one, two, or four sides by the addition of an equal number of cutting heads.

After planing the lumber may proceed through one or more of the following processes:

- preservative dipping
- staining
- end-coating
- moisture proofing

Preservative application is generally accomplished by the methods previously discussed for green lumber handling. Staining, usually with a water base material, is done merely to produce a more pleasing color in the finished lumber. This is generally accomplished by a spray nozzle as the lumber passes through the spray compartment. Excess spray is recirculated. End-coating prevents the ends of the lumber from checking while it is in storage or in service. This is generally done by spraying the end of the lumber with any of various materials such as paint or wax emulsions. Any material which will seal the end of the lumber and is easily applied will suffice. Moisture resistant compounds are sometimes sprayed on the finished lumber to increase durability and resistance to weathering. Compounds specifically formulated for this purpose are available from several manufacturers and are applied in a similar fashion to the stain application discussed above. These materials are generally water soluble.

As previously mentioned, a sawmill is a combination of some or all of the above unit operations. The process diagrams shown in Figures 29 through 31 will serve to illustrate some of these possible combinations and some possible mill layouts.

Figure 29 illustrates a process layout for a small rough green sawmill. Figure 30 illustrates the combination of wet and dry deck storage of logs, with a small to medium size band sawmill and a planing mill. Figure 29 gives a possible layout for a medium-to-large sawmill.

It should be noted that planing mills may exist in combination with sawmills or may be independent mills buying from a number of suppliers. It should also be noted that other unit operations may be present at a sawmill or planing mill. The most common of these additional operations is edge or end jointing of lumber in sawmills and production of millwork in planing mills.

Miscellaneous Operations

There are a number of wood products which are produced by further processing or manufacturing of such primary forest products as lumber, plywood and board products. The large number of such products prohibits a

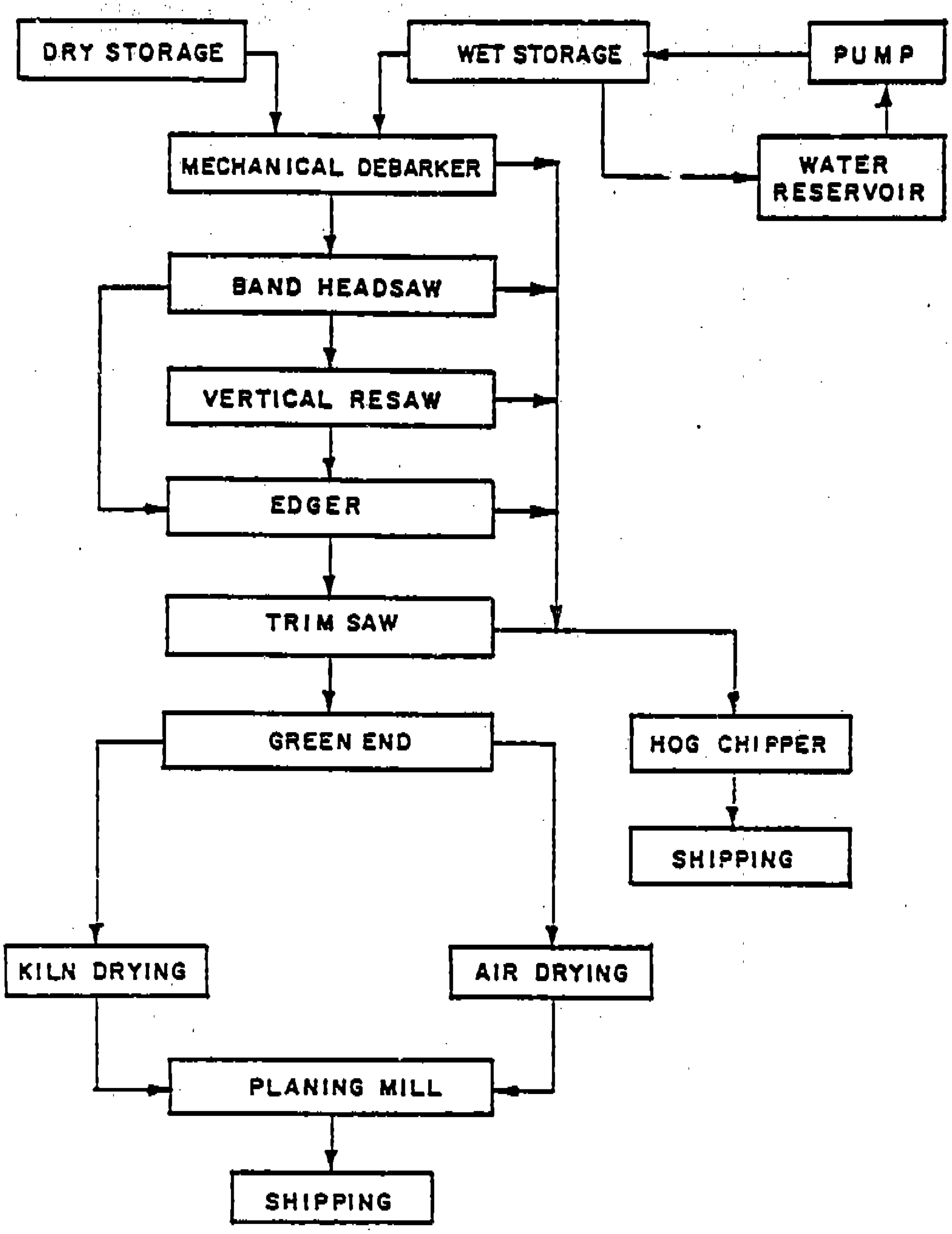

FIGURE 30 PROCESS DIAGRAM OF BAND SAWMILL(6)

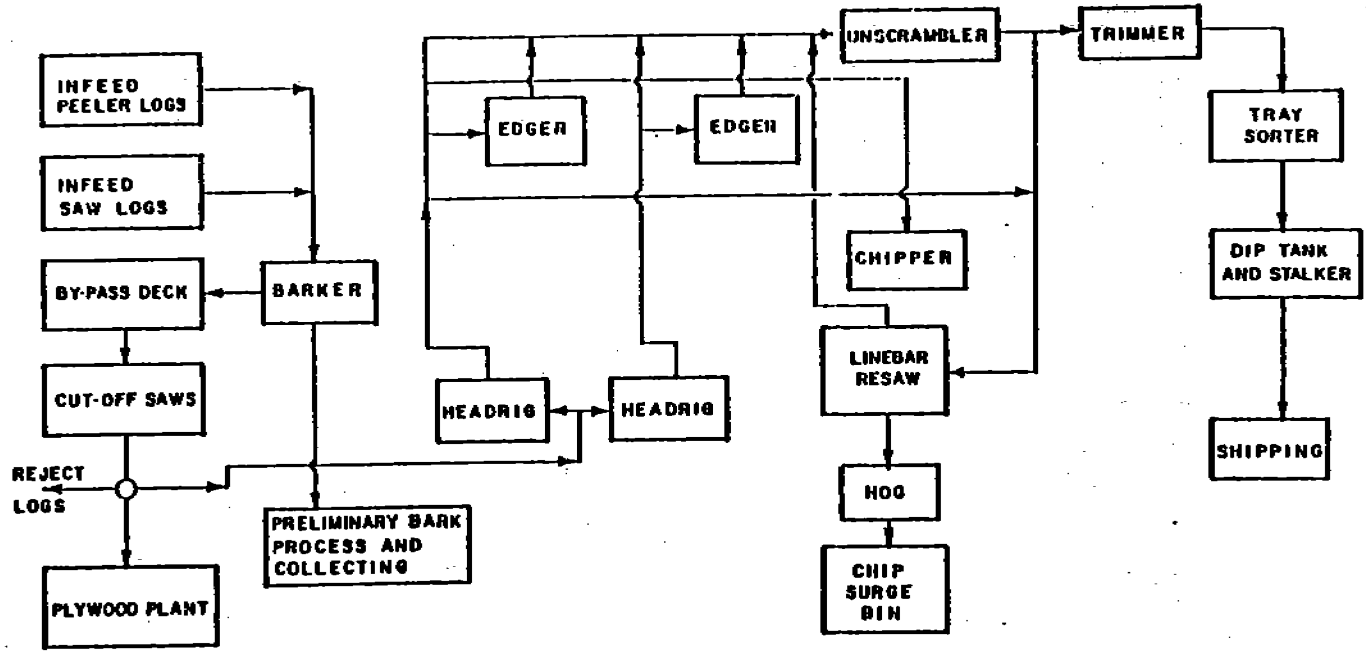

FIGURE 31 PROCESS DIAGRAM MULTIPLE HEADRIG SAWMILL (6)

ers whose operations are not aided by prior heating to the same degree as the wet barking methods, 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, the 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.

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.

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

Drum 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 one cylindrical shell rotating on its 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--

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 inches) in diameter.

Bag Barkers--

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.

Veneers are cut to thicknesses ranging from 0.254 to 9.55 mm (1/10 to 3/8 inch). Most of the rotary cut veneers are either 3.6, 3.2, 2.5, 1.7, or 1.3 mm (1/4, 1/8, 1/10, 1/15, or 1/20 inch) thick. Sliced veneer usually ranges from 1.27 to 0.635 mm (1/20 to 1/40 inch). Sawn veneers vary from 6.35 to 0.795 mm (1/4 to 1/32 inch) 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 salvage veneer. These operations may include grading and matching, redrying, dry-clipping, jointing, taping and splicing, and inspecting and repairing. These operations are self-descriptive and completely mechanical or manual except for jointing and splicing which may use some sort of adhesive. 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 Operation

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

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 used to produce both interior and exterior plywood so that the use of phenol-formaldehyde is increasing rapidly. At present, phenolic glues comprise about 50 percent of all glue consumed.

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 usually 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 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 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 produce desired, may be taken. These operations include (1) redrying, (2) trimming, (3) sanding, (4) sorting, (5) molding, and (6) storing.

WOOD PRESERVING (7)

The wood preserving process consists of two basic steps: 1) preconditioning the wood to reduce its natural moisture content and to increase the permeability, and 2) impregnating the wood with the desired preservatives.

The preconditioning step may be performed by one of several methods including 1) seasoning or drying wood in large, open yards; 2) kiln drying; 3) steaming the wood at elevated pressure in a retort followed by application of a vacuum; 4) heating the stock in a preservative bath under reduced pressure in a retort (Boulton process); or 5) vapor drying, heating of the unseasoned wood in a solvent to prepare it for preservative treatment. All of these preconditioning methods have as their objective the reduction of moisture content of the unseasoned stock to a point where the requisite amount of preservative can be retained in the wood. Preconditioning also results in a more permeable stock allowing penetration of the preservative into the wood as required by American Wood Preservers' Association (AWPA) standards.

Conventional steam conditioning (open steaming) is a process in which unseasoned or partially seasoned stock is subjected to direct steam impingement at an elevated pressure in a retort. The maximum permissible temperature is set by industry standards at 118°C and the duration of the steaming cycle is limited to 20 hours by these standards. Steam condensate that forms in the retort exits through traps and is conducted to oil-water separators for removal of free oils. Removal of emulsified oils requires further treatment.

In closed steaming, a widely used variation of conventional steam conditioning, the steam needed for conditioning is generated in situ by covering the coils in the retort with water from a reservoir and heating the water by passing process steam through the coils. The water is returned to the reservoir after oil separation and reused during the next steaming cycle. There is a slight increase in volume of water in the storage tank after each cycle due to water exuded from the wood. A small blowdown from the storage tank is necessary to account for this excess water and also to control the level of wood sugars in the water.

Modified closed steaming is a variation of the steam conditioning process in which 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 discontinued and the remaining steam required for the cycle is generated within the retort by utilizing the heating coils. Upon completing the steaming cycle, the water in the cylinder is discarded after recovery of oils.

Preconditioning is accomplished in the Boulton process by heating the stock in a preservative bath under reduced pressure in the retort. The preservative serves as a heat transfer medium. After the cylinder temperature has been raised to operating temperature, a vacuum is drawn and water removed in vapor form from the wood passes through a condenser to an oil-water separator where low-boiling fractions of the preservative are removed. The Boulton cycle may have a duration of 48 hours or longer for large poles and piling, a fact that accounts for the lower production per retort day as compared to plants that steam condition.

The vapor-drying process consists essentially of exposing wood in a closed vessel to vapors from any one of many organic chemicals that are immiscible with water and have a narrow boiling range. Selected derivatives of petroleum and coal tar, such as xylol, high-flash naphtha, and Stoddard solvent, are preferred; but numerous chemicals, including blends, can be and have been employed as drying agents in the process. Chemicals with initial boiling points of from 212°F to 400°F (100°C to 204°C) may be used.

Vapors for drying are generated by boiling the chemical in an evaporator. The vapors are conducted to the retort containing the wood, where they condense on the wood, give up their latent heat of vaporization, and cause the water in the wood to vaporize. The water vapor thus produced, along with excess organic vapor, is conducted from the vessel to a condenser and thence to a gravity-type separator. The water layer is discharged from the separator and the organic chemical is returned to the evaporator for reuse.

At the termination of the heating period, the flow of organic vapors to the vessel is stopped and a 30-minute to 2-hour vacuum is imposed to remove the condensed chemical adsorbed by the wood, along with the additional water that is removed from the wood during the vacuum cycle. Since the drying vessel is usually also the retort used for preservative treatment, the wood can be treated immediately using any one of the standard preservative processes.

Following any of the above preconditioning steps, the treatment step may be accomplished by either pressure or nonpressure processes.

Nonpressure (thermal) processes utilize open tanks which contain the preservative chemicals. Stock to be treated is immersed in the treatment chemicals, which may be at ambient temperature, heated, or a combination thereof. Stock treated in nonpressure processes is normally preconditioned by air seasoning or kiln drying.

Treatment methods employing processes consist of three basic types independent of the preconditioning method. Two of the pressure methods, referred to in the industry as empty-cell processes, are based on the principle that part of the preservative forced into the wood is expelled by entrapped air upon the release of pressure at the conclusion of the treating cycle, thus leaving the cell walls coated with preservative. The pressure cycle is followed by a vacuum to remove additional preservative. The retention of preservatives attained is controlled in part by the initial air pressure employed at the beginning of the cycle.

The third method, which is the full-cell process, differs from the other two in that the treating cycle is begun by evacuating the retort and breaking the vacuum with the preservative. The preservative is then forced into the wood under pressure, as in the other processes. Most of the preservative remains in the wood when the pressure is released. Retentions of preservatives achieved in this process are substantially higher than those achieved in the empty cell processes.

Stock treated by any of the three methods may be given a short steam treatment to clean the surface of poles and pilings and to reduce exudation of oil after the products are placed in service.

PARTICLEBOARD (6)

In the majority of cases the raw materials used to produce particleboard are wood residues of any species from other timber product processes. However, roundwood is used in a few instances. At this time, most particleboard in the United States is produced from mill residues such as planer shavings, sawdust, and plywood trim. Furniture waste, particleboard trim, veneer cores, and other chip sources are used occasionally. In cases where a particleboard plant is a part of an integrated complex, a substantial part, or all of the raw materials are supplied by other operations in the complex.

There are three basic steps in producing mat formed particleboard: particle preparation, mat formation, and mat consolidation. Incorporated within these primary operations are particle drying, additive blending, board cooling, and board finishing operations. Figure 32 shows a process flow diagram for particleboard production.

Classification

Prior or subsequent to particle preparation, it is usually necessary to classify the wood by size by the use of vibrating screens or air classifiers. The classification is done primarily to remove particles of undesired shape and size which, if allowed to remain, would increase the resin requirements, present problems during manufacture, or produce defects in the product. Another reason for classifying particles is to allow the use of the finer particles to form the face of the board and the coarser particles to form the core.

Screen classification is usually accomplished by vibrating screens. The wood is fed onto one end of the screen and the vibrating action of the screen transports the wood along the length of the screen. The rejects which are too large to pass through the screen are recycled back into a system such as a hammermill which reduces the size. The fines which are unacceptable for the process are discarded. Although in some cases air classification provides sharper fractionization, it can also involve greater difficulties in operation and controls. The use of air classification allows for the instantaneous adjustment of the classification process. However, it also entails a larger energy consumption than do screens.

Particle Preparation

The four principle methods of particle formation in use are hammermills, flakers, mechanical, and thermo-mechanical refining. Hammermills and similar type machines use free swinging hammers of steel strips or impellers with stiff arms to reduce material by a beating action. These are relatively simple machines with low cost wear parts. On certain raw materials and with the proper choice of hammermill, operating speed, feed rates, and screen size the hammermill produces acceptable particle geometry at an acceptable cost. Under certain operating conditions, a high percentage of dust may be produced. These machines are used primarily for coarse jobs such as the reduction of large reject chips to a size acceptable for feeding flakers or refiners. These machines are also used to produce some core stock in particular operations. After the initial impact, particles that are still too large are pushed through a screen or grate at the periphery. The screen controls the size of the particles produced.

Flakers are used extensively in the particleboard industry for core stock and to some extent for face stock. Different flakers use either roundwood or residues as the feed; however, the basic concept of the machines, the use of knives to reduce the feed wood to particles, is the same. In the case of wood residue flakers, an impeller throws the residue against a ring of knives. The flakes thus produced are generally 0.05 to 0.15 cm (0.020 to 0.060 inch) in thickness. Thirty to 40 percent of the particles produced are in the screen size range of four to ten with only two to ten percent being larger under normal conditions. Flakers used on roundwood operate on a similar principle in that logs are fed to a rotating set of knives. The resulting flakes are larger than those produced from residue but the thicknesses are comparable.

Mechanical refiners consist of two discs between which the chips or residues are passed. In a single disc attrition mill there is one rotating disc. The feed material passes between the rotating disc and a stationary plate and is discharged at the bottom of the case. Double disc mills have two discs rotating in opposite directions, but the product flow is similar to the single disc mill. The product of disc mills is generally an elongated rod shape. The disc plates generally rotate at 1,200 rpm or 1,600 rpm (a relative speed of 2,400 rpm or 3,600 rpm for a double disc mill). Plate separations are generally less than 0.10 cm (0.040 inch). A variety of disc patterns are available and choice depends on the feed's characteristics and type of product desired. The products from these mills are generally used as face stock, i.e., the fiber is deposited on the surface of the board during formation to provide a smooth surface. When phenolic resins are used, the resin frequently is added during refining.

A thermo-mechanical disc refiner is basically a disc refiner receiving feed material which has been subjected to steam pressure four to 15 atm (60 to 220 psi) for a period of time (15 seconds to 3 minutes) before entering the refiner. The pressure continues through the actual refining (in the disc area), in most cases.

Pre-steaming softens the feed material and thus facilitates refining and reduces horsepower requirements. The longer the pretreatment and higher the pressure, the softer the wood becomes. The heat plasticizes primarily the hemicellulose and lignin components of wood which bind the fibers together. In addition, a longer and stronger fiber is produced.

Drying

Following particle preparation, the particles are dried by heat to achieve a uniform moisture content. The moisture content of the particle is critical and is different for various operations; however, the preferred moisture content of the particles at the dryer exit is usually between 5 and 15 percent. Driers are heated by gas, oil, wood residue unsuitable for particleboard (sander dust, etc.), or a combination of the above, but gas and oil fired driers are most common.

The rotary jet drum drier is essentially a horizontal pneumatic drier in which high velocity heated air is directed in such a manner that a spiral flow of particles is achieved through the drier.

Another type of drier in use is situated vertically and uses a fluidized bed principle. The particles enter the drier and are suspended by hot air entering from the bottom. The particles become lighter as they dry and are emitted from the top of the unit.

A third type of drier in use consists of a tube bundle rotating in a trough. The particles dry in contact with the tube bundles while vanes fitted to the bundles convey the particles. In some cases the particles enter a preheater before entering the drier. The preheater is usually heated by exhaust gases from the main drier.

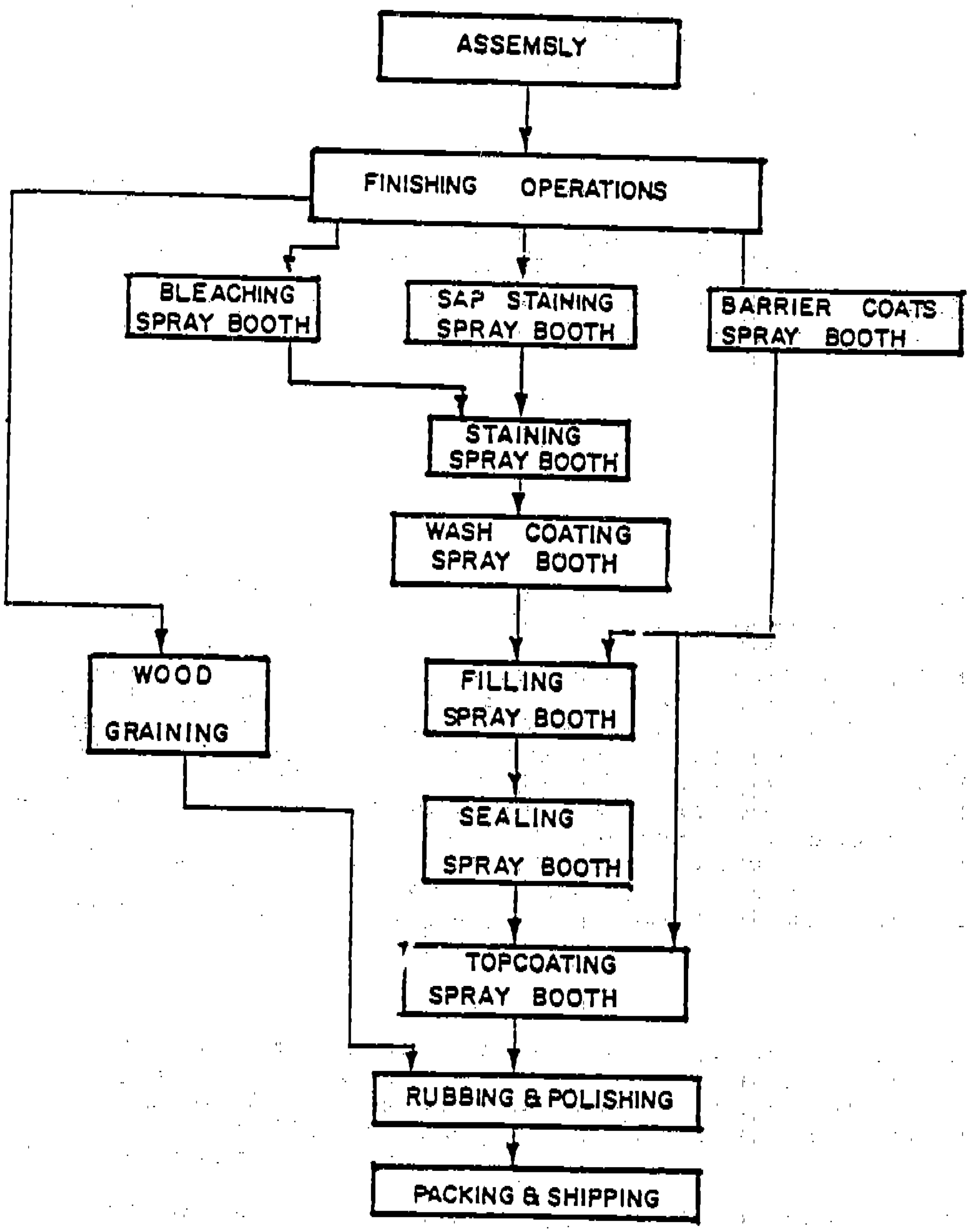

FIGURE 34 FURNITURE MANUFACTURING PROCESS DIAGRAM - FINISHING (8)

the following:

5. U.S. Environmental Protection Agency. Development Document for Interim Final Effluent Limitations, Guidelines and Proposed New Source Performance Standards for the Gum and Wood Chemicals Manufacturing Point Source Category. EPA 440/1-76/060b, April 1976.

6. U.S. Environmental Protection Agency. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Builder's Paper and Roofing Felt Segment of the Builder's Paper and Board Mills Point Source Category. May 1974.

7. U.S. Environmental Protection Agency. Development Document for Proposed Effluent Guidelines and New Source Performance Standards for the Wet Storage, Sawmills, Particleboard, and Insulation Board Segment of the Timber Products Processing Point Source Category. August 1974.

8. Environmental Science and Engineering, Inc. Revised Technical Review of the Best Available Technology Best Demonstrated Technology and Pretreatment Technology for the Timber Products Processing Point Source Subcategory. 1978.

9. U.S. Environmental Protection Agency. Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Wood Furniture and Fixture Manufacturing Segment of the Timber Products Processing Point Source Category. November 1974.