POWER IN THE CELLULOSE INDUSTRIES

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Industries of great commercial importance have been, and are being, built upon the fabrication of plant cellulose after subjection to varying pyrochemical treatment. The differences in plant celluloses, the methods used to remove combined substances, the structural changes wrought in the cellulose itself, as well as the chemical combinations made, all tend toward a wide variety of finished product. Outstanding among these products are paper, rayon, cellulose plastics, and cellulose lacquers.

Power plays an important part in these industries either in the production of the pulp material itself, in the production of chemicals entering into the processes, or in the mechanical operations essential to fabrication. The pulp and paper industry ranks second among all industries in the amount of installed horsepower capacity which totaled 2,700,000 horsepower. At present, only 62 percent of this horsepower capacity is electric, but there is a marked tendency toward greater electrification. The power is required for mechanical operations and for the production of steam. One ton of mechanical pulp requires approximately 1,280 kilowatt-hours of electrical energy. Other types of pulp require 200 kilowatt-hours or less of mechanical power. The total mechanical power necessary to produce 1 ton of newsprint is approximately 1,340 kilowatt-hours. The newsprint produced in this country in 1929 required, therefore, almost 2,000,000,000 kilowatt-hours of energy; if all newsprint consumed in this country had been produced here, the power consumption for newsprint alone would have been in excess of 5,000,000,000 kilowatt-hours of energy. Other kinds of paper require less energy because they do not use mechanical pulp.

The rayon, cellulose plastic, and cellulose lacquer industries are not large consumers of power in themselves although the rayon industry requires a 24-hour-a-day supply. Only when they are considered as markets for electrolytic chemicals do these other cellulose industries become of interest in power development. Each ton of viscose rayon requires 2 tons of high-quality caustic soda or, in 1929, approximately 287,500,000 kilowatt-hours of energy were expended in producing pure caustic soda for rayon. All pulp used is bleached with chlorine compounds, so that an outlet for a part of the chlorine manufactured in the process of caustic soda electrolysis is found in this industry. As two thirds of all chlorine produced is consumed in the pulp and paper industry, an electrolytic caustic soda and chlorine industry would find a market for its simultaneously produced chemicals in pulp and paper and rayon mills located near it.

The nitric acid necessary for cellulose nitrate plastics or lacquers is now made by the oxidation of ammonia, the hydrogen content of which may be obtained in the production of caustic soda and chlorine or by the electrolysis of water as well as by other methods. The cellulose acetate rayon and plastics require acetic acid which is now being manufactured from calcium carbide, an electric furnace product requiring over 3,000 kilowatt-hours of energy per ton to produce. Cellulose acetate products also require acetic anhydride, of which chlorine is an essential part.

While many different kinds of plant cellulose have been made into paper and rayon, wood cellulose has competed successfully with each type either because of its special suitability or because of its lower cost per unit weight. Cotton linters, however, are being used for plastics and lacquers and their use is growing in rayon production.

The wood most easily manufactured into newsprint paper and rayon is spruce. One half of the Nation's spruce reserves are in Washington and Oregon. One fourth of our pines, available for wrapping-paper pulp, are on the Pacific coast. These industries require an abundance of water which is available in these States. The principal chemicals necessary to convert the wood into pulp for paper or rayon are also being manufactured or could be manufactured on the Pacific coast. Yet Washington State produced but 8 percent of the Nation's wood pulp and 3 percent of the Nation's paper requirements in 1928; while Oregon and California produced but 5 percent of the wood pulp and 3.7 percent of the paper requirements. Rayon-pulp manufacture has just begun in Washington State.

The Middle Atlantic States with but 4.6 percent of the national pulpwood reserves, produced 23.2 percent of our total wood pulp and 29.2 percent of the Nation's paper. The New England States have 4.7 percent of our stand of pulpwood, but produced 27 percent of the wood pulp and 19 percent of our paper. The three Lake States contain 9.4 percent of the Nation's pulpwood reserves and produced 24.7 percent of the entire wood-pulp supply and 21.4 percent of the country's paper.

Among the North and Middle Atlantic States and the Central States, Maine alone is able to meet her own pulpwood requirements. Other States have adopted reforestation measures but it will be years before new forests have grown to meet current demands. No large rayon-producing State manufactures any of its spruce-wood pulp.

As a consequence, the United States imported 21 percent of its pulpwood, 28 percent of its wood pulp, and 16.5 percent of its paper in 1928. While imports of pulpwood have remaind stationary, proportionately, in the last 20 years, imports of wood pulp and paper are increasing. These imports are chiefly of newsprint, or of mechanical and sulphite pulp or of spruce wood to be manufactured into newsprint. About 36 percent of our sulphate pulp for wrappings is imported. Newsprint, mechanical pulp, and spruce is imported chiefly from Canada. Sulphite pulp is imported in almost equal amounts from Canada and Sweden, while Finland, Norway, and Germany ship in appreciable quantities. Over 60 percent of the sulphate-pulp imports come from Sweden, Finland, and Norway, while 36 percent are shipped from Canada. More than half the rayon-spruce pulp is imported from Canada. These articles enter free of any duty.

Eastern Canada possesses the same natural resources for mechanical and sulphite pulp and newsprint-paper manufacture as does the Pacific Northwest, that is, extensive spruce forests, cheap hydroelectric power, and an abundance of water. It has the additional advantage of closeness to the largest American consuming markets. Canada's all-rail rate to New York points averages $6 while the Coordinator for Traffic, Federal Traffic Board, reports the freight rate from Seattle to New York to be $15. From Seattle to New Orleans, the entire freight charge is $8 while from New York and New England rates fall between $9.60 and $10.50. The newsprint market in Gulf and lower Mississippi States is entered by Pacific coast producers.

Sweden has been able to supply the American market with wood pulp because she has so correlated her lumber and pulp industries that most of her pulp is manufactured from logging and sawmill waste. Shipments to Atlantic seaports cost but $4.50 per ton. An importer's commission of 5 percent is usually paid.

Integration of the lumber and paper industry has begun in the State of Washington. Over 48 percent of all pulpwood used in 1928 was slabs and other mill waste. As lumber waste gains commercial value in pulp mills and as pulp mill rejects are applied to paper board and cheap wrapping paper, wood waste will become too valuable to burn at the lumber or paper mill as has been done in the past. Other fuels or electricity will be required in its stead.

PULP AND PAPER INDUSTRIES

The Development of the Pulp and Paper Industry in the United States

HISTORICAL DEVELOPMENT

1. *Original sources of material.*—The first paper mill was erected in Pennsylvania in 1690. The Revolutionary War hastened the establishment of paper mills in all the principal Colonies. Imported linen rags and cotton rags served as raw materials. These sources soon proved unequal to the demands for paper. Many experiments were undertaken to utilize corn husks, stalks, and cobs, seagrass, reeds, and other fibrous substances. In 1830 straw was successfully manufactured into paper. In 1855 pulpwood, treated with caustic soda, resulted in a satisfactory pulp; but active adoption of the soda process took at least 25 years. The grinding of wood into pulp began in 1867. The treatment of pulpwood by sulphur and lime was first done commercially in Sweden in 1874 and was adopted in the United States in

the early eighties. Estimates place the consumption of pulpwood at 2,000 cords in 1870, at 40,000 cords in 1880, and at 580,000 cords in 1890. In 1928, consumption exceeded 7,000,000 cords.

2. *Adoption of power machinery.*—Power-driven machinery preceded the use of wood fibers in paper making, for the beating engine, or machine to comb out fibers and cut them into uniform lengths, was introduced in 1775. These were driven by water wheels. A cylinder machine, which turned the wet stock into the finished sheet, appeared in 1817, and in 1827 the Fourdrinier paper machine was introduced. The general adoption of pulpwood as the principal source of paper material after 1880 led to a very rapid extension of the use of mechanical power and an improvement in machine design and machine speed.

3. In 1810, according to the United States Census of Manufactures, the annual production of paper in the United States was 3,000 tons; by 1860 it was 127,000 tons; by 1909, 4,200,000 tons, and by 1928, in excess of 10,000,000 tons.

LOCATION OF INDUSTRY

4. *Paper industry firmly established in New England, New York, and Pennsylvania.*—The colonial paper industry had been established in Berkshire County, Mass.; in Hartford County, Conn.; in Niagara and Columbia Counties, N.Y.; and in Austin and Delaware Counties of Pennsylvania; as well as in Maine, Virginia, and Maryland. The first wood to be turned into mechanical and sulphite pulp was spruce, while broad-leaved species were employed in soda pulp. The spruce forests of New York and New England, the hardwood forests of Pennsylvania, served existing paper mills adequately and led to the establishment of other mills in the same States. Some mills, especially in Massachusetts, continued to make fine papers from rags. An abundant water supply and nearness to consuming paper markets caused the paper industry to become firmly entrenched in these original paper manufacturing States.

5. *Paper industry in Lake States.*—As population moved westward, the spruce forests of Wisconsin, Michigan, and Minnesota were cut for newspaper and the hardwoods of Ohio and Indiana added to the pulpwood supply for book paper. Paper mills were established near these sources of raw material.

6. In 1909, three fifths of all pulp and paper was produced in New England, New York, and Pennsylvania, and about one fourth in the Lake States. This overcentralization, combined with heedless felling of trees, developed a shortage on the supply of spruce in these States. Paper mills turned to Canadian forests for a part of their supply.

7. *Beginnings of paper industry in South.*—In 1907, the sulphate process was developed whereby resinous pines could be utilized in the manufacture of heavy wrapping and other brown paper. This branch of paper making located in the South where stands of pines were very large.

8. *The Pacific coast pulpwoods demand attention.*—Gradually, the spruce, fir, and hemlock forests of the Pacific coast, the largest in the

country, are being cut, first to meet the needs for mechanical and sulphite pulp and paper on the Pacific coast and, more recently, to reach the South and Central Western markets.

9. In 1928, the original paper-making States in New England and in the Middle Atlantic section produced 48 percent of our paper. Lake States and Central States manufacture 38.8 percent, Southern States 6 percent, and Pacific Coast States 6.7 percent.

TABLE I.—*United States consumption and production of paper, wood pulp, and pulpwood during the last 20 years* [1]

Year	Paper			Wood pulp			Pulpwood		
	Apparent consumption (short tons)	Production		Apparent consumption (short tons)	Production		Consumption (cords)	Apparent production	
		Short tons	Percent of consumption		Short tons	Percent of consumption		Cords	Percent of consumption
1928	12, 477, 649	10, 403, 338	83 4	6, 239, 641	4, 510, 800	72. 3	7, 160, 100	5, 641, 280	78. 8
1927	12, 345, 470	10, 002, 070	81. 0	5, 960, 865	4, 313, 403	72. 4	6, 750, 935	5, 213, 207	77. 2
1925	10, 590, 000	9, 182, 204	86. 7	5, 588, 000	3, 962, 217	70. 9	6, 093, 821	5, 005, 445	82. 1
1923	9, 340, 000	8, 029, 482	85. 9	5, 149, 000	3, 788, 672	73. 6	5, 872, 870	4, 636, 789	78. 9
1921	6, 054, 000	5, 356, 317	88. 5	3, 514, 000	2, 875, 601	81. 1	4, 557, 179	3, 740, 406	82. 1
1919	6, 493, 000	6, 190, 361	95. 3	4, 019, 696	3, 517, 952	87. 5	5, 477, 832	4, 445, 817	81. 2
1914	5, 496, 000	5, 270, 047	95. 9	3, 490, 123	2, 893, 150	82. 9	4, 470, 763	3, 641, 063	81. 4
1909	4, 224, 000	4, 216, 708	99. 8	2, 826, 591	2, 495, 523	88. 3	4, 001, 607	3, 207, 653	80. 2

[1] Compiled from U.S. Department of Agriculture Statistical Bulletin No. 21, and U.S. Bureau of the Census, Census of Manufactures, 1927 and 1928.

CHANGING STATUS OF UNITED STATES AS PRODUCER OF PAPER AND PAPER MATERIALS AND AS CONSUMER OF PAPER AND PAPER MATERIAL

10. Table I indicates clearly the changing status of this country in the last 20 years in the production of pulpwood, of wood pulp, and of paper, and in the consumption of the raw material, the semi-finished, and the finished product.

11. *Pulpwood.*—About 20 percent of the pulpwood which we consume has been imported regularly since 1909; our proportionate importations of this raw wood have not increased or decreased materially in 20 years. Table II shows that 80 percent of this imported wood is spruce from Canada, Newfoundland, and Labrador, and the remainder balsam, fir, and aspen.

12. *Wood pulp and paper.*—While our imports of pulpwood have not changed, proportionately, with the passage of the years, our imports of wood pulp and paper have increased greatly. In 1909 we manufactured 88 percent of the wood pulp consumed by paper mills; in 1928 we produced but 72 percent. Whereas almost all paper used in the United States was manufactured within its borders in 1909, in 1928 only 83.4 percent of all paper consumed was produced here. When, therefore, the paper and the wood pulp imported into this country are reduced to their pulpwood content, about 60 percent of the forest material for all paper used in the United States comes from outside our country.

NEWSPRINT IMPORTATIONS, THE TARIFF, AND CANADIAN POLICIES

13. Table II shows clearly that, not only are our pulpwood imports chiefly of woods to be used in newspaper manufacture, but that the type of wood pulp imported is for newsprint manufacture. And 97.3 percent of imported paper is newsprint. The reasons for such importations have an economic and a political origin.

14. In 1907, when the growing shortage of spruce in New England and New York made newspaper supply uncertain, the newspaper publishers of our country asked for a repeal of the tariff on paper so that they might have freedom in newsprint-paper purchase. In 1910 commissions of the United States and Canada worked up an agreement whereby paper, pulp, and pulpwood were to be placed on the free list except when they came from countries that had placed an export duty upon them. Our Congress passed this measure which was signed by President Taft, but it was rejected in the Canadian Parliament. The Underwood-Simmons Tariff Bill of 1913 operated to repeal the section of the act of 1911 that related to pulp and paper; it gave free entry to printing paper worth not more than $0.025 a pound and an ad valorem tax was placed on print paper worth more. The revenue bill of 1916 amended the tariff of 1913 by placing on the free list printing paper of values up to $0.05 a pound. The Tariff Acts of 1922 and 1930 place on the free list "standard newsprint paper."

15. *Canadian pulpwood.*—About 90 percent of the pulpwood lands in Canada are "crown lands," over which the Provincial Governments exercise control while letting the timber-cutting rights. In 1910, the Government of Quebec prohibited the exportation of any wood cut from crown lands. This policy has been followed by other provinces until only from freehold lands can pulpwood be shipped to this country.

TABLE II.—*Imports of paper, wood pulp, and pulpwood by country of origin, in 1928* [1]

Imports	All countries		Canada		Newfoundland and Labrador		Sweden		Finland	
	Short tons	Percent	Short tons	Percent	Short tons	Percent	Short tons	Percent	Short tons	Percent
Paper imports: Total	2,218,257	100.0	1,954,567	88.1	114,175	5.1	61,726	2.8	46,163	2.1
Newsprint	2,157,166	97.3	1,926,748	89.3	114,172	5.3	55,619	2.6	40,239	1.9
Wrapping	14,124	.6	167	1.2	3	(2)	5,532	39.2		
Boards	37,378	1.7	27,581	73.8			277	.7	4,165	11.1
Other [3]	9,589	.4	71	.7			298	3.1	1,759	18.3
Wood pulp imports: Total	1,573,659	100.0	703,793	44.7	157	(2)	540,207	34.3	137,790	8.8
Sulphite	948,586	60.3	356,558	37.6			333,367	35.1	94,278	10.0
Sulphate	395,846	25.2	141,779	35.8			201,757	51.0	32,139	8.1
Mechanical	222,499	14.1	202,382	91.0	157	.1	2,286	1.0	11,273	5.0
Other	6,728	.4	3,074	45.7			2,797	41.6	100	1.4

TABLE II.—*Imports of paper, wood pulp, and pulpwood by country of origin, in 1928* [1]—Continued

Imports	Germany		Norway		Japan		United Kingdom		Netherlands		Other Countries	
	Short tons	Percent	Short tons	Percent	Short tons	Percent	Short tons	Percent	Short tons	Percent	Short tons	Percent
Paper imports: Total	17,019	0.8	11,543	0.5	440	(2)	2,121	(2)	8,330	0.4	2,173	(2)
Newsprint	9,166	.4	10,864	.5			231	(2)	10	(2)	117	(2)
Wrapping	2,462	17.4	631	4.5	5	(2)	24	0.2	4,806	34.0	494	3.5
Boards	1,847	4.9					14	(2)	3,385	9.1	109	.3
Other [3]	3,544	37.0	48	.5	435	4.5	1,852	19.3	129	1.4	1,453	15.2
Wood pulp imports: Total	65,369	4.2	84,662	5.4			3,392	.2	1,160	(2)	37,129	2.4
Sulphite	63,525	6.7	63,668	6.7			2,926	.3	1,160	.1	33,104	3.5
Sulphate	1,290	.3	15,761	4.0							3,120	.8
Mechanical	126	(2)	5,233	2.4			465	.2			577	.3
Other	428	6.4					1	(2)			328	4.9

Imports	All countries		Canada		Newfoundland and Labrador	
	Cords	Percent	Cords	Percent	Cords	Percent
Pulpwood imports: Total	1,546,338	100.0	1,532,466	99.1	13,872	0.9
Spruce	1,215,912	78.6	1,202,869	98.9	13,043	1.1
Other [4]	330,426	21.4	329,597	99.7	829	.3

[1] Compiled from U.S. Department of Commerce, Foreign Commerce and Navigation of the United States.
[2] Less than 0.1 percent.
[3] Does not include 5,845 tons of cigarette paper, cigarette books, and covers, or 1,402 tons of paper boxes. Ninety-eight percent of the former comes from France, also 62 percent of the latter; balance of boxes comes principally from Germany.
[4] Principal kinds include poplar 60 percent and balsam fir 31 percent.

16. *Newsprint manufacturing in Canada.*—The immediate effect of this legislation was to encourage paper manufacture in Canada and to depress the American newsprint industry. In 1911, prior to the enforcement of the pulp and paper agreement, Canada exported newsprint paper valued at $2,000,000 into the United States. In 1913 the value of her printing paper exports doubled and redoubled in 1914. In 1913 only 350,000 tons of newsprint paper was manufactured in Canada. In 1929, 2,728,827 tons were produced. Of this, 80 percent is exported to the United States.

17. *Newsprint manufacture in the United States.*—The effect upon American industry is clearly indicated on table III. From 1909 to 1929 our newsprint paper consumption increased over 227 percent. Our manufacture of newsprint paper increased but 18 percent. In all other kinds of paper our production not only kept pace with consumption but usually permitted an exportable surplus. Today, only 36.6 percent of newsprint paper consumed is manufactured in the United States. Only four newsprint-paper mills have been built in the United States since the reciprocity measure with Canada put newsprint on the free list.

18. *American firms manufacturing in Canada.*—After 1911 some of the newsprint plants in this country were reequipped for use on other

classes of paper. Special inducements in the way of long leases on timber lands and water-power rights in Canada led some American firms to build newsprint mills in Canada and to export the paper to United States newspaper producers.

19. The International Paper Co., once the largest producer of newsprint paper in the United States, owns and operates as the "Canadian International Paper Co." at Three Rivers, and at Gatineau, Quebec; as the "New Brunswick International Paper Co." at Dalhousie, New Brunswick; as the "Bathurst Power and Paper Co." at Bathurst, New Brunswick; and has purchased a plant at Corner Brook, Newfoundland. Its daily Canadian paper operating capacity is about 2,000 tons paper. Its operating capacity in New York and New England is 1,160 tons daily, of which but a small part is used. The company has rights to over 3,000,000 acres of timber lands in Canada. It owns the International Hydro-Electric System which controls the Canadian Hydro-Electric Corporation of which the Gatineau Power Co. is a subsidiary. Power is supplied to the Dalhousie plant from the Grand Falls hydroelectric development of the company on the St. John River.

20. The New York Times and the Kimberly Clark Corporation of Wisconsin operate a plant at Kapaskasing, Ontario, which supplies the New York Times with approximately 100,000 tons of paper annually. The Chicago Tribune gets its newsprint paper from its own factory at Thorold, Ontario. The Crown Zellerback Corporation owns the Pacific Mills at Ocean Falls, British Columbia. It has obtained rights to water power at Campbell River, Canada.

21. *Other paper manufacture.*—Manufacture of all kinds of paper other than newsprint has increased steadily in the United States. Book paper production increased 107 percent between 1909 and 1929, board production 409 percent, wrapping paper manufacture 116 percent, fine paper production 195 percent, and miscellaneous kinds 165 percent.

22. *Boards.*—The largest paper production and consumption in the United States is of "boards." Under this heading are included container boards, folding and set-up box boards, building board, cardboard, and all other types of board. Over 36 percent of all paper produced in the United States is for boxing purposes, while 41 percent is boards of all kinds. Michigan, Ohio, New York, New Jersey, Illinois, and Indiana are the leading board-producing States. Washington produced 69,045 tons of the 4,000,000 tons manufactured in 1928. Since that date several paper-board factories have been built in Washington, and even by 1929 the total United States board production reached 4,500,000 tons.

23. *Wrapping paper.*—More wrapping paper than newspaper is manufactured in the United States although the consumption of newspaper far exceeds that of wrapping paper. Wrapping paper represents 15 percent of our total paper production. Over 80 percent is kraft paper or the heavy brown paper made by the sulphate process. Under this heading are included kraft paper used for twine, tapes, sand paper, mulching, and numerous uses other than wrapping. A little over 3 percent is paper manufactured by the sulphite process. Wisconsin produces the largest amount of wrapping paper. Louisiana ranks high and production is increasing in Virginia, North Carolina,

and other Southern States. New York and Maine are also heavy producers of this type of paper.

24. *Book paper.*—Our book-paper production is almost equal to our wrapping-paper production; it totaled almost 1,500,000 tons in 1929. Included under this heading are all grades of printing paper other than newsprint paper. Magazine paper represents the largest item. Catalogues, printed wrappers, and paper used in book production add to the total. The variations in grade are, therefore, numerous. Ohio, Pennsylvania, New York, Michigan, Wisconsin, Massachusetts, and Virginia are all important book-paper providing States.

25. *Other papers.*—Fine papers, which are used chiefly for typing and stationery, form 5.4 percent of the total United States production. The finest of these papers always has been made largely from rags so that the paper mills have remained chiefly near the Atlantic seacoast where imported rags are easily available. Massachusetts and Pennsylvania are principal producers. Tissue papers represent over 3 percent of our total paper production, building paper over 5 percent, while hanging paper, absorbent paper, and other kinds are finding an ever-increasing market.

TABLE II.—*Principal types of paper consumed and produced in the United States since 1909* [1]

Year	Total		Newsprint			Boards			Wrapping		
	Apparent consumption (short tons)	Production (short tons)	Apparent consumption (short tons)	Production (short tons)	Percent of consumption	Apparent consumption (short tons)	Production (short tons)	Percent of consumption	Apparent consumption (short tons)	Production (short tons)	Percent of consumption
1929	13, 184, 152	10, 894, 000	3, 798, 186	1, 392, 000	36. 6	4, 454, 587	4, 500, 000	101. 0	1, 635, 515	1, 649, 000	100. 8
1928	12, 477, 649	10, 403, 338	3, 560, 926	1, 415, 450	39. 7	4, 035, 581	4, 061, 803	100. 6	1, 461, 463	1, 467, 271	100. 4
1927	11, 944, 202	10, 002, 070	3, 491, 666	1, 516, 929	43. 4	3, 767, 484	3, 773, 608	100. 2	1, 521, 100	1, 525, 305	100. 3
1925	10, 590, 000	9, 182, 204	3, 073, 000	1, 647, 277	53. 6	3, 290, 000	3, 280, 710	99. 7	1, 287, 000	1, 297, 919	100. 8
1923	9, 340, 000	8, 029, 482	2, 814, 000	1, 521, 080	54. 1	2, 802, 000	2, 792, 832	99. 7	1, 177, 000	1, 150, 556	97. 8
1921	6, 054, 000	5, 356, 317	2, 002, 000	1, 226, 189	61. 2	1, 641, 000	1, 664, 931	101. 5	770, 000	782, 468	101. 6
1919	6, 493, 000	6, 190, 361	1, 892, 000	1, 374, 517	72. 6	1, 940, 000	1, 950, 037	100. 5	825, 000	869, 631	105. 4
1914	5, 496, 000	5, 270, 047	1, 576, 000	1, 321, 167	83. 8	1, 292, 000	1, 291, 805	99. 9	892, 000	881, 799	98. 9
1909	4, 224, 000	4, 216, 708	1, 159, 000	1, 175, 554	101. 4	883, 000	883, 088	100. 0	763, 000	763, 067	100. 0

Year	Fine			Book			All other		
	Apparent consumption (short tons)	Production (short tons)	Percent of consumption	Apparent consumption (short tons)	Production (short tons)	Percent of consumption	Apparent consumption (short tons)	Production (short tons)	Percent of consumption
1929	564, 757	585, 000	103. 6	1, 421, 093	1, 440, 000	101. 3	1, 310, 014	1, 328, 000	101. 4
1928	537, 555	550, 472	102. 4	1, 322, 071	1, 334, 326	100. 9	1, 560, 053	1, 574, 016	100. 9
1927	502, 194	508, 808	101. 3	1, 320, 760	1, 328, 782	100. 6	1, 374, 664	1, 348, 638	98. 1
1925	472, 000	473, 804	100. 4	1, 365, 000	1, 367, 595	100. 2	1, 103, 000	1, 114, 899	101. 1
1923	374, 000	377, 029	100. 8	1, 235, 000	1, 242, 005	100. 6	938, 000	945, 980	100. 9
1921	230, 000	242, 485	105. 4	707, 000	725, 992	102. 7	704, 000	714, 252	101. 5
1919	306, 000	343, 762	112. 3	838, 000	914, 823	109. 2	692, 000	737, 591	106. 6
1914	244, 000	247, 728	101. 5	926, 000	934, 979	100. 9	566, 000	592, 569	104. 7
1909	193, 000	198, 213	102. 7	689, 000	694, 905	100. 9	537, 000	501, 881	93. 5

[1] Compiled from U.S. Department of Agriculture Statistical Bulletin No. 21, and U.S. Bureau of the Census, Census of Manufactures, 1927 and 1928.

WOOD PULP PRODUCTION AND CONSUMPTION

26. *Pulp consumption.*—Forty-two percent of all the pulp consumed in the United States is sulphite pulp, that is, a chemical pulp made by removing the incrusted matter in wood with a solution of bisulphide of lime. About 30 percent is mechanical pulp, ground into fibers without the employment of chemical; 20 percent is sulphate pulp in which salt cake is the chemical used; and 8 percent soda pulp applying caustic soda as the processing chemical. A beginning has been made in the new, or semichemical process. The use of sulphite pulp has increased over 100 percent in the last 20 years while mechanical pulp consumption in the United States is only 37 percent more in 1928 than in 1909 due to importations of newsprint paper. The consumption of sulphate pulp, first produced in 1907 and not recorded officially until 1914, increased almost nine times in that period. Soda pulp, the first wood pulp to be produced, shows only an increased consumption of about 50 percent in the last 20 years.

27. *Pulp production.*—The United States production of the several kinds of pulp does not correspond with the respective amounts consumed. We produce all our own soda pulp. We produce 86.6 percent of our mechanical pulp, 60.6 percent of our sulphite pulp, and 63.8 percent of our sulphate pulp. The proportion of sulphite pulp produced in this country has decreased continuously in the last 10 years. The proportion of sulphate pulp manufactured within our borders has increased steadily since it was begun.

28. *Pulp importations.*—Over half the sulphate pulp imported comes from Sweden, while 8 percent is shipped from Finland and 4 percent from Norway. Canada sends 36 percent. Sulphite pulp is imported in almost equal amounts from Canada and Sweden. Ninety-one percent of mechanical pulp imports are from Canada. (See table II.)

TABLE IV.—*Kinds of wood pulp consumed and produced in the United States*[1] *since 1909*

Year	Total		Mechanical			Sulphite		
	Apparent consumption (short tons)	Production (short tons)	Apparent consumption (short tons)	Production		Apparent consumption (short tons)	Production	
				Short tons	Percent of consumption		Short tons	Percent of consumption
1928	6,239,641	4,510,800	1,866,618	1,615,689	86.6	2,633,249	1,595,951	60.6
1927	5,960,855	4,313,403	1,865,413	1,618,638	86.8	2,596,955	1,588,132	61.2
1925	5,588,000	3,962,217	1,951,000	1,629,689	83.5	2,392,000	1,447,191	60.5
1923	5,149,000	3,788,672	1,878,000	1,580,553	84.2	2,230,000	1,448,690	64.9
1921	3,544,000	2,875,601	1,458,000	1,267,382	86.9	1,471,000	1,166,926	79.3
1919	4,079,000	3,517,952	1,733,000	1,518,829	87.6	1,669,000	1,419,829	85.1
1914	3,521,000	2,893,150	1,523,000	1,293,661	84.9	1,524,000	1,151,327	75.5
1909	2,854,000	2,495,523	1,322,000	1,179,266	89.2	1,235,000	1,017,631	82.4

[1] Figures from 1909 to 1925 inclusive were compiled from: U.S. Department of Agriculture, Statistical Bulletin No. 21. Figures for 1927 and 1928 were compiled from: U.S. Bureau of the Census, Census of Manufactures, 1927 and 1928.

TABLE IV.—*Kinds of wood pulp consumed and produced in the United States*[1] *since 1909*—Continued

Year	Soda			Sulphate			Semichemical		
	Apparent consumption (short tons)	Production		Apparent consumption (short (tons	Production		Apparent consumption (short tons)	Production	
		Short tons	Per-cent of consumption		Short tons	Per-cent of consumption		Short tons	Per-cent of consumption
1928	485, 907	488, 641	100. 6	1, 223, 900	780, 552	63. 8	29, 967	29, 967	100. 0
1927	485, 208	487, 478	100. 5	1, 001, 306	607, 172	60. 6	11, 983	11, 983	100. 0
1925	470, 000	472, 647	100. 6	775, 000	412, 690	53. 3			
1923	448, 000	445, 162	99. 4	593, 000	314, 267	53. 0			
1921	296, 000	300, 533	101. 5	319, 000	140, 760	44. 1			
1919	406, 000	411, 693	101, 4	271, 000	120, 378	44. 4			
1914	346, 000	347, 928	100. 6	128, 000	52, 641	41. 1			
1909	297, 000	298, 626	100. 5						

[1] See footnote bottom p. 319.

SOURCES OF WOODS AVAILABLE FOR PAPER MANUFACTURE

29. One reason advanced by the newspaper publishers for the free importation of Canadian paper was "conservation of our own forest resources." The United States Forestry Service has carefully examined the timber reserves of the United States. In its Forest Products Laboratory, the pulping characteristics of a large number of American woods have been studied to ascertain the relative value of species not in common use for pulpwood that are available to the industry. Other bureaus of the United States Department of Agriculture and State agricultural colleges have worked on the utilization of waste farm products for paper.

WOOD SPECIES SUITABLE FOR PAPER PULP

30. The Forest Products Laboratories have been studying woods available for paper pulp manufacture since 1906. The results of these studies are embodied in their report entitled "The Suitability of American Woods for Paper Pulp", dated May 1927. These experiments are continuing. Dr. C. E. Curran, senior chemist at the Madison Laboratories, stated in 1929 that: "Although we admit that paper pulp can be produced from any fibrous raw material, no source of cellulose that can compete with wood, either from the standpoint of suitability for most types of pulp or of cost per unit weight, has yet appeared. While it is true that certain of the so-called 'pulpwoods' are becoming scarce and high priced because of the prodigal way in which they have been consumed, it is also true that these species are few in number and that behind them there is a tremendous reservoir of other woods, less favored for the time being, which at present are not utilized extensively for pulp, but just the same are compact sources of cellulose, needing merely proper technical handing to give them pulping value."

31. Briefly, the results of the Forest Products Laboratory experiments have developed the following facts concerning the availability of groups of woods from different types of paper pulp:

Softwoods.—All spruces tested produce pulp of best quality and may be used in any pulping process.

32. Hemlocks are available for chemical processes, western hemlock being more easily pulped than eastern hemlock. Western hemlock may be used for mechanical pulp but requires more power in grinding to produce a pulp of the same strength as spruce. More bleach is required on hemlock than on spruce wood.

33. Firs may be used in all processes, for their pulp is similar to that of spruce. Red fir gives a darker colored pulp.

34. *Pines.*—All pines are satisfactorily reduced by the alkaline processes and produce bleachable pulp.

Western yellow pine and lodgepole pine are capable of manufacture into excellent mechanical pulp.

Northern white pine, sugar pine, timber pine, and piños may be used successfully for mechanical pulp.

Jack pine, loblolly pine, lodgepole pine, Norway pine, Virginia pine, pond, and sand pine yield sulphite pulp of fair quality.

35. *Other softwoods.*—Douglas fir and larches are usable for the sulphite process although digested with more difficulty than hemlock. Bleaching requires larger amounts of chemicals. The Douglas fir is readily reducible by the sulphate process and if turpentine is recovered from the cooking, process may be economically feasible.

Redwood and cedars are very difficult to pulp or bleach by the sulphite process. They produce satisfactory unbleached wrapping paper in the alkaline processes but the yield is low.

36. *Hardwoods.*—All hardwoods may be reduced by the soda or sulphate processes.

Aspen and basswood are easily pulped and bleached; chestnuts, after extraction, elms, yellow poplar, willows, soft maples, beech, red alder, and balsa are fairly easily treated; while the birches, hard maples, gums, magnolias, buckeye, and butternut are treated with more difficulty but are still within the field of commercial feasibility.

The weakness of the pulp and the greater power consumption make them impractical woods for the mechanical process. The shortness of the fibers are not suited for strong paper. Some may be reduced by the sulphite process for such papers as envelope, books, and other hard-surfaced papers. Sulphite reduceable woods are aspen, willows, maples, birches, gums, magnolias, sycamores, and butternut.

37. *Bark.*—Spruce bark may be employed as a part of the material for manufacture of board and cheap wrapping papers.

Spruce and balsam fir barks in shredded form are used in the manufacture of heat-insulation material.

Southern pine bark added to sulphate pulp makes a satisfactory roofing felt.

Extracted hemlock and redwood tanbark may be used with rags for roofing felts.

QUANTITIES OF PULPWOOD AVAILABLE

38. The last published survey of pulpwood resources by the United States Forest Service is dated 1924; it precedes some of the work of its own laboratories which added new woods to our pulpwood resources. But wood has also been cut from our forests since the survey and new growth has continued. Table V, therefore, may be considered as an approximation of our pulpwood resources without being an accurate statement of such resources in 1930.

TABLE V.—*Total stand of timber of principal kinds, suitable for pulp, by regions* [1]

[Thousands of cords]

Kind of timber	United States	Pacific coast: Washington, Oregon, and California	Lower Mississippi: Mississippi, Louisiana, and Arkansas	South Atlantic: Virginia, North Carolina, South Carolina, Georgia, Florida, and Alabama	Rocky Mountain: Idaho, Montana, Nevada, Wyoming, Arizona, Utah, Colorado, and New Mexico	Lake: Wisconsin, Michigan, and Minnesota	Central: Illinois, Indiana, Ohio, Kentucky, West Virginia, Missouri, Iowa, and Tennessee	New England: Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and Rhode Island	Middle Atlantic: New York, Pennsylvania, New Jersey, Delaware, and Maryland	Southeast Alaska (not included in United States totals)
Regional totals:										
Number	3,530,900	897,400	678,000	611,500	442,700	330,800	241,000	166,900	162,600	167,000
Percent	100.0	25.4	19.2	17.3	12.5	9.4	6.8	4.7	4.6	
Softwoods suitable for all processes:										
Spruce and fir:										
Number	414,000	205,100		3,400	85,500	17,100	3,400	[2] 85,500	14,000	45,300
Percent	100.0	49.5		0.8	20.7	4.1	0.8	20.7	3.4	
Hemlock:										
Number	311,100	200,900		6,400	2,500	51,300	19,700	6,400	23,900	121,400
Percent	100.0	64.6		2.1	0.8	16.4	6.3	2.1	7.7	
Total:										
Number	725,100	406,000		9,800	88,000	68,400	23,100	91,900	37,900	166,700
Percent	100.0	56.0		1.4	12.1	9.4	3.2	12.7	5.2	
Pines and larches: [3]										
Southern yellow pine	977,800		487,200	453,000			21,400	1,100	15,100	
Tamarack and larch	69,300	12,800			34,200	21,400		900		
White and sugar pine	209,300	81,200		4,300	42,700	21,400	2,500	35,000	22,200	
Western yellow pine	521,400	384,600			136,800					
Lodgepole pine	141,000	12,800			128,200					
Jack pine	38,400					38,400				
Total:										
Number	1,957,200	491,400	487,200	457,300	341,900	81,200	23,900	37,000	37,300	
Percent	100.0	25.1	24.9	23.4	17.5	4.1	1.2	1.9	1.9	

Hardwoods:										
Aspen and cottonwood	85,900		21,400	5,100	12,800	27,300	10,700	6,400	2,200	200
Birch, beech, and maple	381,200		16,330	16,200		136,800	102,600	29,000	80,300	100
Yellow poplar	47,000		1,000	15,400			29,900		700	
Basswood	34,300			1,700		17,100	10,700	2,600	2,200	
Red gum	168,400		97,400	51,300			18,800		900	
Black and tupelo gums	131,800		54,700	54,700			21,300		1,100	
Total:										
Number	848,600		190,800	144,400	12,800	181,200	194,000	38,000	87,400	300
Percent	100.0		22.5	17.0	1.5	21.3	22.9	4.5	10.3	

[1] U.S. Department of Agriculture Bulletin No. 1241, p. 91. 1924.

[2] Contains no allowance for reduction in stand by spruce bud worm, which amounts to 40 percent, or about 27,500,000 cords, in Maine.

[3] Contains no allowance for Douglas fir, although a small volume is now being used. The stand is very large, probably 2 or 3 times that of pine and other species suitable for sulphate pulp.

39. *Total reserve.*—In continental United States there are approximately 3,500,000,000 cords of wood suitable for pulp. In southeast Alaska there are an additional 167,000,000 cords. This timber, while available for pulp, is also used by the lumber industry. The pulp and paper industry has the advantage of being able to use small-sized trees and poorer grades of saw-log material. It can also use woods' and sawmill waste that cannot be saved in lumber manufacture.

40. *Spruce, fir, and hemlock.*—The supplies of pulpwood of greatest value for mechanical and sulphite pulp, that is, spruce, fir, and hemlock, total 725,000,000 cords in continental United States while almost all southern Alaskan wood is of these species. Reports state that Canada has over 1,000,000,000 cords of these three species.

41. *Pines.*—The pines, all of which are adaptable to the sulphate or soda-pulp processes, and a few of which may be used for other pulps, constitute our largest pulpwood reserves, totaling almost 2,000,000,000 cords in continental United States. Douglas firs, not included in the pulpwood resources listed on table V but upon which pulp experimentations are under way, would add almost 800,000,000 cords to our sulphate, and possibly our sulphite, pulp reserves. These are not true firs and are, therefore, never included under fir species.

42. *Hardwoods.*—The hardwoods listed on table V total approximately 850,000,000 cords, all of which are suitable for soda pulp. This reserve would be augmented if all hardwoods now regarded as of commercial value in soda-pulp manufacture were included. Canada's aspen reserves—the hardwood giving best results in the soda process—are stated to be 250,000,000 cords.[96]

LOCATION OF PULPWOOD RESOURCES

43. *Spruces, firs, and hemlocks—Pacific coast resources.*—About half of all spruce and fir, the ideal woods for mechanical and sulphite pulp, is growing on the Pacific coast. Hemlock, valuable for all chemical processes, is also found chiefly on the Pacific coast. While the firs are found in all the Pacific Coast States, the spruce and hemlock stands are almost entirely in Washington and Oregon. The logging operations in these States have frequently left these pulpwoods, so that it is possible to secure hundreds of thousands of cords of pulpwood from the area logged over annually. While these softwoods are usually mixed in the Pacific forests, in Alaska practically pure stands of pulp timber are found.

44. *Other resources.*—New England has 21 percent of the Nation's reserves of spruce and fir while the Rocky Mountain States also have about 21 percent. About a sixth of the Nation's hemlock resources are in Lake States.

45. It is obvious that 56 percent of our reserves of pulpwood, still regarded as best for newsprint-paper manufacture, are located in Washington, Oregon, and California, 12 percent are in the Rocky Mountain States, less than 10 percent are still found in the three Lake States, while but 18 percent of the total stands remain in the New England and Middle Atlantic States. The Pacific Coast States have not only the advantage of large virgin stands of these softwoods

[96] Kellogg, Royal. Pulpwood and Wood Pulp in North America.

but growth of spruce, fir, and hemlock is far more rapid in these States than in the East.

46. Canadian spruce is distributed as follows: Eastern Provinces 55 percent, Prairie Provinces 20 percent, British Columbia 25 percent. Balsam fir is found principally in the Eastern Provinces and hemlock in British Columbia.

47. *The pines.*—The Nation's reserves of pines suitable for sulphate or soda pulps are found in almost equal amounts on the Pacific coast, in the lower Mississippi region, and in the South Atlantic States. Large forests are also located in the Rocky Mountain States. The principal pulping pine of the South is southern yellow pine; the principal pulping pine of the West is western yellow pine which also makes excellent mechanical pulp.

48. Should pulp from Douglas fir be able to compete with pines in sulphate pulp production, a source of pulpwood would be added to Pacific reserves, for over half the stand of Douglas fir, known also as Douglas spruce, red pine, Oregon pine, and Puget Sound pine, is found in western Washington and Oregon.

49. *The hardwoods.*—The stands of hardwoods, suitable for soda pulp are distributed evenly in the three Lower Mississippi States, the three Lake States, and the eight Central States, each section having about 22 percent of the Nation's supply. Middle Atlantic States still have 10 percent and South Atlantic States 17 percent.

Relation of Pulpwood Reserves to Consumption Markets

KINDS OF PULPWOOD CONSUMED

50. In 1928, the United States consumed 7,160,100 cords of pulpwood. Spruce constituted 43 percent of this amount, hemlock 16.5 percent, fir 6.5 percent, southern yellow pine 13 percent, jack pine 2.5 percent, tamarack or larch 1 percent, aspen 6 percent, yellow poplar 1.7 percent, other hardwoods about 4 percent. Lumber-mill waste constituted 6 percent of the total pulpwood consumed.

TABLE VI.—*Principal kinds of pulpwood consumed in the United States since 1909* [1]

Year	Total		Spruce			Hemlock			Pines		
	Consumption (cords)	Consumption of domestic wood (cords)	Total consumption (cords)	Amount domestic		Total consumption (cords)	Amount domestic		Total consumption (cords)	Amount domestic	
				Cords	Percent of consumption		Cords	Percent of consumption		Cords	Percent of consumption
1928	7, 160, 100	5, 641, 280	3, 063, 781	2, 000, 433	65. 3	1, 177, 635	1, 158, 958	98. 4	1, 101, 655	1, 101, 655	100. 0
1927	6, 750, 935	5, 213, 207	3, 026, 109	2, 077, 893	68. 7	1, 143, 831	1, 138, 783	99. 6	923, 909	923, 909	100. 0
1925	6, 093, 821	5, 005, 445	3, 071, 362	2, 253, 219	73. 4	1, 034, 814	1, 013, 109	97. 9	633, 197	633, 197	100. 0
1923	5, 872, 870	4, 636, 789	3, 249, 668	2, 195, 395	67. 6	970, 102	[2] 970, 102	100. 0	488, 292	488, 292	100. 0
1921	4, 557, 179	3, 740, 406	2, 514, 893	1, 813, 762	72. 1	863, 043	[2] 863, 043	100. 0	282, 375	282, 375	100. 0
1919	5, 477, 832	4, 445, 817	3, 187, 214	2, 313, 419	72. 6	795, 154	[2] 795, 154	100. 0	293, 610	293, 610	100. 0
1914	4, 470, 763	3, 641, 063	2, 660, 795	1, 892, 739	71. 1	602, 754	[2] 602, 754	100. 0	141, 359	141, 359	100. 0
1909	4, 001, 607	3, 207, 653	2, 421, 581	1, 653, 249	68. 3	559, 657	[2] 559, 657	100. 0	90, 885	90, 885	100. 0

[1] Figures from 1909 to 1925, inclusive were compiled from U.S. Department of Agriculture, Statistical Bulletin No. 21. Figures for 1927 and 1928 were compiled from U.S. Bureau of the Census. Census of Manufactures, 1927 and 1928.

[2] Importation, if any, negligible.

TABLE VI.—*Principal kinds of pulpwood consumed in the United States since 1909*—Continued

Year	Aspen			Balsam fir			All other [3]		
	Total consumption (cords)	Amount domestic		Total consumption (cords)	Amount domestic		Total consumption (cords)	Amount domestic	
		Cords	Percent of consumption		Cords	Percent of consumption		Cords	Percent of consumption
1928	547,803	347,932	63.5	359,666	257,379	71.6	909,560	884,332	97.2
1927	538,131	351,436	65.3	389,230	305,143	78.4	729,725	729,725	100.0
1925	402,920	206,982	51.4	267,190	214,600	80.3	684,338	684,338	100.0
1923	334,694	152,886	45.7	237,509	[2] 237,509	100.0	592,605	592,605	100.0
1921	246,680	131,038	53.1	226,726	[2] 226,726	100.0	423,462	423,462	100.0
1919	338,380	180,160	53.2	288,814	[2] 288,814	100.0	574,660	574,660	100.0
1914	390,157	328,513	84.2	125,296	[2] 125,296	100.0	550,402	550,402	100.0
1909	328,498	302,876	92.2	95,366	[2] 95,366	100.0	505,620	505,620	100.0

[2] Importation, if any, negligible.
[3] Slabs and mill waste included. They formed 66.6 percent of the total in 1928, 39.2 percent in 1927, 22.8 percent in 1925, 17.5 percent in 1923, 15.8 percent in 1921, 30.5 percent in 1919, 46.1 percent in 1914, and 49.2 percent in 1909.

51. *Decreased consumption of spruce.*—While our consumption of spruce far exceeds that of any other wood species, the 1928 figure of 3,063,781 cords represents a material decrease in the proportion of spruce employed over earlier years as well as a slight decrease in the actual amount of wood. For as late as 1922 the census reported a consumption of 3,032,890 cords of spruce which formed 54.7 percent of the total pulpwood consumption in that year. This decrease in spruce consumption was distributed through three major processes of wood-pulp production but, strange to say, was not found in the one process where but small amounts of spruce have been used, that is, in the soda process. In 1928, 82 percent of the wood entering into mechanical pulp was spruce as compared with 87 percent in 1922. The sulphite process took 53 percent in 1928 as compared with 60 percent in 1922; the sulphate process 4.5 percent as compared with 15.5 percent in 1922. The soda process, however, increased its spruce consumption from 1,121 cords to 35,549 cords.

52. Increased application of hemlock and aspen is chiefly responsible for the decreased consumption of spruce for mechanical pulp. Use of mill waste has increased materially in sulphite pulp mills since 1922. Hemlock, jack pine, and larch had come into extensive use in sulphate pulp mills since 1928.

53. *Pulpwoods used in other processes.*—Table VII shows the extent to which each species was employed in the several pulp-manufacturing processes in 1928. It is obvious that sulphate pulp reduction depends chiefly on the pines although 13 percent of this type of pulp was made of hemlock. Soda pulp still clings closely to aspen as its principal wood material.

54. An interesting development is the beginning of semichemical pulp production utilizing sawmill waste and jack pine. While this new process consumed but 40,790 cords of wood, yet its increased application may widen the types of commercial pulpwood by reducing manufacturing costs.

55. In 1922, less than 90,000 cords of waste wood was manufactured into pulp in this country; in 1928, this consumption had reached 455,605 cords; and 548,800 cords in 1929, a development taking place chiefly in the State of Washington in the production of sulphite pulp.

TABLE VII.—*Pulpwood consumption, by kind of wood and process of manufacture, 1928* [1]

Kind of wood	Total		Process of manufacture									
			Mechanical		Sulphite		Soda		Sulphate		Semi-chemical	
	Cords	Percent	Cords	Percent	Cords	Percent	Cords	Percent	Cords	Percent	Cords	Percent
United States	7,160,100	100.0	1,558,818	100.0	3,196,939	100.0	928,300	-----	1,435,252	-----	40,791	-----
Spruce	3,063,781	42.8	1,283,831	82.4	1,680,513	52.6	35,549	3.8	63,888	4.5	-------	-----
Hemlock	1,177,635	16.5	108,885	6.9	875,610	27.4	4,770	.5	188,370	13.1	-------	-----
Yellow pine, southern	925,698	12.9	7,125	.5	7,205	.2	92,844	10.0	818,524	57.0	-------	-----
Aspen	425,065	5.9	21,935	1.4	13,098	.4	383,346	41.3	6,686	.5	-------	-----
Balsam fir	359,666	5.0	84,043	5.4	205,690	6.4	-------	-----	69,933	4.9	-------	-----
Jack pine	175,957	2.5	9,553	.6	20	(2)	100	(2)	151,339	10.5	14,945	36.6
Yellow poplar	122,738	1.7	53	(2)	-------	-----	122,685	13.2	-------	-----	-------	-----
Beech, birch, and maple	82,327	1.1	14	(2)	2,692	.1	76,530	8.3	3,091	.2	-------	-----
White fir	105,161	1.5	27,494	1.8	75,602	2.4	-------	-----	2,065	.1	-------	-----
Gum	72,611	1.0	-------	-----	-------	-----	70,422	7.6	-------	-----	2,189	5.4
Tamarack or larch	67,394	.9	-------	-----	327	(2)	-------	-----	67,067	4.7	-------	-----
Other wood [3]	126,462	1.8	2,389	.1	-------	-----	123,856	13.3	217	(2)	-------	-----
Slabs and other mill waste	455,605	6.4	13,496	.9	336,182	10.5	18,198	2.0	64,072	4.5	23,657	58.0

[1] Compiled from U.S. Bureau of the Census, "Census of Manufactures", 1928.
[2] Less than 0.1 percent.
[3] Basswood, cedar, chestnut, cottonwood, Douglas fir, box elder, buckeye, white pine, and willow.

PULPWOOD CONSUMPTION AND PULPWOOD PRODUCTION IN THE SEVERAL STATES

56. *Pacific Coast States.*—With 56 percent of our spruce, fir, and hemlock stands located in Washington, Oregon, and California, these States consumed but 600,000 cords of these woods out of a total United States consumption of 4,700,000 cords, or but 12.8 percent. With 25 percent of the pines available for sulphate pulp growing on the Pacific coast, less than 3 percent of the total consumption took place in these States. Washington State produced 8 percent of our wood pulp and 3 percent of our paper; Oregon and California, 5 percent wood pulp and 3.7 percent of the total paper in 1928.

57. The United States Forest Service states that "under proper timber-growing methods", Washington, Oregon, and Alaska can supply approximately 5,000,000 cords of spruce, hemlock, and fir annually,[97] or enough to meet all present needs of these pulpwoods.

58. *Middle Atlantic States.*—The Middle Atlantic States of New York, Pennsylvania, New Jersey, Delaware, and Maryland have 4.6 percent of our national pulpwood reserves. They consume 21.7 percent of all pulpwood. They produce 23.2 percent of our total wood pulp and 29.2 percent of the Nation's paper.

59. *New York.*—New York State produces more paper than any other State, or 1,454,000 tons. It ranks third in wood-pulp production. But less than 14,000,000 cords of spruce and fir, of which 7,000,000 are on State preserves where cutting is prohibited, are growing in the State; yet the consumption of spruce and fir pulpwood in 1928 totaled in excess of 655,000 cords. While the total stand of hemlock is about equal to that of spruce and fir, it is held by lumber companies and used chiefly for purposes other than pulp. Birch, beech, and maple are available but such domestic woods are not used.

[97] U.S. Department of Agriculture, Department Bulletin No. 1485. The Suitability of American Woods for Paper Pulp, p. 5.

60. Out of 802,115 cords of pulpwood consumed by New York pulp and paper mills in 1928, 596,378 cords were imported. In the total amount consumed 53 percent is imported spruce and 21 percent domestic spruce; 6 percent is imported fir and 1 percent domestic fir; 12.7 percent is imported aspen and 1 percent domestic aspen. New York is carrying out a program of extensive reforestation but for a number of years to come New York's pulp and paper mills will be dependent on pulpwood from sources outside the State.

61. *Pennsylvania.*—Pennsylvania ranks fifth in the production of paper and wood pulp. It is first in the production of soda pulp and ranks high in book-paper manufacture. It consumes 5.7 percent of our annual domestic pulpwood supply, produces 5 percent of the wood pulp, and manufactures 7 percent of our paper. Information concerning its pulpwood stands are inadequate though they include 9,500,000 cords of hemlock, about 2,000,000 cords of pitch pine, and 1,000,000 cords of aspen. Forest lands containing mixed hardwoods cover a large acreage.[98]

62. But few Pennsylvania mills secure their timber entirely from within the State. While 60 percent is imported, nearby States ship in other woods. Importations are chiefly of spruce and aspen. Domestic woods are largely southern pine and yellow poplar, beech, birch maple, and gum.

TABLE VIII.—*State consumption of pulpwood and production of wood pulp and paper in 1928* [1]

State	Pulpwood consumption				Wood-pulp production				Paper production	
	Total		Domestic	Imported	Total		From domestic pulpwood	From imported pulpwood	Total	Percent of total
	Cords	Percent	Cords	Cords	Tons	Percent	Tons	Tons	Tons	
United States	7,160,100	100.0	5,750,689	1,409,411	4,510,800	100.0	3,546,988	963,812	10,403,338	100.0
New England:										
Maine	1,309,988	18.3	1,126,407	183,581	970,690	21.5	834,668	136,022	987,201	9.5
New Hampshire	351,349	4.9	290,880	60,469	198,587	4.4	164,347	34,240	200,163	1.9
Vermont	20,081	.3	16,834	3,247	19,831	.4	16,649	3,182	72,198	.7
Massachusetts	51,325	.7	48,201	3,124	32,370	.7	30,415	1,955	541,268	5.2
Connecticut									180,887	1.7
Middle Atlantic:										
New York	802,115	11.2	205,737	596,378	633,182	14.0	162,326	470,856	1,453,597	13.9
Pennsylvania	405,276	5.7	171,143	234,133	218,598	5.0	92,246	126,352	712,874	6.9
New Jersey	(2)		(2)	(2)	(2)		(2)	(2)	552,963	5.3
Maryland	(2)		(2)	(2)	(2)		(2)	(2)	103,278	1.0
Virginia	342,813	4.8	296,432	46,381	189,925	4.2	164,223	25,702	219,235	2.1
Lake:										
Michigan	331,697	4.6	231,727	99,970	196,203	4.4	137,182	59,021	1,061,358	10.2
Minnesota	282,691	3.9	282,691		194,399	4.3	194,399		273,637	2.6
Wisconsin	1,225,630	17.1	1,053,852	171,778	720,781	16.0	619,665	101,116	893,017	8.6
Central:										
West Virginia	(2)		(2)	(2)	(2)		(2)	(2)	42,907	.4
Indiana									342,202	3.3
Illinois									528,138	5.1
Ohio	(2)		(2)	(2)	(2)		(2)	(2)	894,805	8.6
Pacific coast:										
Washington	651,657	9.1	641,307	10,350	349,107	7.7	343,741	5,366	309,164	3.0
Oregon } California	308,264	4.3	308,264		213,407	4.7	213,407		198,397	1.9
California									183,923	1.8
South Central: Louisiana	413,602	5.8	413,602		226,708	5.0	226,708		238,424	2.3
All other States	663,612	9.3	663,612		347,012	7.7	347,012		413,702	4.0

[1] Compiled from: U.S. Bureau of the Census, "Census of Manufactures", 1928.
[2] Not shown separately in order to avoid disclosing the output of individual establishments.

[98] U.S. Department of Agriculture. Department Bulletin No. 1241. How the United States Can Meet Its Present and Future Pulpwood Requirements.

63. *The New England States.*—The six New England States have 4.7 percent of the Nation's stand of pulpwood. Their mills required 24.3 percent of the entire pulpwood consumed in the United States in 1928. They produced 27 percent of its wood pulp and 19 percent of its paper.

64. *Maine.*—Maine is the largest pulpwood-consuming State in the country and also the largest wood-pulp-producing State. It consumed approximately 1,310,000 cords of wood in 1928, or over 18 percent of the total amount consumed in the United States. It has probably under 45,000,000 cords of spruce and fir, about 3,500,000 cords of hemlock, and 3,500,000 cords of poplar or aspen. Some pulpwood is shipped from Maine to New Hampshire, but some is also imported from Canada. Of the total pulpwood consumed in 1928, 65 percent was Maine spruce and 10 percent Canadian spruce; 4 percent was Maine fir and 2 percent Canadian fir; 4 percent was Maine hemlock and 11 percent Maine poplar or aspen.

65. *New Hampshire.*—New Hampshire finds use for 5 percent of our pulpwood. It has less than 6,000,000 cords of spruce and fir available for pulp and paper and, as it consumes over 300,000 cords annually, spruce is gotten from Vermont and Maine and some comes from Canada.

66. While Massachusetts and Connecticut produce together 7 percent of our paper, they count on rags as their principal source of raw material and are not heavy pulpwood-consuming States.

67. *Lake States.*—Michigan, Wisconsin, and Minnesota contain 9.4 percent of the Nation's timber reserves. These are largely hemlock and hardwoods. They consume 25.6 percent of our annual pulpwood and produce 24.7 percent of the entire wood-pulp supply and 21.4 percent of the country's paper.

68. *Michigan.*—Michigan ranks second as a paper manufacturing State in this country but manufactures but 4 percent of the wood pulp and, consequently, has a pulpwood consumption of but 300,000 cords. While it has stands of spruce, fir, and hemlock in the upper Peninsula these are more accessible to Wisconsin mills than to Michigan mills in the lower Peninsula. Also, it has jack pine and hardwoods. The woods actually consumed in 1928 were made up of 22 percent domestic spruce and 27 percent imported spruce; 17 percent domestic hemlock, 12 percent domestic fir, almost 10 percent jack pine and 6 percent larch. Slabs and mill waste formed 5 percent of the total woods converted into pulp.

69. *Wisconsin.*—Wisconsin, on the other hand, is second only to Maine in pulpwood consumption and wood-pulp production, and ranks fourth in paper production. Its supply of spruce and fir is small; hemlock stands contain about 30,000,000 cords. A large amount of spruce is secured, therefore, from Minnesota and northern Michigan, and also from Canada. Hemlock is drawn from its own supplies and from Michigan although competition for hemlock is had from the lumber industry. Jack-pine reserves are large but scattered. The 1,225,000 cords of pulpwood consumed by Wisconsin in 1928 were made up as follows: Domestic spruce constituted 19 percent, imported spruce 13 percent; domestic hemlock 43 percent, domestic fir 11 percent, jack pine 9 percent, and larchwood but 4 percent.

70. *Minnesota.*—Minnesota has less than 8,000,000 cords of spruce and fir, much of which is being attacked by insects. It has about 16,000,000 cords of jack pine, about 15,000,000 cords of aspen, and about 15,000,000 cords of tamarack. Its pulpwood consumption in 1928 was chiefly made up of its own spruce, fir, aspen, and jack pine. The State produces but 4 percent of our wood pulp and 3 percent of our paper.

71. *The Central States.*—The pulp wood reserves of the Central States are chiefly hardwoods. The pulp mills now producing in these States are so few that they are not listed by the United States Census. Paper production totals 17.4 percent, however, most of which is manufactured in Ohio and Illinois. Production in West Virginia is increasing. These mills manufacture chiefly book and board for which waste papers and rags, purchased sulphite pulp, purchased soda pulp, and some soda pulp manufactured locally in book-paper mills, are used.

TABLE IX.—*Pulpwood consumption in each State in 1928 by kinds of wood* [1]

State	Total		Spruce				Hemlock			
			Domestic		Imported		Domestic		Imported	
	Cords	Percent	Cords	Percent	Cords	Percent	Cords	Percent	Cords	Percent
United States	7,160,100	100.0	2,000,433	27.9	1,063,348	14.9	1,158,958	16.2	18,677	0.3
Maine	1,309,988	100.0	845,837	64.6	135,374	10.3	55,561	4.2	3,681	.3
Wisconsin	1,225,630	100.0	233,151	19.0	156,047	12.7	522,721	42.6	9,307	.8
New York	802,115	100.0	170,836	21.3	426,793	53.2	9,884	1.2	3,533	.4
Washington	651,657	100.0	43,208	6.6	455	(3)	211,105	32.4	2,156	.3
Louisiana	413,602	100.0								
Pennsylvania	405,276	100.0	8,100	2.0	142,761	35.2	11,484	2.8		
New Hampshire	351,349	100.0	274,670	78.2	60,469	17.2				
Virginia	342,813	100.0	9,138	2.7	46,381	13.5	17,650	5.1		
Michigan	331,697	100.0	71,490	21.6	88,708	26.7	55,416	16.7		
Oregon and California	308,264	100.0	30,633	9.9			207,023	67.2		
Minnesota	282,691	100.0	198,086	70.1						
Massachusetts	51,325	100.0	41,084	80.0	3,113	6.1				
Vermont	20,081	100.0	3,508	67.3	3,247	16.2				
Other States [2]	663,612	100.0	60,692	9.2			68,114	10.3		

State	Yellow pine southern		Aspen				Balsam fir			
			Domestic		Imported		Domestic		Imported	
	Cords	Per cent	Cords	Percent	Cords	Percent	Cords	Percent	Cords	Percent
United States	925,698	12.9	225,194	3.1	199,871	2.8	257,379	3.6	102,287	1.4
Maine			143,254	10.9	21,277	1.6	47,369	3.6	22,860	1.8
Wisconsin			8,517	.7			130,627	10.7	6,424	.5
New York			9,025	1.1	102,136	12.7	11,078	1.4	46,816	5.8
Washington										
Louisiana	403,533	97.6								
Pennsylvania	50,404	12.4			76,447	18.9	900	.2	14,925	3.7
New Hampshire							8,520	2.4		
Virginia	198,115	57.8								
Michigan			217	(3)			38,190	11.5	11,262	3.4
Oregon and California										
Minnesota			31,431	11.1			17,369	6.1		
Massachusetts			7,117	13.9	11	(3)				
Vermont							3,326	16.5		
Other States [2]	273,646	41.2	25,633	3.9						

[1] Compiled from U.S. Bureau of the Census, Census of Manufactures, 1928.
[2] Arkansas 1 establishment, Delaware 1, District of Columbia 1, Maryland 2, Mississippi 1, New Jersey 1, North Carolina 3, Ohio 1, South Carolina 1, Tennessee 1, Texas 1, West Virginia 2.
[3] Less than 0.1 percent.

TABLE IX.—*Pulpwood consumption in each State in 1928 by kinds of wood*—Con.

State	Jack pine		Yellow poplar		Beech, birch, and maple				White fir	
					Domestic		Imported			
	Cords	Per-cent	Cords	Per-cent	Cords	Per cent	Cords	Per cent	Cords	Per-cent
United States	175,957	2.5	122,738	1.7	65,227	0.9	17,100	0.2	105,161	1.5
Maine					24,321	1.9				
Wisconsin	108,658	8.9								
New York	100	(3)			414	(3)	17,100	2.1		
Washington									37,563	5.8
Pennsylvania			16,721	4.1	31,170	7.7				
Virginia			49,323	14.4	3,169	.9				
Michigan	31,798	9.6								
Oregon and California									67,598	21.9
Minnesota	35,401	12.5			34	(3)				
Other States [2]			56,694	8.5	6,119	.9				

State	Gum		Tamarack or larch		Other [4]				Slabs and mill waste	
					Domestic		Imported			
	Cords	Per-cent	Cords	Per-cent	Cords	Per-cent	Cords	Per-cent	Cords	Per-cent
United States	72,611	1.0	67,394	0.9	118,334	1.7	8,128	.1	455,605	6.4
Maine					3,769	.3	389	(3)	6,296	.5
Wisconsin			48,758	4.0	217	(3)			1,203	.1
New York									4,400	.6
Washington					32,365	5.0	7,739	1.2	317,066	48.7
Louisiana									10,069	2.4
Pennsylvania	18,513	4.6			62	(3)			33,789	8.3
New Hampshire									7,690	2.2
Virginia	4,439	1.3							14,598	4.3
Michigan			18,266	5.5					16,350	4.9
Oregon and California									3,010	1.0
Minnesota			370	.1						
Other States [2]	49,659	7.5			81,921	12.3			41,134	6.2

[2] Arkansas 1 establishment, Delaware 1, District of Columbia 1, Maryland 2, Mississippi 1, New Jersey 1, North Carolina 3, Ohio 1, South Carolina 1, Tennessee 1, Texas 1, West Virginia 2.
[3] Less than 0.1 percent.
[4] Basswood, box elder, buckeye, cedar, chestnut, cottonwood, douglas fir, white pine, and willow.

72. *Southern States.*—The Southern States from Virginia to Texas have abundant reserves of pines and hardwoods. Two thirds of the timber stands of these States is regarded as suitable for pulp and the cut of pulpwood timber has been very small until recent years. The Forest Service states that with the adoption of forestry measures, the South can take care of all present and normal increases in the Nation's sulphate pulp needs; that the hardwood pulps now imported can be secured from southern forests continuously if forest management began with thinning out and improvement cuttings. Louisiana is already consuming 6 percent of our pulpwood and producing 5 percent of the wood pulp and 2.3 percent of the paper. The pulpwood consumption is almost entirely of yellow pine.

73. *Rocky Mountain States.*—The Northern Rocky Mountain States, that is, northern Idaho and northwestern Montana, have forests similar in character to those of Washington and Oregon. Spruce, fir, and hemlock stands are large. Farther south the stands are scattered. The lodge-pole pine, yellow pine, and the larch are numerous in Wyoming, Montana, Utah, and Colorado. While well-

developed lumbering industries are found in these Rocky Mountain States, pulp mills are few.

NATIONAL INDEPENDENCE IN PULPWOOD DEPENDS ON DEVELOPMENT OF INDUSTRY ON PACIFIC COAST AND IN SOUTH

74. Maine, our largest pulpwood consuming State, is the only State, therefore, in the North or Middle Atlantic or Central groups capable of meeting her own pulpwood requirements. New York and Michigan, the largest paper-producing States, must secure large amounts of raw materials from outside their borders. Pennsylvania, Wisconsin, and Ohio cannot supply pulpwoods for their own pulp and paper mills.

75. The Pacific Coast States have huge virgin stands of spruce, fir, and hemlock suitable, under forestry management, for the Nation's newsprint paper. They contain larger reserves of pine available for wrapping papers and boards. Southern States have ample reserves of pines for sulphate pulp, and possibly sulphite pulp, and much hardwood for book papers.

FOREST AND LUMBER MILL WASTE UTILIZATION

76. *Total waste.*—The United States Forest Service estimates the waste in logging and sawmill operations per year has run into the billions of cubic feet of wood. In the woods this is due to trees shattered or damaged in felling larger trees, defective logs, stumps, and tops, and other losses through careless handling. Only a little more than half of the log that enters the sawmill is used for manufactured products, the bark, saw kelp, slabs, edgings, and trimmings, as well as cuts, in many localities representing entire loss.

77. *Swedish use of waste.*—In Sweden the lumber and the pulp and paper industry have been so correlated that almost 3,000,000 tons of pulp and paper are manufactured in large part from logging and sawmill waste. Logs are diverted to sawmills, planing mills, box factory, charcoal, or paper plant as conditions warrant.

78. *United States.*—Beginnings of such integration are to be found in the United States with the grouping of plants making varied products from wood in a single location, and with removal of pulpwood from forests immediately following logging operations. In 1928 the pulp and paper mills of the United States turned 455,605 cords of slabs and other mill waste into wood pulp. Practically all of this waste was used in the sulphite and semichemical processes. The largest amount of such waste utilization took place in Washington.

79. *Following after the lumber companies.*—Washington is the largest lumbering State in the country, producing over a fifth of the Nation's lumber. Oregon is the second largest lumbering State. This lumber is shipped into eastern markets. Douglas fir is the species most used by the lumbering industry, but growing among the douglas fir stands are the finest pulpwood species. A survey made by one of the foresters revealed that in one timbered county alone, 70,000,000 feet of pulp material was left annually, and that if broken logs could be economically gathered this amount would be much greater.[98] One paper com-

[98] R. W. Vinnedge, president North Bend Timber Co., in address before National Conference on Forest Products. 1924.

pany, at least, is now gathering hemlock which remains after logging operations. The major obstacles to the more general adoption of such methods is the high freight rate charged to carry the lower-priced wood to pulp mills and the number of small logging companies operating in the Pacific Northwest.

80. *Use of sawmill waste.*—But the lumber and pulp industries are appreciating the value of amalgamation. The Olympic Forest Products Co., of Port Angeles, Wash., has a sawmill with a capacity of 160,000 feet of lumber every 8 hours, and an "all electric" bleached sulphite plant of 175 tons capacity. The Everett Sulphite Pulp Mill has a two-department mill. In one is installed equipment for cutting up hemlock logs for pulp; in the other logs will be cut up into lumber lengths. The profitableness of each market will determine the amount devoted to sulphite pulp produced. All rejects from the pulp mill are shipped to roofing mills. The Fir-Tex Board Mill, of St. Helens, Oreg., is manufacturing insulating board entirely from chips sent to it from sawmills along the Columbia River. The Western Board Products Co. is beginning operations at Salem, Oreg., to manufacture trunk board, container board, and other specialties from the waste of lumber and paper mills.

81. *Waste for sulphate pulp.*—The Great Southern Lumber Co., cutting yellow pine in Louisiana, sends its sawmill and woods refuse to a kraft pulp mill and a container board mill. All wood down to 3 inches in diameter is brought in from the forests for pulpwood. Two years before any trees are cut they are turpentined. Turpentine is also extracted by steam from lumber as it goes through dry kilns and from the wood chips going through the pulp mill.

82. *Correlated industries.*—Cloquet, Wis., once a lumber manufacturing center only, now has a correlated wood industry based on clearing the forests used of all species. Northern Minnesota furnishes white pine for lumber and spruce, jack pine, aspen, birch, and other hardwoods for paper. Short materials from the planing mills are worked up by a box factory. The paper mill makes newsprint, book, and wrapping paper from spruce, aspen, birch, tamarack, and jack pine. Small pieces of birch produce clothespins, tongue depressors, toothpicks, and other small wooden objects. Waste from the sawmill and paper mills is converted, in part, into insulating and sound-deadening board, part of which is used by the local refrigerator factory. Another mill uses the mill waste for manufacturing paper plugs, wire reels, and other specialties.

TABLE X.—*Paper material consumed in 1929* [1]

Chief materials	Quantity	
	Short tons	Percent
Total	11,522,131	100.0
Wood pulp	6,245,349	54.2
Paper stock	3,841,942	33.3
Rags	739,571	6.4
Straw	566,469	5.0
Manila stock: Rope, jute, bagging, etc.	128,800	1.1

[1] Compiled from: U.S. Bureau of the Census, Census of Manufactures, preliminary reports for 1929.

Other Sources of Paper Materials

WASTE MATERIALS

83. *Paper.*—Although wood pulp was our principal source of raw material, waste paper, to the extent of almost 4,000,000 tons, was used in the manufacture of board and book paper.

84. *Textiles.*—Rags were the original source of material out of which paper was made. They continue to be used for fine grades of paper. Approximately 700,000 tons were consumed in papermaking in 1929. Of this amount, 220,000 tons are imported, coming chiefly from European markets where linen is still in common use. Manila stock, such as rope, jute, bagging, to the extent of 129,000 tons, went into paper manufacture. The largest amount of this was imported.

TABLE XI.—*Imports and exports of paper stock other than pulpwood and wood pulp, in 1928* [1]

Imported from or exported to—	Imports						Exports	
	Rags		Waste bagging, waste paper, old rope, etc.		Total		Rags and all other miscellaneous paper stock (total)	
	Short tons	Percent	Short tons	Percent	Short tons	Percent	Short tons	Percent
Total	219,946	100.0	109,740	100.0	329,686	100.0	115,313	100.0
France	37,102	16.9	7,561	6.9	44,663	13.5	164	.1
Germany	32,471	14.8	9,269	8.5	41,740	12.7	839	.7
United Kingdom	30,126	13.7	33,013	30.1	63,139	19.2	5,154	4.5
Japan	28,394	12.9	3,269	3.0	31,663	9.6	2,617	2.3
Belgium	22,129	10.1	10,273	9.4	32,402	9.8	130	.1
Italy	16,853	7.6	3,116	2.8	19,969	6.1	1,181	1.0
Netherlands	13,378	6.1	9,043	8.2	22,421	6.8	347	.3
Canada	9,965	4.5	22,014	20.1	31,979	9.7	34,245	29.7
Spain	9,577	4.4	2,651	2.4	12,228	3.7	11	[2]
Egypt	3,466	1.6	29	[2]	3,495	1.1	0	------
Austria	2,870	1.3	280	.3	3,150	1.0	29	[2]
Java and Madura	----------	------	----------	------	----------	------	20,509	17.8
Hong Kong	----------	------	----------	------	----------	------	18,321	15.9
China	1,299	.6	110	.1	1,409	.4	12,575	10.9
British India	65	[2]	69	[2]	134	[2]	5,128	4.5
Philippines	30	[2]	33	[2]	63	[2]	4,661	4.0
Other countries	12,221	5.5	9,010	8.2	21,231	6.4	9,402	8.2

[1] U.S. Department of Commerce: Data compiled from Foreign Commerce and Navigation, 1928.
[2] Less than 0.1 percent.

85. *Cereal straws.*—Straw wrapping paper and strawboard have been manufactured in this country for almost a hundred years. The amount of straw entering into paper-making is approximately 566,000 tons. Board from cornstalks, board from bagasse, and bleached paper from cornstalks are being manufactured in a few factories today.

86. Many experiments have been conducted both by the United States Department of Agriculture, Iowa State College, and other colleges to find a method of utilizing this farm waste. While not only coarse paper but white paper has been made from straw and cornstalks, these materials have not succeeded commercially in meeting the competition from pulpwood in newsprint-, wrapping-, or book-paper manufacture.

87. *Quantities available.*—The supply of straws and cornstalks in the United States is very extensive. The yield of cured corn fodder, according to the Department of Agriculture, is from 1 to 2 tons per acre, giving from 100,000,000 tons to 150,000,000 tons of field-cured cornstalks annually. The usual production of field-cured wheat straw is approximately 50,000,000 tons. Bagasse production in Louisiana reaches 375,000 tons. The principal corn-producing States are Iowa, Illinois, and Nebraska; the wheat States are Kansas, North Dakota, Nebraska, Oklahoma, and Washington.

88. *Pulp yields.*—The yields of pulp from these straws vary widely, the range being from 30 percent to 50 percent. The density of the material permits the cooking of but about 3 pounds of cornstalks or bagasse in a cubic foot of digester space that will hold 10 pounds of chipped wood. The nonfibrous cellulose present in large amounts in cornstalks has value only where water resistance and hardness are essential.[99] Larger amounts of water and chemicals and more steam are usually required to produce bleached papers.

89. *Value in papers.*—These factors have not yet made commercial development of cereal straws for printing paper successful, although such paper has been manufactured by the Cornstalk Products Co. at Danville, Ill., and by the Meade Corporation of Chillicothe, Ohio. The profitable application of bagasse and cornstalks in insulating wall board, of straws for unbleached egg-case fillers and chip board has, however, been established.

90. *Manufacturers.*—A large manufacturer of straw board is the Steward Inso Board Co. of St. Joseph, Mo. The Maizewood Products Corporation at Dubuque, Iowa, produces a building insulation board and a lighter board for nonstructural insulation. The Celotex Co. of New Orleans holds the patents for manufacturing fiber board from bagasse.

Manufacturers of Pulp and Paper in the United States and in Canada

91. So much of Canadian pulp and paper enters the United States markets that the picture of manufacturing control would be incomplete without inclusion of the principal Canadian mills with those in the United States. Wood pulp is produced by paper mills either at the paper mill itself or at scattered plants, and it is also manufactured by firms producing wood pulp only. Paper mills do not confine their manufacture entirely to one type of paper, but the larger mills produce a number of kinds. Figures on number of plants producing any one type of pulp or any one type of paper are not, therefore, mutually exclusive.

92. In 1930 there were 259 pulp mills operating in the United States and 119 operating in Canada. The largest number in both countries were mechanical pulp mills. In the United States these totaled 105; in Canada, 67. The United States had 85 producing sulphite mills, 25 soda pulp mills, and 36 sulphate pulp mills. Canada had 43 sulphite, 1 soda, and 8 sulphate pulp mills in operation in 1930.

93. In the same year there were 757 paper mills producing in the United States and 84 operating in Canada. Some of these mills

[99] U.S. Bureau of Chemistry and Soils, Industrial Farm Products Division. Farm Wastes for Paper and Board Making. June 1929.

were, of course, using stock other than pulpwood. This is especially true of board mills where waste paper is the chief raw material. Others purchased stock from pulp mills in this country, but a large number of paper mills were dependent upon imported pulp for their operations.

94. States which have a number of paper mills but not a single pulp mill are Connecticut, Illinois, and Indiana; while Massachusetts, Michigan, New Hampshire New Jersey, Pennsylvania, and Ohio have many paper mills and but few pulp mills. Maine, on the other hand, has 38 pulp mills and 32 paper mills, while Washington State has 26 pulp mills and 14 paper mills, and in Oregon 10 pulp mills and 7 paper mills were operating in 1930. These pulp mills are selling, in most cases, sulphite pulp.

95. Twenty-one firms, operating a number of mills in the United States and Canada, had daily capacities of finished products of 500 tons or over per day. These were:

Company	Principal product	Location of mill	Daily capacity (tons of finished product)
International Paper Co.	Mechanical and sulphite pulp	New York, Maine, and New Hampshire.	5,000
	Newsprint paper	Quebec, New Brunswick, and Newfoundland, Canada.	
	Special sulphite pulp	Quebec, Canada	
	Book and fine paper	New York and Massachusetts	
	Boards, ground wood, and sulphite pulp.	Ontario, Canada	
	Sulphate pulp, kraft, wrapping, and bag.	Alabama, Arkansas, Louisiana, and Mississippi.	
	Insulating and building board	Illinois and Indiana; Ontario and Quebec, Canada.	
	Hanging	Illinois and Maine	
	Specialties	Illinois, New York, and West Virginia.	
	Wrapper	Maine	
	Magazine	Maine and Massachusetts	
	Poster	Massachusetts	
	Tablet, bond, mimeo, litho, and ledger.	New York	
Canada Power & Paper Corporation.	Newsprint, wrapping, news half-tone, pulpboard, kraft wrapping, ground wood, sulphite, and sulphate pulp.	Quebec, Canada	2,624
Crown Zellerback Corporation.	Newsprint, wrapping, ground wood, and sulphite pulp.	Washington and Oregon; British Columbia, Canada.	2,140
	Tissues and kraft, and sulphate pulp.	Washington; and British Columbia, Canada.	
	Boards	California and Washington	
Abtibi Power & Paper Co., Ltd.	Newsprint, board, ground wood, and sulphite pulp.	Ontario, Canada	2,100
Price Bros. & Co., Ltd	Newsprint, mill wrappers, wood board, ground wood, and sulphite pulp.	Quebec, Canada	1,293
Container Corporation	Container, chip and box boards, and liners.	Illinois, Indiana, Ohio, and Pennsylvania.	1,190
Minnesota and Ontario Paper Co.	Newsprint, insulating board, ground wood, and sulphite pulp.	Minnesota; and Ontario, Canada.	1,150
	Kraft, liner, wrapper, building board, and sulphate pulp.	Minnesota	
Kimberly Clark Corporation.	Newsprint	Ontario, Canada	1,144
	Book	Wisconsin and New York	
	Absorbent wadding and ground wood pulp.	New York	
	Catalog, wrapping, board, etc	Wisconsin	
	Ground wood and sulphite pulp.	Wisconsin; and Ontario, Canada.	
Great Northern Paper Co.	Newsprint, wrapper, waxing, bag, and specialties; sulphite and ground wood pulp.	Maine	1,025

Company	Principal product	Location of mill	Daily capacity (tons of finished product)
Robert Gair Co	Miscellaneous board and liners	Massachusetts, New York, and Illinois.	995
	Chip and test jute liners	Connecticut	
West Virginia Pulp & Paper Co.	Book, writing, and soda pulp	Virginia, Pennsylvania, and Maryland.	815
	Magazine and specialties	Pennsylvania	
	Book and specialties	New York	
	Sulphite pulp	Virginia and New York	
	Sulphate pulp	Virginia	
Consolidated Paper Co	Miscellaneous boards and liners.	Illinois and Michigan	740
	Auto panel board	Michigan	
Fraser Cos., Ltd	Core paper, boards, and specialties; ground wood and sulphite pulp.	New Brunswick, Canada	650
	Bond, ledger, catalog, boards, and specialties.	Maine	
Consolidated Water Power & Paper.	Newsprint, book, bond, wrapping, wall paper, crepes, and tissues; canary and white second sheets; ground wood and sulphite pulp.	Wisconsin	637
Kieckhefer Container Co	Chip and container board	New Jersey and Michigan	625
River Raisin Paper Co	Board, shipping cases, packing materials, and silicate of soda.	Michigan	600
Hinde, Dauch Paper Co	Test jute liner	New York, New Jersey, and Indiana.	590
	Straw papers for corrugating	Indiana, Iowa, and Ohio	
	Miscellaneous boards	Ontario, Canada	
United Paperboard Co	Straw paper for corrugating	Illinois and Indiana	533
	Miscellaneous boards and specialties.	New York, Maine, New Jersey, and Ohio.	
Brown Paper Mill Co., Inc.	Kraft, wrapping, bag, board, and sulphate pulp.	Louisiana	500
Champion Coated Paper Co.	Coated papers and boards, mimeo, post card, etc.	Ohio	500
Powell River Co., Ltd	Newsprint ground wood, and sulphite pulp.	British Columbia, Canada	500

NEWSPRINT PAPER MANUFACTURERS

96. There are now only 38 newsprint paper manufacturers in the United States. These own or control 50 domestic mills that were in operation in 1928. Three companies produced 50 percent of the newsprint manufactured in the United States in 1928.

97. The largest newsprint manufacturer in the United States, the Great Northern Paper Co., of Millinocket, Me., owns three mills in Maine having a newsprint paper capacity of 970 tons daily. They produced 311,637 tons of paper in 1928. The company produces its own mechanical and sulphite pulp and also holds stands of spruce and fir in New England.

98. The Crown Zellerback Corporation, of San Francisco, acting as a holding company, owns or controls the Crown Willamette Paper Co., with newsprint mills at Camas, Wash., and West Linn, Oreg., and the Washington Pulp & Paper Co., with a newsprint mill at Port Angeles, Wash. These three American mills have a capacity of about 800 tons daily; they produced 211,085 tons in 1928, or 15 percent of the total United States newsprint production for that year. This company controls timber stands in Washington and Oregon having approximately 6,500,000,000 feet of timber. It also has timber leases to 3,500,000,000 feet in Canada and large acreage in the Tongas National Forest in Alaska.

99. The International Paper Co., of New York, produced only 165,405 tons of newsprint within the United States in 1928, although

it is regarded as the largest producer of newsprint paper in the world. Only 5 of its United States mills produced newsprint in 1928, although 15 have newsprint paper equipment and have a total newsprint paper capacity of 1,160 tons daily. Of the 5 mills operated, 2 are located in New York State, 1 in Maine, and 2 in New Hampshire. In 1930 only four plants were operated. The company owns timber in Maine, New Hampshire, Vermont, and New York. The capacity of its Canadian and Newfoundland newsprint plants is 2,275 tons per day, and its timber holdings in Quebec, New Brunswick, Nova Scotia, and Ontario total over 3,000,000 acres.

100. Other United States companies having plant capacities in excess of 100 tons newsprint pulp per day are:

Company	Location	1930 daily newsprint capacity (short tons)
Consolidated Water Power & Paper Co	Wisconsin Rapids and Biron Rapids, Wis.	328
Minnesota & Ontario Paper Co	International Falls, Minn	262
Maine Seaboard Paper Co	Bucksport, Me	250
St. Croix Paper Co	Woodland, Me	190
St. Regis Paper Co	Norwood, Norfolk, and Raymondsville, N.Y.	160
Finch, Pruyn & Co	Glens Falls, N.Y	144
Pejepscot Paper Co	Pejepscot and Lisbon Falls, Me	137
Escanaba Paper Co	Groos, Mich	135
Cushnoc Paper Co	Augusta, Me	133
Inland Empire Paper Co	Millwood, Wash	106
Algonquin Paper Corporation	Ogdensburg, N.Y	102
Gould Paper Co	Lyons Falls, N.Y	102
Hawley Pulp & Paper Co	Oregon City, Oreg	100

101. Canadian newsprint plants having capacities in excess of 100 tons newsprint per day are:

Company	Location	1931 daily newsprint capacity (short tons)
Abitibi Power & Paper Co. (merged in 1931 with Anglo-Canadian Pulp & Paper Mills).	Ontario, Manitoba, Quebec	2,480
Canada Power & Paper Group	Quebec	1,945
Thunder Bay Paper Co. (owned by 2 companies listed above).	Ontario	245
International Paper Co. (American company)	Quebec, New Brunswick, and Newfoundland.	2,275
Price Bros. & Co	Quebec	1,260
Dominion Securities Corporation	do	950
Minnesota & Ontario Paper Co. (American company).	Ontario	825
Powell River Co., Ltd	British Columbia	650
Spruce Falls Power & Paper Co. (American company).	Ontario	475
Ontario Paper Co. (American company)	Thorold, Ontario	340
Mersey Paper Co	Nova Scotia	240
Crown Zellerback Corporation	British Columbia	230
J. R. Booth, Ltd	Ontario	160

102. It is obvious that Canadian newsprint mills are much larger than those operating in the United States. All operated by Canadian companies in Ontario and Quebec are members of the Newsprint Institute of Canada, organized through the efforts of the prime ministers of these Provinces to bring about a more even distribution of available business.

BOOK-PAPER MANUFACTURERS

103. There were, in 1930, approximately 40 large companies operating mills whose principal output was book paper, or print paper for other than newsprint consumption. In addition, some newsprint mills also produced book paper.

104. The largest of these companies is the West Virginia Pulp & Paper Co., having a daily capacity of 815 tons of paper, which is principally book. It also produces soda, sulphite, and sulphate pulp. It has plants in New York, Pennsylvania, Maryland, and Virginia, the largest being in the latter State. It specializes in supercalendered magazine papers.

105. Crocker, Burbank & Co., of Fitchburg, Mass., have plant capacities for 330 tons of book paper, most of which is supercalendered, magazine, and cover paper. The Mead Corporation, with plants in Ohio and Tennessee, has a capacity of 435 tons book paper. This company produces a large part of its soda pulp and bleaches some of the sulphite pulp purchased. The Kimberly Clark Corporation, of Wisconsin, produces mechanical and sulphite pulp and paper specialties, as well as having daily capacity for 425 tons of book paper. Other important book paper and soda pulp manufacturing plants are: The Castanea Paper Co., of Pennsylvania; the S. D. Warren Co., of New York; the Bryant Paper Co., of Michigan; the Jessup & Moore Paper Co., of Delaware; the Champion International, of Massachusetts; the Oxford Paper Co., of Maine; and the Everett Pulp & Paper Co., of Everett, Wash. This Washington company is listed as having a daily manufacturing capacity for 60 tons soda pulp and 65 tons of book, label, and writing paper.

WRAPPING-PAPER MANUFACTURERS

106. While southern and western wrapping paper manufacturers usually produce their own sulphate and sulphite pulp for manufacturing this type of paper, a number of northeastern manufacturers located on the St. Lawrence and the Great Lakes manufacture kraft paper from pulp imported chiefly from Scandinavia. Twenty-one manufacturers produced over 95 percent of all kraft pulp made in the United States in 1929.

107. The Brown Paper Mill Co., at Monroe, La., has the largest single sulphate paper mill in the United States. It can produce annually 150,000 tons of sulphate wrapping, bag, and liner board. The company also owns more than 300,000 acres of shortleaf pine in the South.

108. Among the other larger producers of kraft paper are the International Paper Co. at its southern plants; the Gulf States Paper Co. with plants in Alabama and Louisiana; the Bogalusa Paper Co., of Louisiana; the Advance Bag & Paper Co., with mills in Maine and Louisiana; the Albemarle Chesapeake Co., with over 400 tons daily draft capacity plants in Virginia; Union Bag & Paper Co., of New York; Central Paper Co., of Michigan; Nashua River Paper Co., of Massachusetts; Thilmany Pulp & Paper Mills and Falls Manufactur-

ing Co., of Wisconsin. Plants producing wrapping paper and wrapping paper pulp on the Pacific coast are:

Plant	Location	Daily capacity
Crown Willamette Paper Co.	Lebanon, Oreg.	340 tons wrappings.
	Camas and Port Townsend, Wash.	200 tons kraft liner and kraft.
St. Helens Pulp & Paper Co.	St. Helens, Oreg.	80 tons wrapping and envelope.
Longview Fiber Co.	Longview, Wash.	130 tons liner and wrapping.
Willapa Pulp & Paper Mills	South Bend, Wash.	100 tons sulphate pulp.
St. Regis Kraft Co.	Tacoma, Wash.	162.5 tons sulphate pulp.

109. The Pacific States Pulp & Paper Co. was building a 100-ton sulphate pulp plant at Priest River, Idaho, and had plans under way for a sulphite fiber plant at Aberdeen, Wash. This will be the first pulp mill in Idaho.

BOARD MANUFACTURERS

110. Because "board" is made of so many different raw materials, its manufacture is scattered throughout all the large centers of population, and many firms have fairly large plant capacities. Among the largest manufacturers are the Robert Gair & Co., of New York, with a daily capacity of 1,000 tons; the Consolidated Paper Co., of Michigan, with a daily capacity of 740 tons; the Fibreboard Products Co., of California, with a daily capacity at its several plants of 680 tons; the United Paperboard Co., of New York, with a daily capacity of 675 tons; the River Raisin Paper Co., of Michigan, having a daily capacity of 600 tons; the Minnesota & Ontario Paper Co., with 450 tons daily insulating board capacity; and the Celotex Co., of Louisiana having plant capacity of 500 tons bagasse board daily.

111. Five mills in the Pacific Northwest are manufacturing board. The two principal producers are the Fibreboard Products, Inc., of Port Angeles and Sumner, Wash., with daily capacities of 75 tons and 50 tons, respectively, and the Fir-Tex Insulating Board Co., of St. Helens, Oreg., with 75 tons daily insulating board capacity.

OTHER PACIFIC COAST PULP AND PAPER MILLS

112. As has been stated, there are several mills on the Pacific coast that produce pulp only. These are: The Puget Sound Pulp & Timber Co., with three Washington plants having total daily capacities of 330 tons bleached or unbleached sulphite pulp; Grays Harbor Pulp & Paper Co. with 150 tons daily capacity, at Hoquiam, Wash.; the Olympic Forest Products Co., having 175 tons daily sulphite pulp capacity, at Port Angeles; the Rainier Pulp & Paper Co., at Shelton, Wash., who are producing a good grade of rayon pulp, with 285 tons sulphite capacity; Willapa Pulp & Paper Mills, producing 100 tons sulphate pulp daily, at South Bend; the St. Regis Kraft Co., having capacity for 162.5 tons sulphate fiber at its Tacoma plant; the Shaffer Box Co., of Tacoma, producing sulphite fiber; Sitka Spruce Pulp & Paper Co., at Empire, Oreg., manufacturing 55 tons unbleached sulphite fiber; the Crown Willamette Paper Co., producing mechanical pulp only at its Oregon City plant; and the Spaulding Pulp & Paper Co., having a 60-ton sulphite fiber capacity plant at Newberg, Oreg.

113. Other Washington and Oregon plants that have not been mentioned elsewhere because they produce a number of paper products are: The Oregon Pulp & Paper Co., at Salem, which manufactures specialties, has a capacity of 120 tons of sulphite fiber daily; and the Columbia River Paper Mills at Vancouver. The latter plant has a capacity for 140 tons of ground wood and sulphite pulp and produces some newsprint paper, fruit wrappers, and other products.

Pulp and Paper Manufacturing Processes

PULP PRODUCTION IN MODERN MILLS

114. The standard processes by which pulp is manufactured do not differ in essentials from mill to mill, but equipment details and chemical formulas obtaining in individual mills cover a wide range. The descriptions of production methods that follow are those prevailing in new mills.

115. In the last 10 years many modifications of existing processes, and some new processes, have been patented. These patented processes are too numerous to include; only those known to have received commercial application are described.

116. *Barking.*—Sawmills are sometimes located at pulp mills and sometimes at lumber camps. As the case may be, wood is floated downstream, to be cut into 2- to 4-foot lengths at the pulp mill, or is delivered at the pulp mill already cut to size. The wood may be stacked or floated in the mill pond until needed. Electric drag rakes are used now to gather hundreds of pieces of wood from the pond, stack them, or deliver them to a conveyor. The pieces of wood are conveyed to drum or disk barkers. The "drum barkers" are revolving drums which require, on an average, 45 kilowatts power to remove bark from 100 tons of wood in 24 hours. The bark is removed by the rubbing of logs against each other and against the sides of the drum. In "disk barkers" logs are held against knives fastened to a revolving disk; these require less power than drum barkers, but remove some wood with the bark. The barked wood passes over screens which clean and sort it for further mechanical or chemical treatment.

MECHANICAL PULP

117. *Usual process.*—Wood is fed automatically into hydraulic magazine grinders. It is forced against a rapidly revolving stone by hydraulic pressure until the wood is reduced to pulp. As it comes from beneath the stone as a "slush" it collects in pits and flows to coarse screens that remove knots and larger pieces. It is further diluted and passes over diaphragm screens after which its water content is partially removed in thickners.

118. *Power requirements.*—Both artificial and natural grindstones are used. These are driven by electric motors, the power varying with the sharpness of the stone and the pressure used. An average consumption of energy required to operate the grinders is 1,160 kilowatt-hours per ton of pulp. The total energy required to grind the pulp, screen, and thicken it is about 1,250 kilowatt-hours. Adding, therefore, the power requirements of the wood sawing and bark-

ing room, 1 ton of mechanical pulp requires approximately 1,280 kilowatt-hours of electricity.

119. A greater fiber recovery is obtained by the mechanical process than by any of the other chemical processes. Usually, about 88 percent of the rossed wood is converted into pulp.

120. *Semichemical process.*—Mechanical pulp has a short fiber that does not produce strong paper; it is, therefore, combined with chemical fibers in paper making. Patents have been taken out which would produce a mechanical-chemical pulp that could be used without other kinds of pulp. According to the Bache-Wing process, the wood is first treated with sulphur dioxide under pressure and cooked in a salt or bisulphite solution. After such treatment, the wood is ground as in the mechanical process. By the Enge process, logs are heated with steam in a boiler and maintained at 147 or more pounds steam pressure for a number of hours before being ground. The United States Forest Products Laboratory has developed a process whereby the chips are first cooked with a liquor consisting of sodium sulphite and sodium bicarbonate, sodium carbonate or caustic soda, at a temperature reaching 140° to 160° C. They are then ground as in the regular mechanical process. Several mills have adopted this method in utilizing chestnut for corrugated boards.

121. *Sulphite pulp.*—Barked wood is washed well and sent through log and cant chippers which reduce it to chips from five eighths to one and three fourths inches long by knives set in heavy iron disks. Chips are cleaned by passing over an inclined wire screen through which dust passes and against which an air blast blows carrying the knots to a separate conveyor. Chips are stored above digesters preparatory to chemical treatment which removes lignin from the cellulose.

122. *Sulphite liquor.*—The cooking liquor used in the sulphite process is a solution of bisulphite of lime. Liquid sulphur dioxide may be purchased, or sulphur dioxide is produced by burning sulphur or iron pyrites in a furnace regulating the air supply so that for each unit of sulphur a corresponding unit of oxygen is supplied. The gases formed in the combustion chambers pass through water-cooled lead pipes to be cooled.

123. Many pulp plants use tower absorption apparatus. Towers are filled with marble, limestone, or dolomite lumps low in magnesium. These are moistened by water sprayed from the top. The sulphur dioxide gas enters at the towerbase and as it rises through the stone is absorbed by the film of lime water, producing bisulphite of lime. Others use partition tanks, or a 3-tank system in which the gas is mixed with milk of lime, made from lime high in magnesia.

124. *Cooking.*—Chips and bisulphite of lime are dumped into digesters which are brick-lined steel cylinders having capacities varying from 1 ton of fiber to 23 tons fiber. Quick cooking is done by steam at a pressure of about 80 pounds and at a temperature of approximately 365° F. In this so-called "quick" process from 2.4 to 4.5 pounds steam is required per pound of fiber. The sulphites, during this cooking, unite with the decomposed lignin, evolving gas which is blown off at intervals and its sulphur content recovered. Slow cooking uses less chemical, less steam, but requires more time.

125. *Blowing and washing.*—After cooking is completed, steam pressure of about 50 pounds forces the digested contents into pits

having screened bottoms through which the liquor drains. The pulp is then washed and drained to remove all remaining soluble, ligneous, and resinous matter. It passes over screens which take out uncooked chips, dirt, and other undesirable particles.

126. Frequently the sulphite mill combs the fibers apart on separators, blends tanks of pulp, passes it through rifflers whose partitions further remove solid substances, after which it is again screened. Water is removed and the pulp dried for dry shipment.

127. *Byproducts.*—Waste liquors are now purified in American mills by separating out the fibers and neutralizing the free acid with lime. But even so, many tons of waste are poured into streams. It is claimed that the waste liquor and reclaimed gases contain substances that will yield methyl, alcohol, acetaldelhyde, acetone, and other products of use in other chemical industries. Many other products from this waste are suggested but only a few are being produced. Tanning extracts, sodium lignin sulphonate to replace tartaric acid in mordanting wool, and alcohol are some of the materials that have been manufactured.

128. *Power required.*—No process in sulphite pulp production demands any unusual amount of power. The saws, barkers, chippers, pumps, and screens, as well as the conveying and other handling apparatus require small amounts, which total to approximately 185 kilowatt-hours per ton of pulp.

129. *Soda pulp.*—The vigorous action of the chemicals employed in this process make it possible to use waste lumber from lumber mills and round woodworking factories as well as logs of a number of species. The logs must have both inner and outer bark removed. They are cut up into chips by being held diagonally against the chipper disk from which several knives project. Waste lumber is chiped in a hogging machine very similar to the chippers. All chips are conveyed to shaking screens which screen out the sawdust; chips that are too large fall off into hog cutters for recutting. Chips of uniform size are blown to chip storage bins located above the digesters. Mill shavings received are freed of sawdust in revolving screens and are blown directly to the chipped wood storage bins without any chipping.

130. *Caustic liquor.*—Caustic soda under steam pressure is used to release the resinous and nonfibrous portions of the wood from the wood fibers. Caustic soda may be purchased, in which case it is a simple undertaking to dilute it to the proper consistency for cooking liquor. Or it may be made at the pulp mill by the electrolysis of salt or by causticizing soda ash. The electrolysis of salt has been described in detail on pages 289–291 of the section entitled "Power in the Manufacture of Chemicals and Metals from Brine." Because waste liquors are used in causticizing soda ash, this process will be described as it is carried on in paper mills. Sodium carbonate or soda ash is recovered from the black liquors, or liquors used in previous cooking operations. The water from this liquor is evaporated in triple-effect Swanson evaporators. The resulting mass is heated in a large rotating furnace, fired by special coal which gives a very hot fire without smoke. The furnace is open at each end so that the hot flames and gases pass over the sticky mass and burn out the ligneous and carbonaceous materials. The residue is leached, dissolving out the soda ash, while the carbon particles settle at the

tank bottom. About 85 percent of the soda ash is recovered. The heat generated in the incinerators is used to produce steam for the evaporators.

131. This recovered liquor is placed in large tanks. To it are added fresh soda ash, quick lime, and water. The mixture is brought to a boil and agitated. As the calcium carbonate formed is precipitated, the caustic soda is held in solution and syphoned out.

132. *Cooking.*—The digesters are the usual stationary or rotating types varying as to capacity, although modified types are on the market. In the stationary digester, the chips drop down from chip bins placed above the digesters, after which the lid is bolted firmly. For every cord of chips from 500 to 1,100 gallons of caustic liquor is pumped into the digester. Live steam effects the cooking; the pressure reaches 110 pounds, is reduced, and then allowed to come up again repeatedly to insure more even cooking. A 15-cord digester averages from 24,200 pounds steam in summer to 39,700 pounds in winter.[1] More than half of the wood weight is lost in the chemical reactions taking place in caustic cooking. Diciduous woods cook in 4 hours, coniferous in 6 hours.

133. *Washing.*—When cooking is completed, a valve is opened into iron pipes. The steam pressure inside the digester forces the cooked pulp through these pipes into wash tanks. Here a weak solution of spent caustic from previous washings is pumped over the cooked wood and the black liquor drained off goes to evaporators for recovery. The fresh water is run over the pulp, the drained liquor being recovered for use as a first wash water for the next cooked pulp. Additional washing is done until all waste is removed. The diluted mass is screened to remove uncooked pieces, knots, or other impurities. Surplus water is removed in the thickeners.

SULPHATE PULP

134. *Sodium sulphate cooking liquor.*—In general, the wood preparation and cooking equipment used in the sulphate process is similar to that required by the soda process. The major differences lie in the cooking liquor which permits the use of resinous woods and which gives slightly higher yields than does the soda process. Sodium sulphate or salt cake is the chief chemical used. About 320 to 395 pounds are required per ton of pulp produced. To this is added from 530 to 660 pounds lime. The sodium sulphate is purchased as it has been produced as a byproduct of hydrochloric acid manufacture for many years. Recent changes in the processes of manufacturing this acid have curtailed the production of its byproduct salt cake, so that importations have been large. The salt cake is manufactured in one United States chemical factory by the reaction of sulphuric acid on salt. Numerous natural deposits of salt cake exist in the Western States although only a few have been developed to date.

135. The cooked pulp is washed thoroughly to recover the highest possible amount of chemicals. Recovered black liquor is evaporated and burnt in a rotary furnace as in the soda process. But it must also pass through a smelting furnace from which the sodium sulphide formed flows to a dissolving tank containing water or dilute washings.

[1] Sutermeister, Edwin. Chemistry of Pulp and Paper Making.

After reaching the desired density, this so-called "green liquor" goes to the causticizing system.

136. When dark-colored fiber is to be produced, a part of the cooking liquor is made up of black liquor. When stock is to be bleached, fresh liquor is used.

137. *The explosion process.*—This process was patented in 1926. It makes possible the utilization of sawmill waste. Wood is reduced to uniform size in chippers. It is steamed, full pressure reaching 1,000 pounds for a few seconds, through the use of compressed air. At this pressure, the discharge valve is opened and the forced-out chips explode into fibers as they pass the valve.

138. This fiber is used in insulating board. The incrusted lignin or other substances which have been softened but not removed by the process, serve as binding agents after the board has been dried in hydraulic presses with steam-heated pattens.

139. *Chlorination processes.*—Wood or straw is given a preliminary cooking in a weak caustic soda solution. The liquor is removed and the pulp put under a vacuum after which chlorine gas is admitted for several hours. The wood is water washed and given a second alkaline treatment. It is then washed again and bleached with hypochloride.

OLD PAPER PULP

140. *For boards.*—The treatment afforded shavings from newspaper plants and other waste paper depends somewhat on the uses to which it is to be put. If it is to be made into board for which deinking and bleaching is not necessary, the bales are broken and fed into a breaker beater. As it is broken into shreds a continuous stream of water keeps the stock at a consistency of 5 percent or less. The paper is passed under a roll and flows out through perforations in the backfall into a regulator box. All trash larger than one fourth inch remains in the beater tanks from which it is removed by a rag catcher that is lowered into the tank.

141. *Power consumed.*—The power consumption of the breaker is dependent upon the size of the roll and its spud as well as upon the consistency of the stock. Mr. Humble, industrial fellow of the American Scandinavian Foundation, reported after visiting a number of American paper mills, that the average power consumption of the breaker per ton of pulp produced was 21 kilowatt-hours.

142. *For book paper.*—More careful preparation is necessary in reducing waste paper for reuse in paper that is to be printed. The old paper is sorted over at the paper mill as it passes over an endless belt conveyor into the knives of a shredding machine. The loose dirt is blown out by motor-driven fans into discharge vats. The shredded paper is soaked and agitated in a steam-heated soda ash solution to loosen ink and sizing. The softened paper is then circulated continuously through defibering tanks by powerful pumps. The violence of the agitation tears apart the separate fibers. The pulp is pumped along to rifflers which remove heavier foreign particles. From these it goes to vibrating screens which further remove solid matter and also keep the fibers separated. Ink and chemicals are then removed by a series of washings in tanks having wire mesh revolving drums.

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143. It is ready for bleaching which is accomplished with a small amount of liquid chlorine bleaching solution. One ton of old paper produces approximately three fourths ton of pulp.

144. *Rag pulp.*—Bales of rags, chiefly from Europe, are opened and the rags are thrown into a thrasher where they are torn to pieces by the teeth on a revolving cylinder and on the cylinder case. After dust has been removed, the rags are sorted to remove all foreign matter. They are then cut by hand or by machine into pieces 2 to 4 inches square. Clean cut rags are boiled in a caustic soda, or lime and soda ash solution to free them of grease, dirt, and coloring matter. They are then washed in large engines and bleached.

145. *Straw pulp.*—Straw, which includes the stems and leaves of cereals, is dusted by air blasts and cut into short lengths. It is then cooked with milk of lime in rotary boilers at 35 to 45 pounds steam pressure for 8 to 10 hours. Only a small part of incrusting matter and mineral matter is removed by this treatment. The cooked pulp is permitted to age for several days, after which it is washed and passed through heaters. This yellow-brown pulp is suitable for egg-case fillers, coarse papers, and some wall board.

146. *Corn-stalk pulp.*—Baled stalks are broken into pieces and fed into a hammer mill shredder which reduces the stalks to from ½ inch to 6 inches. Foreign matter is separated out on a magnetic separator and a centrifugal fan blows out dust. The cleansed fiber is digested under steam pressure of 100 pounds. After washing, the fibers are cut, rosin sized, and go to the stock chests.

147. *Pulp bleaching.*—Wherever a white paper is desired, it is essential to oxidize out impurities which remain in all wood pulp regardless of the process employed in isolating the fibrous cellulose. As chlorine and some of its compounds liberate oxygen while in the presence of moisture, these are the principal commercial bleaching chemicals used on pulp.

148. *Calcium hypochlorite.*—Liquid chlorine is shipped to the pulp mill in tank cars. As required, it is passed into an evaporator, where, by the application of heat, chlorine gas is formed. This enters the base of a tank filled with partition tile. A solution of lime and water trickles down through the hollow tile while the chlorine gas rises. A continuous circulation is carried on until lime is completely absorbed by the chlorine. The solution settles in mixing tanks, any excess lime being precipitated.

149. It is not necessary, however, to gasify the chlorine, for liquid chlorine can be added directly to milk of lime in deep tanks where adequate circulation is maintained.

150. *Chlorine gas.*—Chlorine gas may be applied directly to moist stock in tightly closed receptacles. It is excellent to produce a clean pulp from muddy matter and to remove metallic particles. However, it is claimed that better color is produced when the chlorine gas bleach is followed by a hypochlorite bleach, the total chlorine consumed being less than when calcium hypochlorite alone is used.

Sodium hypochlorite, made by electrolyzing a cold solution of salt, has made no headway among paper-pulp producers in the United States.

151. *Bleaching.*—Bleaching of pulp takes place in tile-lined tanks, engines, or drains. Tanks are divided into three compartments, open at one end. At the closed end a pump is placed that delivers the

stock as received from the two outer compartments back to the central compartment through which it moves by gravity back to the outer compartments. This continuous agitation in bleaching liquor is kept up for about 12 hours by the slow bleaching process. The rapid bleaching process adds an excess of strong bleach liquor and requires less time but careful control. Air blasts are sometimes blown on pulp to speed agitation.

152. *Washing.*—Bleached stock must be thoroughly washed to remove all chlorine. This is sometimes done by pumping it through worm-washers, a spray of water being constantly played upon it. The pulp is then ready for the paper-making process, when the paper mill and the pulp mill are together. When the pulp is to be shipped to paper mills it is passed through riffles, over a battery of flat screens into thickeners. It is then dried by passing over steam-heated cylinders.

153. *Alpha fiber.*—Alpha fiber is a substantially pure cellulose recently produced to take the place of rag stock in paper making or to be used in the preparation of cellulose esters and ethers. It is a sulphite pulp bleached with chlorine or chlorine compounds and with caustic soda. For example, by one patented process the pulp is bleached with chlorine hypochlorate at about 10-percent density, and with up to 4.5 percent caustic soda per unit of pulp. By another, sulphite is bleached with 10 to 25 percent bleaching powder per unit weight, washed, and then subjected to a chlorine bleach.

Paper from this type of pulp is soft but has good tearing and folding qualities.

PAPER MAKING IN MODERN MILLS

154. Again, there is a general similarity in methods of manufacturing all papers, but many variations in detail produce the many kinds of paper consumed.

NEWSPRINT PAPER

155. *Preparing the pulp.*—Paper for newsprint is made from mechanical pulp and sulphite pulp. From 75 to 80 percent groundwood pulp and 20 to 25 percent sulphite pulp are thoroughly mixed in beating engines. Small proportions of fillers, such as talc and china clay, are added during the mixing. Sometimes blue or red aniline dyes are also introduced to give a white color to the paper. In addition to mixing pulps and chemicals, beaters serve to separate the individual fibers from the pulp lumps and reduce them to a nearly uniform length.

156. From beaters, the pulp goes to stuff-chests, where it is kept in agitation. Jordon engines are sometimes used to complete the fiber separation and to make the stock uniform, in which case a second set of stuff-chests are necessary, as these regulate the flow of pulp. From them the stock is pumped through weight regulators into mixing boxes where water is added, and to screens which remove any trace of impurities.

157. *Paper machine.*—The fourdrinier machine is almost universally used for newspaper making. It is especially designed to meet the needs of different papers and may have special parts, but the major features of operation are the same on all machines.

158. Screened stock enters a box at the head of the machine which extends across the full width of the machine. This head box keeps an even flow of pulp going onto an endless moving belt which carries stock into the machine rolls. This belt is made of woven copper wires and its width determines the width of the paper produced. Water in the pulp drains through the wire, such drainage as well as fiber felting being assisted at definite points by suction boxes placed under the wire. A sidewise motion of the belt also aids the fiber felting. At the end of the belt the fibers pass between a pair of rolls called "couch rolls" which squeeze out more moisture. The sheet of paper produced runs onto a felt belt which carries it through press rolls. Sufficient water is removed by these rolls to permit the paper to have sufficient strength to travel unaided through a series of steam heated iron cylinders which dry out the sheet. Finally, the sheet is finished by passing through polished calender rolls. The paper is then wound on reels ready for shipment.

159. A new vacuum drier is being installed in some mills which dries the pulp in the absence of oxygen at a temperature of approximately 100° F. A vacuum pump driven by electric motor provides the vacuum on the couch roll, while a flat box pump, water driven, exhausts the flat boxes. All heat used to dry the paper is condensed and returned as hot water for other mill purposes. It is claimed this drier requires less steam than the fourdrinier drier.

160. *Power consumed.*—The paper machine requires the largest amount of power in the paper mill. The actual amount varies with the width of roll, speed of machine, kind of drive, and composition of the paper. A machine 234 inches wide at a driven speed of 1,000 feet per minute, requires 448 kilowatts, or each ton of newsprint produced consumes 86 kilowatt-hours. Closely related equipment, such as beaters, jordons, screens, and pumps require approximately 746 kilowatts or 144 kilowatt-hours power per ton, making a total paper mill consumption of 230 kilowatt-hours per ton. To this must be added at least three fourths of the power necessary to produce a ton of mechanical pulp or 960 kilowatt-hours, and one fourth the power required to manufacture a ton of sulphite pulp or 149 kilowatt-hours. Or the mechanical power required to produce 1 ton of newsprint paper from pulpwood totals approximately 1,340 kilowatt-hours.

In addition, from 8,000 pounds to 14,000 pounds of low-pressure steam is required per ton of paper produced.

161. *Book paper.*—The wide variety of papers included under this heading, that is, all print paper other than newsprint, calls for differences in manufacturing detail. In general, however, book paper passes through the same manufacturing processes as newsprint. The chief distinctions are that book pulp is made up of bleached chemical pulp and that finishing processes are extensive.

162. A usual combination of pulp entering into book paper is 40 percent soda pulp, 35 percent sulphite pulp, and 25 percent old paper and rag stock. The soda pulp slush is first run into the beater; followed by the sulphite pulp, and as the process is completed, old paper pulp is added. Several chemicals necessary to impart desired characteristics to the paper are fed into the pulp during the beating operation, or the paper web as it goes through the paper machine may be led through troughs filled with chemical solutions.

163. *Sizing.*—When paper is to be made nonabsorbent of ink and water, sizing is added to the pulp or web which gives the final paper

ink and water resisting qualities. Sizing materials vary. Rosin is most often used in this country although gelatine, glue, cornstarch, and casein have their respective market demands.

164. *Rosin.*—Rosin has been secured as the residue after distillation of pine for turpentine. An increasing scarcity of this rosin has brought about the extraction of rosin from stumpage and other pine waste. This wood rosin, it is claimed, is inferior to the gum rosin in paper making. Rosin sizing is usually made by cooking lump rosin and a soda-ash solution in a steam-jacketed tank. The mixture is boiled until much rosin is saponified. Steam pressure then forces the soda-rosin soap and warm water through a very fine spray, which causes the sizing to emulsify.

165. *Alum.*—When added to the paper stock in the beaters, a precipitant must also be put into the mixture, for the rosin requires such an agent to become deposited evenly over all the fibers. That used most frequently is aluminum sulphate or alum. This is manufactured from aluminous clays or bauxite by the addition of sulphuric acid. It is usually purchased by paper manufacturers.

166. *Casein.*—Casein sizing does not make paper water-repellant but it imparts strength and a smooth surface. Casein is made from skimmed milk and buttermilk as a byproduct of the dairy industry. It is prepared for the paper beater by dissolving it in an alkali, after which it may be added to the rosin size or added directly to the beater. When coated paper, such as is used in half tones, is desired, casein mixed with clay or other fillers, is spread onto the sheets by a coating machine.

167. *Gelatine, glue, or starch.*—Pure gelatine and glue, made from bladders of fish, from hides, and from bones are used in surface sizing. These dissolve in hot water and jell on cooking. The papers so sized must be dried slowly. Starch is employed both in surface and in beating engine sizing. Cornstarch is the type used in this country while in Europe potato starch is employed. It may be added as a raw solution or after boiling to a paste.

168. *Fillers.*—Fillers are employed to fill in the interstices between fibers in the finished paper thereby making a high finish, such as is required for process cuts and half-tones, possible. Common fillers are china clay, talc, precipitated chalk, blanc fixe, heavy spar, asbestine, and different forms of calcium sulphate.

169. China clay is imported in large amounts from England, although good deposits are found in the United States. It is reduced to a powder, mixed with water, and strained for use in the beating engine to which it is usually added before the sizing.

170. Gypsum, a natural calcium sulphate, makes a soft paper. Different hydrated calcium sulphates, made by precipitating a solution of calcium chloride with sodium sulphate, are on the market under several trade names. Calcium carbonate, or precipitated chalk, is usually employed by mixing a solution of calcium chloride with the paper stock and then precipitating it with a soda-ash solution. Talc or hydrated magnesium silicate imparts a rag-like appearance to paper. Asbestine is a fibrous talc used extensively in New York.

171. *Coloring.*—Coloring agents are also added to book-paper stock during the beating process, for almost all papers require some coloring to produce white papers as well as colored papers. Aniline dyes are chiefly employed although natural mineral colors, such as ochre, and artificial color, such as chrome yellow, are used. Or,

pigments may be used in coating the paper, or by applying it to the surface of the web as it passes through calenders.

172. *Finishing.*—After leaving the winding rolls at the end of the paper machine, more glaze may be imparted to the paper by passing it through a super calender. This is made up of a number of heavy rolls one on top of the other. The bottom roll is driven by motor while all others operate by friction from contact with each other. Paper may be passed between these rolls a number of times to give the requisite polish to both sides. It is then slit to size and rewound on iron cores. Or, if sheet paper is desired, automatic cutters cut it into sheets and pile it up. This is inspected, counted, and wrapped in bundles.

173. For illustration printing, still smoother paper is required. Paper is coated on one side by brushes with a solution of clay mixed with casein as it passes through a coating machine. It passes over the machine roller and is caught up by a bar and carried to the ceiling. As the traveling chains moving the bar operate at a slower speed than the coating machine roll, the paper sags between the supporting bars. This permits the air to dry the coating. The paper must be run through the coating machine again if both sides of the paper are to be coated, in this type of machine. Another machine coats both sides at the same time and partially dries it by a blast of air before hanging.

174. *Special papers.*—When very delicate papers, such as tissues and cigarette, are to be produced, a paper machine is used which permits the stock to be supported by a long felt through the entire machine after leaving the wire screening. Such machines have but one set of press rolls and are otherwise adapted to the fine web they handle.

175. Some papers, such as bag paper, are produced on Yankee machines. These dry the paper on a large drying cylinder against which a set of press rolls operate. Paper becomes glossy on one side only.

176. *Board manufacture.*—The materials entering into board manufacture are numerous. While some box or wall boards are made entirely of straw pulp, others of corn stalks, others of bagasse, and still others of paper-pulp screenings, the larger amount of box board is built up out of waste paper mixed with sulphite, sulphate, or mechanical wood pulp.

177. The cylinder paper machine which is used to form board has wire-covered rolls that revolve in a vat of paper stock. The stock flows through the wires, fibers forming a film on it as the water drains off. This film is picked up by a felt which passes over a couch roll and is carried through the squeeze rolls to presses and driers as in the fourdrinier machine. When heavy boards are made, the felt may pass over a number of cylinders revolving in different vats, each time adding a layer of paper to its load. Other mills form the sheet on vacuum cylinders and run it through continuous plate presses. The finishing mill cuts the board into sizes for specific uses.

POWER EQUIPMENT OF PULP AND PAPER MILLS

178. An abundant water supply is essential to all kinds of paper and pulp manufacture. Early paper mills located on streams and secured their motive power from water wheels. A few mills continue

to operate water wheels today. But with the development of the steam engine and the steam turbine, and the adoption by the paper industry of the Fourdrinier paper machine, and of chemical pulp, both requiring steam pressure heat, steam prime movers were installed in many plants for driving machinery as well as for supplying thermal requirements.

179. *Boilers.*—Usually a separate set of boilers is employed, one to care for the constant steam pressure and uniform speed of the paper machine, and the other to supply the intermittent load required in cooking chemical pulp. When wood is barked at pulp mills, the refuse is available for boiler fuel. It is supplemented by anthracite or bituminous coal, oil, or gas, depending upon mill location.

180. *Steam engines and steam turbines.*—Steam generated from these boilers propels steam engines or turbo generators, or both. The latest figures on prime movers in pulp and paper mills indicate that present steam engine and steam turbine capacities are about the same, that is, 546,190 horsepower and 522,169 horsepower, respectively. Until recently, these drove the several machines and conveyors by slow-speed Corliss engines, belted direct to the line-shafts, by high-speed turbine units, driving through belts, or by high-speed turbines with speed-reduction gears.

181. Gradually, however, the electric motor drive is appearing even in steam engine and steam turbine operated mills. The advantages of independent control of each section of the paper machine, made possible by electrical sectional drives, is leading to the increased adoption of motor drives throughout the plant. The slowness with which electricity has gained footing in pulp and paper mills is due to the economies believed to result from use of steam prime movers, which furnish the low-pressure steam necessary for thermal requirements, for power purposes. With the use of higher steam pressures, an increasing number of kilowatts have been made available for mechanical power.

182. *Electrification.*—The larger number of plants have both electrical and steam equipment today, regardless of type of pulp or paper manufactured. Only where hydraulic turbines drive the main electric generator, are pulp and paper mills entirely electrified. The Electrical World of August 1929, estimated that 62 percent of the power capacity in pulp and paper mills was electrical, that there is still over 1,000,000 nonelectric horsepower equipment installed. Table XII gives the prime movers, motors, and generators in pulp and paper mills in 1927.

TABLE XII.—*Prime movers, motors, and generators in paper and pulp industry* [1]

Type	Number	Rated capacity (horsepower)
Prime movers, total	22,663	2,642,806
Steam engines	2,796	546,190
Steam turbines	566	522,169
Internal-comubstion engines	48	6,047
Water wheels and turbines	1,975	899,157
Electric motors driven by purchased current	17,278	669,243
Electric motors driven by own plant	33,438	971,961
Electric generators (kilowatts)	1,293	692,451

[1] United States Bureau of the Census, "Census for 1927."

183. *A steam-electric plant.*—The following power equipment is found in a mill employing both steam and electric motor power and producing 150 tons book paper a day. Six boilers have a combined horsepower production of 5,000 horsepower. These require 180 tons of coal and 400,000 gallons of water per 24 hours. The generated steam propels steam engines and turbogenerators, serves for various pulp-cooking and paper-drying processes, and heats the plant in winter. Two turbogenerators are employed, one a straight condenser type and the larger an extractor type from which a portion of the steam entering the turbine is extracted for paper drying. These generators furnish 3,150 kilowatts of electrical energy, a part of which is converted into direct current by six motor-generator sets. Two excitor sets, one steam driven and one motor driven, are also provided to excite the generators on the steam turbines and the synchronous motors on the Jordon engines.

184. While variable speed motors are used on several paper machines and in the finishing room, small steam engines and pumps are operated in the pulp room, the beater room, for two paper machines, for plant heating fans, and for the Sunday lighting current, as well as for one excitor set.

185. *An electric pulp and paper mill.*—Several new mills are electrified throughout. Some purchase their current and others operate hydroelectric plants. A new pulp and paper mill producing 225 tons of newsprint a day operates two turbine-generator units in parallel with a hydroelectric system. "The main nonconducting turbine, using process steam from a throttle pressure of 400 pounds to 125 pounds back-pressure exhaust, is connected to a 7,500 kilovolt-ampere 6,600 volt generator." A standby condensing turbine generator is also installed. Motors are connected directly to grinders. Each paper machine (226 inches wide operating at 1,200 feet per minute) has a 1,000 boiler horsepower steam turbine operating at 125 pounds throttle pressure against a back pressure of 10 pound gage, connected to a direct-current generator and an excitor. All the various sections of the paper machine are started by a motor-generator set consisting of a 300 horsepower, 900 revolutions per minute, synchronous motor connected to a direct-current generator. The couch, the presses, the calender, and the reel have their own individual starting panels of full continuation type, while the drier section is driven in groups of six driers through drive-in shafts connected to eight 45-horsepower motors.

WATER AND CHEMICALS CONSUMED IN PAPERMAKING

186. *Water requirements.*—The quantity and quality of the water supply are a matter of vital importance to pulp and paper manufacture. While economic factors, such as the quantity available, reuse of water, cost of pumping and necessity of filtration, determine whether water is used lavishly or sparingly, plant engineers make definite allowances for water requirements when figuring on different types of mills. According to Power Plant Engineering of January 1930, allowances for each type of pulp should be as follows:

> Fifty thousand gallons water per ton of mechanical pulp; 75,000 gallons water per ton sulphite pulp unbleached; 100,000 gallons water per ton bleached sulphite pulp; 100,000 gallons water per ton bleached soda pulp; 75,000 gallons water per ton sulphate pulp; 30,000 to 40,000 gallons water per ton paper all grades.

At these rates of consumption, the paper mills in the United States take over 600,000,000,000 gallons annually.

187. *Chemicals consumed in wood-pulp manufacture.*—Mechanical pulp requires only water and power as it is seldom bleached. Sulphite pulp is reduced by bisulphite of lime. The amount of sulphur required for the production of this lignin dissolvent is from 250 to 300 pounds per ton pulp, while 300 pounds lime is necessary, or, the total annual consumption of sulphur reaches approximately 250,000 tons and of lime 260,000 tons for sulphite pulp. While sulphite pulp applied to newsprint or wrapping paper is not bleached that used for book, tissues, and many miscellaneous paper products undergoes a chlorine bleach. The amount of bleach used depends on the whiteness of the paper desired, the length and temperature of cooking, and other plant factors. Roughly, it is estimated that 84,000 tons of liquid chlorine are consumed in sulphite-pulp bleaching. To this must be added the lime required to manufacture bleaching powder.

188. The soda process depends on caustic soda for its wood-fiber reduction. Caustic soda is purchased or it is produced electrolytically or by causticizing soda ash at the pulp mill. That purchased as caustic soda and that produced electrolytically totaled approximately 75,000 tons caustic soda in 1929. The soda ash consumed is not estimated, as recoveries of soda as high as 88 percent were effected in some soda-pulp plants. Lime consumption approximates 100,000 tons. Soda pulp is usually bleached, the liquid chlorine consumed totaling approximately 50,000 tons. How much bleaching powder is also purchased is not recorded.

189. Sulphate-pulp producers report a consumption of 205,670 tons sodium sulphate in 1928. Lime consumption by the same companies was approximately 20,000 tons.

CHEMICALS CONSUMED IN PAPER MANUFACTURE

190. According to the 1929 Census, preliminary reports, the paper industry purchased 38,390 tons of rosin to be made into sizing by the addition of soda ash and 98,423 tons of rosin sizing. It applied 468,-191 tons of clay and 18,451 tons of casein as fillers and in paper coating. Minor amounts of other fillers were used. Aluminum sulphate consumption is not recorded, but is estimated to exceed 100,000 tons.

191. To sum up: The principal chemicals applied to pulp and paper manufacture were consumed in 1928–29 approximately in the following amounts:

	Tons
Liquid chlorine [1]	136, 500
Caustic soda [1]	75, 000
Soda ash [1]	110, 000
Sulphate	250, 000
Lime	380, 000
Sodium sulphate, see page 356	205, 670
Aluminum sulphate, see page 349	100, 000
Clays	468, 191
Casein, see page 349	18, 451
Rosin	38, 390
Rosin sizing	98, 423

[1] For manufacturing details see Power in the Manufacture of Chemicals and Metals from Brine.

COSTS OF PRODUCTION

192. Actual production costs of pulp and paper manufacture by different companies are frequently not comparable because of differences in bookkeeping methods. Paper companies owning their own forests may enter the cost of pulpwood used in paper manufacture at actual production costs, at production costs plus interest and all capital costs, or at the price of pulpwood sold in the open market. Paper mills operating their own pulp mills may charge pulp against paper costs by any of these methods.

As far as possible, duplication of capital costs and double interest have been avoided in the estimates that follow.

COST OF PRODUCING UNBLEACHED SULPHITE PULP

193. Sulphite pulp is consumed in larger quantities than other pulps. It enters into the manufacture of newsprint, book paper, board, wrapping, and many different kinds of paper. While some paper mills produce their own sulphite pulp, sulphite enters into the trade as pulp more extensively than other forms of pulp. Its production costs will be considered apart, therefore, from the cost of producing paper. While sulphite pulp varies in quality from wrapping to finished bleached pulp, costs given are for "strong unbleached," a medium grade.

194. *Wood cost.*—The major item of cost in producing sulphite pulp is the cost of the wood. Two tons are required per ton of pulp produced. The major differences in such costs are due to varying distances from forest to pulp mill, and to different kinds of wood used. It is roughly estimated that transportation makes up about one fourth the total cost of pulpwood at the mill. Spruce shipped from Canada to New York and Pennsylvania may carry a freight of $8.50 while that from Canada to Lake States may bear a $3.50 transportation cost. In the West, average transportation costs on pulpwood are figured at $2.[2] Rough spruce market prices average $13.90 in Maine, $14.54 in Michigan, and $15.40 in Wisconsin. The peeled wood spruce at Watertown, N.Y., was $18.50. The cost of the pulpwood used in sulphite pulp is reduced, however, through the use of hemlock, priced at $10 in New England and at lower prices in Wisconsin, and by the consumption of lumber mill wastes on the Pacific coast.

195. By correlating the lumber industry with the sulphite pulp industry, material savings in wood costs have been effected in Washington and Oregon and in Scandinavian countries. Pacific coast sulphite mills report the cost of spruce and hemlock waste necessary to produce 1 ton of sulphite pulp at $14; whereas in the Middle West, where hemlock is chiefly used, the cost of wood is $18, and in Eastern States, $24 when produced by the manufacturer of the pulp. When mills purchase imported pulpwood, costs would be several dollars higher than those quoted.

196. *Total costs.*—This differential in raw material cost, together with a lessened fuel and power cost, makes it possible to produce sulphite pulp for approximately $12 less in the Pacific Northwest than in the East, and for about $5 less than in the Lake States.

[2] Report of woodlands section of the American Paper and Pulp Association.

197. *Possible substitution of waste sulphur dioxide in West.*—It may be possible to further reduce the cost of sulphite pulp manufactured in Washington by the use of the new wasted sulphur dioxide available at zinc refineries in northern Idaho. The sulphite pulp mills purchase sulphur from Texas and Louisiana at $18 a ton and pay a freight rate of approximately $7 a ton additional; they install equipment to convert this sulphur into sulphur dioxide for absorption in limestone. The zinc refineries in Idaho waste sulphur fumes for lack of a market. As these fumes are deleterious to all vegetation, it is only a question of time before zinc refineries in Idaho will be compelled by law to collect these fumes as is now the case in Butte, Mont. Such fumes afford the cheapest source of sulphur dioxide. The pulp mill would also have less capital tied up in equipment and require less labor and fuel.

TABLE XIII.—*Approximate cost of producing 1 ton unbleached sulphite pulp in different manufacturing regions*

[Based on 100 tons daily mill capacity]

Item	Pacific coast	Eastern United States	Middle West	Canada
Capital cost: Amortization, taxes, insurance, and interest charged at 12 percent on $60 [1]	$7.20	$7.20	$7.20	$7.20
Production costs: [2]				
Spruce and hemlock	[3] 14.00	24.00	18.00	10.25
Sulphur (270 pounds)	2.40	2.40	2.40	2.65
Limestone (300 pounds)	.60	.60	.60	.60
Electric power	1.10	2.00	2.00	.75
Steam	2.50	4.00	4.00	3.00
Labor and salaries	17.40	17.00	16.00	17.00
Repairs and miscellaneous supplies	2.00	2.00	2.00	2.00
	40.00	52.00	45.00	36.25
Total cost	47.20	59.20	52.20	43.45

[1] Includes sulphur dioxide manufacturing plant.
[2] Manufacturers of Unbleached Chemical Sulphite Pulp, in hearings before the Committee on Ways and Means, House of Representatives. 1929.
[3] Largely sawmill waste.

198. The major competitors of Pacific mills for the eastern sulphite pulp markets are Canada and Scandinavia, for nearly 40 percent of the sulphite pulp consumed in the United States is imported. While 38 percent comes from Canada; Sweden, Finland, and Norway ship in 52 percent. Pacific coast producers believe production costs in Canada to be $36. Assuming capital costs are the same as in this country, this makes a total cost per ton of pulp $3.75 less than the present low cost on the Pacific coast. Scandinavian countries sell this grade sulphite pulp at an average price of $48 per ton on the Atlantic seaboard. To this must be added the import agent's commission of 5 percent or $2.40 making a total cost, including a $4.50 transportation cost, of $50.40.

199. *Cost of producing mechanical pulp.*—Mechanical pulp is usually manufactured by paper mill companies. Capital costs are, therefore, less than appear in the following accounting of independent pulp mills. At the Atlantic seaboard, domestic pulp brings from $26 to $30 and imported pulp $28 to $30 for moist pulp and $30 to $32 for dry pulp. These prices would not permit shipment of Pacific coast mechanical pulp into the eastern market unless production costs

could be materially reduced below those shown in the following estimate.

TABLE XIV.—*Estimated cost of producing 1 ton mechanical pulp on Pacific coast and in eastern Canada*

Item	Pacific coast	Canada
Capital costs: Amortization, overhead, interest, and taxes charged at 15 percent on $23	$3.45	$3.45
Production costs:		
Spruce and fir, 1.1 cord	11.20	10.40
Electricity, 1,300 kilowatts, at $0.003	6.90	6.90
Labor	3.00	2.50
Repairs and miscellaneous supplies	2.50	2.50
	23.60	22.30
Total cost	27.05	25.75

200. *Newsprint production costs.*—According to earlier studies of newsprint manufacturing costs, pulp production represents two thirds the total cost of manufacturing newsprint paper. On the basis of 80 percent mechanical pulp and 20 percent sulphite per ton of newsprint, production costs of newsprint would be approximately $35.85 on the Pacific coast and $33.45 in eastern Canada. If an allowance of 12 percent is made for all overhead, depreciation, insurance, taxes, and interest on a ton-year investment of $160, costs are brought to $55 and $52.65, respectively.

201. *Cost of producing sulphate pulp.*—The producers of sulphate pulp in this country usually manufacture it into its finished paper form. Firms desirous of selling pulp as such find themselves in very active competition with imports from Sweden, Norway, and Finland. Details of costs of Scandinavian production are not available. It is claimed these total $40 to which must be added an importer's commission of 5 percent, making a total of $42 without any freight cost. The production costs on the Pacific coast are approximately $40 while those in southern mills are nearer $35 per ton of sulphate pulp.

Market prices on kraft range from $42 to $55.

202. While as yet but little mill waste is used for sulphate pulp on the Pacific coast, the tendency is toward a closer relationship between this industry and the Douglas fir lumber mills. Such an integration of the two industries, together with the possible recovery of rosin and turpentine, would bring the Pacific coast production figures almost to the level of those prevailing in the South.

203. Another factor which may lower the production cost of sulphate pulp on the Pacific coast is the change which is taking place in the production of sodium sulphate or salt cake. This has been a byproduct of hydrochloric acid manufacture for many years. But changes in manufacturing processes are decreasing this byproduct production at the same time that demands for sodium sulphate are increasing. Heavy imports of the chemical have resulted from Germany where the salts are produced as byproduct from the Stassfurt potash minerals. Magnesium sulphate and sodium chloride (common salt) are subjected to a freezing process which gives a hydrous sodium sulphate or Glauber's salt. This is evaporated artificially to produce anhydrous sodium sulphate or salt cake. The United

States has natural deposits of sulphate of soda in eastern Washington, at Searles and Owens Lakes, Calif., in Nevada, Wyoming, and Utah. The difficulty of developing these deposits lies, at present, in the foreign competition offered, for German sulphate sells in New Orleans for $12 and in the Pacific Northwest for $13.50 per ton in bulk, and for $15.50 per ton sacked. However, the changes which are occurring in this country in methods of manufacturing hydrochloric acid and nitric acid are also under way in Germany and her production of the byproduct may be curtailed. It is, of course, always feasible to manufacture sodium sulphate directly from ocean brine, if the development of the natural deposits is delayed.

TABLE XV.—*Estimated cost of production of sulphate pulp in Pacific coast and southern mills*

Item	Pacific coast	Southern mills
Capital costs: Amortization, overhead, interest, taxes charged on $80 per ton-year, at 15 percent	$12.00	$12.00
Production costs:		
Pine, hemlock, and mill waste	14.00	10.50
Sodium sulphate (350 pounds)	2.55	2.55
Lime (500 pounds)	2.50	2.25
Labor, 1.4 man-days	6.30	5.60
Repairs and miscellaneous supplies	2.00	2.00
	27.35	22.90
Total cost	39.35	34.90

204. *Cost of manufacturing kraft paper.*—The cost of sulphate pulp manufacture represents 70 percent of the cost of producing kraft wrapping paper. The figures above would bring the cost of manufacturing sulphate paper to approximately $56 on the Pacific coast and to $50 in the South. The selling prices of "southern" kraft and domestic no. 2 ranges from $60 to $75.

205. *Cost of bleached soda pulp production.*—Paper mills manufacturing book paper frequently manufacture their own soda pulp although some is purchased from pulp manufacturers. Because many plants have their own equipment for manufacturing either electrotlytic caustic soda and chlorine or for manufacturing caustic soda from soda ash as well as for the recovery of soda ash, the capital invested in such mills is higher than in pulp mills that purchase their chemicals ready for use.

TABLE XVI.—*Estimated cost of producing bleached soda pulp when causticization chemicals are manufactured at plant*

Item	Central States
Capital cost: Amortization, overhead, interest, taxes, etc., at 15 percent on $80	$12.00
Production cost:	
Wood, 2 cords	18.00
Soda ash (1,200 pounds, 75 percent recovered), at $18.90	2.85
Lime, at $7.30 ton	2.50
Chlorine bleach	4.20
Fuel and power	5.50
Labor	7.20
Repairs and miscellaneous supplies	3.35
	43.60
Total cost	55.60

Bleached soda pulp sells for from $58 to $64 a ton.

206. *Book paper costs.*—The numbers of print papers produced by each mill, the different kinds and quantities of raw materials applied, make it difficult to estimate the cost of producing any particular type of book paper. Market prices on such papers have a 100 percent range indicating the variation in value of the papers included in this heading. The large number of chemicals necessary for the finish of this paper, the several kinds of pulp employed, make material cost the largest item in its manufacture. Roughly, pulp and waste paper would represent 58 percent of production costs; chemicals, other than those used in producing pulp, 8 percent, fuel and power 5 percent, labor 14 percent, and such items as wires, felt, belting, 2 percent.

207. The following statement of the materials required per ton of book paper produced in a steam-electric plant manufacturing some of its soda pulp, purchasing some unbleached and some bleached sulphite pulp, bleaching some sulphite pulp and buying waste paper is indicative of book paper-mill requirements.

208. Quantities of materials required in the manufacture of 1 ton book paper were:

Fibrous materials:		Water ... gallons	73, 685
Pulp wood ... cord	0. 25	Lime ... pounds	164
Waste lumber- wood shavings and veneer ... cord	. 1	Soda ash ... do	40
Old papers and magazines ... pounds	547	Liquid chlorine ... do	13. 7
White shavings ... do	50	Alum ... do	50. 5
Bleached soda pulp ... pounds	80	Rosin ... do	8. 8
Bleached sulphite pulp ... pounds	147	Clay ... do	336. 8
Unbleached sulphite pulp ... pounds	168	Starch ... do	1. 1
		Sodium silicate ... do	. 04
		Dyes and color ... do	. 04

Pulp and Paper Markets and Freight Rates

WOOD PULP MARKETS AND FREIGHTS

209. Paper mills which must purchase wood pulp from distant localities in order to operate are located principally in New York State, in Michigan, in Pennsylvania, and in Ohio. Massachusetts, Connecticut, New Jersey, Maryland, Indiana, and Illinois purchase some pulp stocks, together with waste paper and waste textiles.

210. The wood pulp coming from Canada has gone into New York and Pennsylvania by rail. Paper mills locating on Lake Michigan have secured pulp by Lake shipment from western Ontario. Pulp from Scandinavian countries may go down the present St. Lawrence canal in small vessels. However, more is' shipped to Baltimore, Norfolk, New York, and Boston.

211. *Sulphite pulp.*—Swedish costs of shipping sulphite or sulphate to the Atlantic seaports are $4.50 per ton. This, added to the Scandinavian production costs, plus the importer's commission (see p. 356) brings the cost of Swedish sulphite pulp delivered at the Atlantic seaboard, to $50.40.[3]

212. Pacific coast shipments to New York through the Panama Canal total $15 per ton when wharfage, overweights, and other items are included. Or, the cost of sulphite pulp delivered in New York

[3] Brief of the Pulp and Paper Trading Co. before Committee on Ways and Means, House of Representatives, 70th Cong., vol. XV., sec. 15, p. 8789.

from Seattle would be $62. Canada's all-rail rate to New York points averages $6 making the Canadian sulphite pulp cost $49.50 in the North and Middle Atlantic States. As the larger amount of sulphite pulp is now imported from Sweden, the possibilities of an Eastern market for Washington and Oregon sulphite depend upon a lower production cost than has as yet been achieved on the coast.

213. For the present, the Middle Western paper mills seem closed to Washington and Oregon sulphite pulp producers. The all-rail haul to Middle Western points is from $12 to $13 a ton, while Michigan mills can be supplied from Canada with pulp bearing a freight rate of $4.

214. *Sulphate pulp.*—Although sulphate pulp mills are usually owned by paper companies, there are a number of paper companies manufacturing sulphate paper or board that produce no pulp. These are located in the Northern and Middle Atlantic States and in the Middle West, in which sections Maine and Wisconsin are the only sulphate-pulp producing States. The Southern States of Louisiana, Virginia, Arkansas, Mississippi, Alabama, North Carolina, and Florida are the growing sulphate pulp producing States as are Washington State and Oregon. The Northern and Middle Atlantic paper mills have not counted on American sulphate pulp mills for their pulp supply but have secured approximately 60 percent from Scandinavia and 35 percent from Canada.

215. Scandinavian sulphate pulp has been put down ex-dock Portland, Maine; Boston, New York, or Baltimore from $48 to $49. The freight rate from usual Scandinavian points varies from $4.50 to $5 and some pulp must have an inland freight rate in the country of export. Seattle sulphate pulp could be sold in New York at $47 or $48. It would seem as though Pacific coast mills could compete in Middle and Northern markets with European sulphate ports.

216. *Wood pulp exported.*—In spite of our heavy imports of wood pulp we export 30,000 tons. Most of this, in the form of sulphite pulp, goes back to Canada. But Japan took 6,000 tons in 1928.

217. *Paper markets and freights.*—The size of paper markets in the United States is determined principally by the population in given areas. The final product, whether it be newspapers, magazines, paper boxes, wrapping paper, or building boards, is dependent for its consumption largely upon the size and character of specific retail purchasing markets. The New York City metropolitan area consumes far more paper than any other section. The printing and publishing business of all types of matter is largest in New York State; Illinois ranks second, Pennsylvania third, and Ohio fourth. Massachusetts and California follow. Such converted paper products as bags and boxes not made in paper mills, envelopes, patterns and card designs, and wall paper, find their heaviest production in New York. Ohio ranks second, New Jersey, Pennsylvania, and Wisconsin third, and Indiana, Missouri, and California fourth.

218. *Newsprint paper.*—New York City newspapers took approximately 700,000 tons of the 3,800,000 tons of newsprint available in the United States in 1929. The Chicago area consumes approximately 400,000 tons annually. In all of California, Oregon, and Washington, only 320,000 tons newsprint is consumed annually.

219. According to reports made to the Federal Trade Commission,[4] newspapers with daily circulations of over 100,000 required from 600

[4] Senate Document No. 214, Newsprint Paper Industry, July 1930, p. 71.

to 780 pounds of newsprint per 1,000 circulation. Newspapers with from 50,000 to 100,000 daily circulation used from 550 to 590 pounds per 1,000 circulation. Daily papers of less than this circulation varied in amount of paper consumed from 274 to 342 pounds per 1,000 circulation. Weekly papers reporting took 146 pounds of newsprint per 1,000 circulation.

220. Newspaper publishers make from 1- to 10-year contracts with newsprint paper mills for their supply of paper. The Hearst papers require the largest amount of newsprint paper or almost 15 percent of the total amount available in 1929 in the United States. This paper is purchased through the American Paper Co. of San Francisco and the Newspaper and Magazine Paper Corporation of New Jersey. The latter purchasing organization buys for all papers east of the Rocky Mountains in amounts totaling about 446,000 tons of paper. The San Francisco purchasing agent contracted for 115,000 tons during 1929 with the Crown Willamette Paper Co.

221. The Scripps-Howard newspapers, comprised of 27 dailies, require 261,924 tons of paper purchased from a number of manufacturers. The next largest consumer of newsprint is the Patterson-McCormick group which owns the Chicago Tribune and the New York Daily News. These two papers consume 224,502 tons of newsprint paper annually. As has been stated elsewhere, these publishers own a paper mill at Thorold, Canada. The Ochs papers (New York Times and Chattanooga Times) complete the group of newspaper publishers that take more than 100,000 tons of newsprint annually. That is to say, four publishers in the United States purchase about 30 percent of all newsprint paper available.

222. The large daily papers issued in cities purchase the bulk of the newsprint supply, or over three fourths of the total. Hundreds of small daily papers and thousands of weekly papers buy in less than ton lots through jobbers or through cooperative associations. These small publishers frequently buy paper in sheets instead of rolls and pay a differential of $5 per ton. Or they may buy ready-print sheets from companies sending out these printed sheets. Even such ready-print sheet producers as the Montana Newspaper Association of Great Falls, Mont., purchase only a little over 100 tons of paper a year. Only 13 percent of newsprint paper is sold on the open market.

223. *Distribution of Pacific coast newsprint.*—The three principal newsprint companies in Washington and Oregon have a combined capacity of about 1,000 tons newsprint daily. The Powell River Co., Ltd., has a capacity of 650 tons and the Pacific Mills (Crown Zellerback owned) of 230 tons, in British Columbia, or 1,880 tons of newsprint is available daily on that coast. California, Oregon, and Washington consume approximately 320,000 tons a year. Almost three fourths of this is supplied by the Crown Zellerback Co., the rest by the Inland Empire Paper Co., of Millwood, Wash., and the Hawley Pulp and Paper Co., Oregon City, Oreg. The latter companies sold one half their production outside the three coast States.

224. The Powell River Co., Ltd., sells 60 percent of its output in the United States through the George F. Steele Co. of New York City. This is not sold on the Pacific coast but is shipped via the

Panama Canal to Texas, Louisiana, Oklahoma, New Mexico, Arkansas, Nebraska, and Kansas publishers. Some also reaches Colorado.

225. *Distribution of eastern production.*—The New England and Middle Atlantic news publishing markets are served by the Great Northern Paper Co., the International Paper Co., from its Canadian and Eastern newsprint mills, and by small producers in Maine and New York, and by large producers of Canada. Many Canadian mills are represented by the Canadian Export Co. The New York Times secures almost all its newsprint from Canada; the Hearst Newspaper and Magazine Paper Corporation has contracts to purchase the entire output available for shipment to the United States of the Anglo-Canadian Pulp and Paper Mills, the Brompton Pulp and Paper Co., and the Lake St. John Power and Paper Co.; it also has similar contracts with New York newsprint mills.

226. The International Paper Company also sells in the Pittsburgh, Chicago, and South Atlantic markets, practically in all sections east of the Mississippi, and usually under 5-year contracts. The Great Northern Paper Companies sell in carload lots only, throughout the East. For the most part, Eastern mills count on the Eastern, Southern, and Southwestern markets, however, and leave the Middle Western market to Lake mills.

227. *Distribution of Lake States production.*—The Minnesota and Ontario Paper Co. is the chief local newsprint distributor in the Middle West. The largest newsprint paper manufacturer of Canada sells throughout the Central States through the George H. Mead Co. of Dayton, Ohio. While these Lake and Canadian mills sell in South Atlantic markets as well as in Gulf markets, their principal market is west of Pittsburgh.

228. Some newspapers in this area own their own newsprint mills. This was true of the Minneapolis Tribune and the St. Paul Dispatch. Almost all newspaper holdings of the International Paper Co. have been sold.

229. *Newsprint prices and freight rates.*—The International Paper Co. sets the market price for newsprint paper in all sections of the United States except the Pacific coast. Other producers await the announcement of this company's prices before changing their own price schedules. On the Pacific coast, control is exercised by the Crown Zellerback Corporation and the Powell River Co. of British Columbia.

230. The price holding to June 30, 1930, was $65 per ton f.o.b. mill, with the seller paying all freight to destination. All territory east of the Mississippi River was zoned, and the delivered price for customers in each zone named. The same practice was entered into by the Minnesota and Ontario Paper Co. Some of these prices are as follows:

$67.70 f.o.b. mill freight allowed to San Antonio, Tex.
$68.00 f.o.b. mill freight allowed to Enid, Okla.
$63.00 f.o.b. mill freight allowed to Omaha and Kansas City.
$65.00 f.o.b. mill freight allowed to Atlanta, Ga.
$62.00 f.o.b. mill freight allowed to New York, Baltimore, Washington, Detroit Pittsburgh, and Chicago.
$61.50 f.o.b. mill freight allowed to Boston, Albany, Rochester, Syracuse.

These prices were met by United States and Canadian producers.

231. Freight rates on newsprint from Canada to New England and Middle Atlantic points run from $4 to $7, or less than the cost of an all-water shipment from Seattle to the Atlantic seaboard. Rates from New York and New England to New Orleans fall between $9.60 and $10.50, whereas newsprint can be shipped from Seattle for $8. The Powell River Co. sells to Texas publishers at $58 per ton, c.i.f., Houston. It sells to Oklahoma publishers at $65 per ton or at better prices than received from Eastern producers.

232. From Eau Claire, Wis., to St. Louis the rail rate on a ton of newsprint is $4.90; to Kansas City, $6 per ton. From Seattle to Kansas City via the Panama Canal, the total shipment cost is $26.40. Obviously, such markets cannot be reached via the Panama Canal. The rate from Seattle to Cincinnati, St. Louis, and Chicago via Panama Canal and New Orleans is $14.60, while from Eastern points it averages $6.60 and $7.70, respectively. While States located near to Lake paper manufacturers such as Iowa enjoy a low freight rate, all-rail rates increase rapidly with the increasing distances.

233. Unquestionably, a market exists for Pacific coast newsprint along the Gulf coast and southern Mississippi points as well as in the Rocky Mountain States and a few of the mid-Central States.

234. *Paper exports.*—While our exports of paper are only 174,000 tons, the shipment of newsprint to the Philippines and China, and of wrapping paper to these countries and to Mexico, are of interest to Pacific coast paper manufacturers.

TABLE XVII.—*Exports of paper, wood pulp, and pulpwood in 1928* [1]

Exported to	Paper exports													
	Total		News		Wrapping		Boards		Book		Writing		Other [2]	
	Short tons	Per-cent	Short tons	Per-cent	Short tons	Per-cent	Short tons	Per-cent	Short tons	Per-cent	Short tons	Per-cent	Short tons	Per-cent
Total exports	174,248	100.0	11,390	6.5	19,932	11.4	77,187	44.4	12,256	7.0	12,916	7.4	40,567	23.3
Canada	62,560	35.0	122	1.1	7,880	39.5	29,491	38.2	4,669	38.1	1,333	10.3	19,065	47.0
Newfoundland and Labrador	1,295	.7	2	(3)	11	(3)	270	.4	33	.3	64	.5	915	2.3
Sweden	544	.3			6	(3)	363	.5	2	(3)	6	(3)	167	.4
Finland	98	(3)			1	(3)	89	(3)	4	(3)			4	(3)
Germany	2,234	1.3	2	(3)	50	.3	1,355	1.8	164	1.3	632	4.9	31	.1
Norway	596	.3			33	.2	510	.7	3	(3)	6	(3)	44	.1
Japan	3,577	2.1	191	1.7	309	1.6	1,255	1.6	131	1.1	419	3.2	1,272	3.1
United Kingdom	17,320	10.0	17	.2	1,632	8.2	11,646	15.1	55	.5	617	4.8	3,353	8.3
Netherlands	1,808	1.0			3	(3)	1,427	1.8	4	(3)	82	.6	292	.7
Argentina	6,769	3.9	1,796	15.8	174	.9	888	1.2	329	2.7	1,762	13.6	1,820	4.5
Philippine Islands	9,315	5.4	3,746	32.9	1,757	8.8	1,140	1.5	1,333	10.9	959	7.4	380	.9
China	14,803	8.5	1,399	12.3	1,332	6.7	7,113	9.2	921	7.5	777	6.0	3,261	8.0
Cuba	15,043	8.6	1,900	16.7	1,793	9.0	4,713	6.1	2,416	19.7	2,237	17.3	1,984	4.9
Venezuela	2,171	1.2	734	6.4	60	.3	595	.8	165	1.3	218	1.7	399	1.0
Mexico	6,298	3.6	233	2.0	2,460	12.3	1,735	2.2	255	2.1	598	4.6	1,017	2.5
Other countries	29,817	17.1	1,248	10.9	2,431	12.2	14,597	18.9	1,772	14.5	3,206	24.8	6,563	16.2

Exported to	Wood-pulp exports								Pulpwood exports, kind not specified	
	Total		Sulphite		Soda		Other			
	Short tons	Per-cent	Short tons	Per-cent	Short tons	Per-cent	Short tons	Per-cent	Cords	Per-cent
Total exports	29,896	100.0	22,272	74.5	2,441	8.2	5,183	17.3	27,518	100.0
Canada	19,394	64.9	17,669	79.3	214	8.8	1,511	29.2	27,508	99.9
Newfoundland and Labrador										
Sweden	1	(3)					1	(3)		
Finland	33	.1	33	.2						
Germany	115	.4	15	.1	20	.8	80	1.5		
Norway	5	(3)					5	.1		
Japan	6,304	21.1	2,627	11.8	1,467	60.0	2,210	42.6		
United Kingdom	920	3.1	170	.8	165	6.8	585	11.3		
Netherlands	30	.1	29	.1			1	(3)		
Argentina	240	.8					240	4.6		
Philippine Islands	2	(3)					2	(3)		
China	49	.2			49	2.0				
Cuba										
Venezuela										
Mexico	123	.4	27	.1	46	1.9	50	1.0	10	(3)
Other countries	2,680	8.9	1,702	7.6	480	19.7	498	9.6		

[1] Compiled from: U.S. Department of Commerce, Foreign Commerce and Navigation of the United States.
[2] Includes 16,975 tons of hanging paper, going principally to Canada, United Kingdom, and Newfoundland; 7,231 tons of tissue (crepe, toilet, towels, etc.) going chiefly to Canada, Argentina, and Cuba; and 7,427 tons building paper going chiefly to Canada, United Kingdom, Argentina, Japan, Australia, and Mexico. Does not include 14,224 tons of boxes and cartons going chiefly to Canada, Spain, Mexico, and Cuba, or 11,261 tons paper bags, adding-machine paper, vulcanized paper, etc., going chiefly to Canada, Philippines, Panama, Colombia, Cuba, Peru, and Mexico.
[3] Less than 0.1 percent.

240. *Producers of sulphite pulp for rayon.*—Canada exceeds all other countries in the manufacture of wood pulp for rayon manfuacture. The Canadian International Paper Co. at its Kipawa Mills, Temiskaning, Quebec, produced 100,000 tons annually of high-grade alpha pulp, or about one half of the world's supply. This plant is about 200 miles up the Ottawa River from Ottawa. The only large producer of rayon sulphite pulp in the United States is the Brown Co. of Berlin, N.H. This plant is on the Androscoggin River about 40 miles from the Canadian boundary. It has a capacity of 90,000 tons annually.

241. The only company manufacturing a rayon grade of sulphite pulp on the Pacific coast is the Rainier Pulp & Paper Co. of Shelton, Wash. This company is using hemlock and has a capacity of 285 tons of sulphite pulp daily.

242. In Europe, one of the principal rayon pulp producers is the Uddeholms Aktiebolag of Sweden. While the United States imports sulphite pulp from Sweden as well as from Norway and Germany, the amount that enters the rayon industry is not certain.

243. *Cotton linters.*—About 20 percent of the world's rayon and a number of the cellulose plastics employ cotton linters and short cotton fibers as their basic raw material. Staple cotton, such as is used for cotton materials, is too expensive to compete with wood pulp, but cotton linters obtained from a second ginning after the staple cotton has been removed in the first ginning, have proved very satisfactory. Approximately 36,000 tons of cotton linters and short fibers were used in the United States in 1929 for cellulose solutions.

244. The production of cotton by States is given in the following table. It is evident the States that can furnish the country with this raw material are not those that can furnish the nonresinous softwood pulp.

TABLE XVIII.—*Production of cotton in the several States in 1928* [1]

States	Number of 500-pound bales	States	Number of 500-pound bales
Texas	5,106,000	Tennessee	428,000
Mississippi	1,475,000	California	172,000
Arkansas	1,246,000	Arizona	149,000
Oklahoma	1,205,000	Missouri	147,000
Alabama	1,109,000	New Mexico	88,000
Georgia	1,030,000	Virginia	44,000
North Carolina	836,000	Florida	19,000
South Carolina	726,000	All others	7,000
Louisiana	691,000		

[1] U.S. Department of Agriculture 1930 Yearbook

245. *Purification of cotton linters.*—While cotton linters are sometimes freed of oil, fats, pectin, and other undesirable matter in the cotton districts, this purification takes place more often, at the rayon mill. The linters are shredded and freed of sand and dirt. They are then boiled in a solution of caustic soda under steam pressure for from 4 hours to 10 hours to remove the noncellulosic material and other impurities. After thorough rinsing the linter pulp is bleached in a sodium hypochlorite solution ($NaClO$). Sodium hypochlorite is made by passing liquid chlorine into a caustic soda solution. This bleach is used in preference to bleaching powder, or calcium hydrochloride, in order to avoid the elimination of lime which must be removed when the latter bleach is used.

246. It is then "soured", or bleaching solution is removed from the fibers by a dilute solution of sulphuric acid. The pulp is washed and dried as in sulphite pulp preparation. It must be stored under conditions permitting a controlled temperature and humidity.

METHODS OF MANUFACTURING CELLULOSE SOLUTIONS AND FINISHED PRODUCTS

247. In 1929, 84.1 percent of all rayon was produced in the United States by the "viscose process", 8.3 percent by the nitrocellulose process, 5.7 percent by the cellulose acetate process, and 1.9 percent by the cupra-ammonium process. Although the viscose process far outranks any other process, there is a slight but decided increase in the use of the acetate process. This is expected to grow, due to the entry of two large viscose manufacturers into cellulose acetate production.

TABLE XIX.—*United States rayon production by processes* [1] (*approximate*)

Year	Total		Viscose		Nitrocellulose		Acetate		Cupra-ammonium	
	Short tons	Percent	Short tons	Percent	Short tons	Percent	Short tons	Percent	Short tons	Percent
1929	61,565	100.0	51,790	84.1	5,125	8.3	3,500	5.7	1,150	1.9
1928	48,851	100.0	41,051	84.0	4,250	8.7	2,500	5.1	1,050	2.2
1927	37,525	100.0	31,850	84.9	3,750	10.0	1,750	4.6	175	0.5
1926	31,288	100.0	26,538	84.8	3,500	11.2	1,250	4.0		
1925	26,105	100.0	22,755	87.2	2,600	9.9	750	2.9		
1924	19,425	100.0	17,300	89.1	2,125	10.9				

[1] Compiled from Rayon Yearbook, 1928 and 1930, published by Textile World.

248. *The viscose process.*—Sulphite pulp is the basic raw material employed in the viscose process. It reaches the rayon manufacturer in dry sheets which are analyzed and, if not of proper moisture content, are subjected to further drying. Some manufacturers add cotton linter pulp to the sulphite pulp.

249. *Preparation of viscose solution.*—Properly prepared pulp sheets are then soaked in a caustic soda solution of approximately 18 percent. A high quality caustic soda is required. It is purchased either in liquid form in 25 percent or 50 percent strength or in solid form shipped in 760 pound drums. The pulp combines with the caustic soda to form sodium cellulose ($C_6H_9O_4ONa$). Excess solution is removed by pressing out the sheets.

250. The sodium cellulose is then shredded to very finely lintered particles called "crumbs." These are aged in closed iron or steel cylinders which are kept at about 75° F. Ageing requires 48 hours to 72 hours. Crumbs are then ready for "xanthating." They are dumped into revolving drums which mix them with carbon disulphide (CS_2). The reaction results in cellulosexanthate, a jelly-like mass.

TRANSFORMING INTO FINISHED PRODUCTS

251. *Transparent wrapping.*—This viscose solution may be transformed into a transparent moisture-proof sheet by passing it through a narrow slit into an acidulated glycerine bath which causes it to

coagulate. Such sheets may be dyed any color, printed, or cut into desired forms.

Or the viscose solution may be further treated by spinning it into filament form.

252. *Preparation of spinning solution.*—Cellulose xanthate is mixed with a dilute caustic soda solution until the mixture contains 61 percent cellulose and 8 percent caustic soda. Several batches are then run together in order to produce a uniform mixture. The viscose solution must be ripened, a process which takes 4 to 5 days. During this period, the solution is filtered so that all particles which might later clog the minute holes of the spinnerets are removed. This is accomplished by pressing it through a cotton wool or through woven or knit cloth. Lastly, all air bubbles must be removed from the viscose solution. This is done by subjecting the solution to a vacuum for 24 hours or more. The viscose is then ready for the spinning operation.

253. *Conversion into filaments.*—Through a pipe system the viscose solution is brought to the spinning machine. It is forced through holes in spinnerets either with direct air pressure or by means of hydraulic pumps. Spinnerets are cups usually made of platinum or other precious metal alloys and have from 1 to 1,000 holes per cup. The solution is passed through these holes into a coagulating bath which renders the molecules in solution immovable, thereby effecting a filament structure. The holes in the spinnerets may produce filaments of the exact diameter desired. Or they may be somewhat larger, in which case the filament is passed into a mildly coagulating bath where it is stretched to lessen its diameter during the process of gradual coagulation. Sometimes the complete coagulation takes place in this mild bath and sometimes the partially solidified filament passes to a more powerful bath for final coagulation.

254. The coagulating bath preparation is basically sulphuric acid. Sodium sulphate, zinc, and ammonium salts, are sometimes added. Manufacturers endeavor to keep secret the exact composition of this bath preparation.

255. *Spinning and cleaning the filament.*—These filaments are gathered up centrifugally and are wound about rapidly turning spools, reels, or bobbins on different types of spinning machines. Some twist is imparted to the filament in this process. As the threads still are in a semigelatinous condition, the bobbins are immersed in water which is pulled through them by suction. The rayon is then dried in heat-insulated chambers having careful humidity and temperature controls. A part of the moisture removed in drying is cooled and used again in order to facilitate the later spooling and twisting operations.

256. *Thread manufacture.*—From this point, machine operations are similar to those used in silk-yarn manufacture. The single filaments are twisted together to form threads. Threads are reeled into skeins for bleach. Before bleaching, however, remaining sulphur must be removed by treatment with an aqueous solution of sodium sulphide.

257. *Bleaching and finishing.*—Rayon skeins are bleached with either sodium or calcium hypochlorite containing about 1 percent available chlorine. The skeins are soured in a weak solution of hydrochloric acid and then washed thoroughly. When water has

been extracted, skeins are hung on frames and pass through a continuous drier. After sorting into grades, the skeins are made up into bundles of 10 or more pounds and packed into cases for shipment.

258. *Quantities of principal raw materials used.*—Although differences in manufacturing detail necessarily bring about a varying amount of materials applied to the manufacture of a ton of rayon, the importance of several materials in the manufacture of viscose rayon are indicated by the following rough estimates of requirements:

Principal materials required in the manufacture of 1 ton of rayon:[6]

Sulphite pulp ______ tons	122
Cotton linters ______ ton	0.4
Caustic soda ______ tons	2
Carbon disulphide ______ pounds	1,200
Sulphuric acid ______ tons	1.5

THE NITROCELLULOSE OR CHARDONNET PROCESS

259. Although but 8 percent of the rayon manufactured in the United States is produced by the Chardonnet or nitrocellulose process, the cellulose nitrate made forms the basis of lacquers, photographic films, of celluloid and a number of the plastics, as well as of explosives.

260. Cotton linters serve as the raw material of this process in the United States. Wood pulp, however, was used in Germany during the World War, for the manufacture of nitrocellulose or gun cotton. Cotton linters are freed of their noncellulosic materials at the chemical plant by a treatment with caustic soda. After bleaching in a sodium hypochlorite solution, souring, washing, and drying, they are ready for nitration.

261. *Nitration of cotton.*—The solution necessary to nitrate cotton will vary in exact consistency from plant to plant and according to the final product desired. It may be made up of nitric acid, sulphuric acid, and water, in approximate proportions of 33 percent, 58 percent, and 9 percent, respectively. About 1,600 pounds of solution is applied to 35 pounds of bleached cotton. The time allowed for chemical reactions to take place varies from 15 minutes to 1 hour, depending upon the use to which the nitrate is to be put. Cellulose to be dissolved is not nitrated as long as is cellulose to be used as gun cotton. At the proper time, the mixture flows from the reaction pots into a centrifugal machine where acid is squeezed out to be used again in producing the new solution. The cotton is washed in cold water and then boiled to remove all free acid; soda ash may be added to aid in this process.

262. *Finishing.*—The matted material must next be reduced to a fibered pulp, which is accomplished by the revolving cutters of a shredding machine. Each fiber is then freed of remaining traces of free acid or of unstable nitrated decomposition products by a long boiling in slightly alkaline water. After a final washing the material from several batches is blended to secure an even mixture.

263. If the nitrated cellulose is to be shipped, it is dehydrated by forcing denatured alcohol under pressure through the wet cotton. Because the nitration of cotton carries with it a high explosion hazard, the manufacturers of lacquers and plastics usually buy their cellulose nitrate. Rayon plants carry on the nitration as well as the filament processes in the same factory. The further treatment of cellulose nitrate for rayon will, therefore, be considered first.

[6] Chemical quantities are given by Mois H. Avram in The Rayon Industry, 1929.

TRANSFORMING CELLULOSE NITRATE INTO RAYON

264. The nitrate is first removed from the cellulose nitrate by dissolving it in alcohol and ether. The proportions used in the solvent solutions as well as in the solvent mixture depend upon the type of spinning to follow. For wet-spinning, only 10 percent cellulose nitrate is desirable, while about double the amount is essential for dry spinning. Only a little ether is present in the first nitration type of spinning while it may constitute 60 percent of the solution used for drying spinning filament. The final solution is deaerated and forced by hydraulic presses through cotton and silk filtering cloths into pipes feeding the spinning machine.

265. *Spinning.*—In dry spinning, the solution is forced through spinnerets into air instead of a coagulating bath as in the viscose process. The ether evaporates and then nitrate containing cellulose hardens into filaments as soon as it is passed into the air. In wet spinning, the filament falls into water which dissolves the alcohol-ether content. In either case, solvents are recovered. The twisting and spooling processes are similar to those used in the viscose process.

266. *Denitration.*—The cellulose nitrate thread is highly inflammable and it is essential that the nitrate be removed before use. Usually a sodium hydrosulphide treatment is given the skeins, which are then washed, bleached, and dried in the usual manner.

TRANSFORMING CELLULOSE NITRATE INTO PLASTICS

267. Camphor is the principal chemical which converts the cellulose nitrate into a plastic material. When camphor is mixed with twice the amount of pulped nitrate the dissolved product is pressed into cakes, dried, and made into molding powder or into sheets, rods, or tubes. It may be mixed with aniline dyes or metallic pigments to produce any color. And when heated it may be pressed into any shape; or it may be turned, carved, ground, or bent into any form. It enters into many articles such as films, unshatterable glass, toilet articles, toys, pens, umbrella handles, and other "trade ware."

268. When manufactured into film, the cellulose nitrate acts as a backing for the gelatin coating. In glass manufacture, a sheet of cellulose nitrate is interposed between two sheets of glass. On the glass is sprayed a gelatinous cement or resinous lacquer which is dried. The cellulose nitrate may be put between the glass and fastened in place with tamplets, the whole placed in a sealed bag and subjected to heat and pressure. Or an intermediate bonding solution may be used to soften the plastic sheet and the lacquer coating on the glass before the three sheets are put into the press.

TRANSFORMING CELLULOSE NITRATE INTO LACQUERS

269. In the manufacture of lacquer, nitrated cellulose is mixed with resin, pigments, and a plasticizer and then dissolved in a mixed solvent. Dr. Stanley Smith gives the following formula of a well-known American lacquer:

	Parts
Cellulose nitrate	12
Resin (dammar)	8
Pigment	15
Plasticizer (castor oil and diethyl phthalate)	8
Solvent (made up of 50 percent butyl acetate, 15 percent alcohol, and 35 percent toluol)	100

270. A jet-black enamel formula quoted by Samuel P. Wilson [7] is as follows:

Cellulose nitrate or other lacquer cotton	4 parts 6 ounces.
Pigment	1. 75 parts.
Ester gum solution	0. 5 part.
Butyl acetate	0. 5 part.
Acetone	0. 5 part.
Tricresyl phosphate	0. 75 part.

THE ACETATE PROCESS

271. Like cellulose nitrate, cellulose acetate is used for purposes other than fiber manufacture. It was applied extensively to airplane wings during the war to give them a protective coating and is used in coating metals, to make photographic films, unshatterable glass, lacquers, molding powders, and transparent wrappings.

272. *Acetation of cellulose.*—Today, cotton linters are used as the basic cellulose material in this process. These are purified as in other processes by kier boiling. They are then treated with acetic anhydride in the presence of sulphuric acid, phosphoric acid, or some other chemical which aids in the synthesis of cellulose and acetic acid without entering into the combination. Acetic acid as such is too weak to unite with the cellulose to form the ester; therefore, acetic anhydride and a catalyst are used although acetic acid may be present in the solution.

273. In practice about 100 parts of cotton cellulose, 400 parts of acetic acid, and 10 parts of sulphuric acid are mixed and placed in a vessel which holds the temperature below 30° C. Four hundred parts of acetic anhydride are added while the mixture is agitated. To dissolve the cotton requires 12 or more hours at this temperature.

274. *Precipitation and purification.*—Cellulose acetate may be dissolved in chloroform. To make an acetone-soluble cellulose acetate, such as is used in rayon, the solution is thinned with acetic acid and water and allowed to stand. After desired solubility is obtained the cellulose acetate is poured into water, at which time the acetate is precipitated. The mixture is filtered and all uncombined acids are washed away. It is then carefully dried.

TRANSFORMING CELLULOSE ACETATE INTO RAYON

275. *Spinning solution.*—With acetone-soluble cellulose, the dried cellulose is placed in a closed mixer containing acetone and agitated until completely dissolved. It is then filtered, blended, and de-aerated.

276. *Spinning operation.*—The cellulose acetate solution is forced through spinnerets as in other rayon operations. In dry spinning, the spinneret is at the top of a narrow air chamber through which hot air is circulated. This warm air evaporates the solvent, leaving the cellulose acetate in filament form. The filaments are gathered upon a bobbin as in spinning viscose and after being twisted and wound are ready for the market without any further treatment.

277. *Quantities of raw materials consumed.*—Successful cellulose acetate plants are very secretive concerning the details of their processes. Rough estimates place the consumption of materials at the

[7] Wilson, Samuel P., "Pyroxylin Enamels and Lacquers."

following figures: Per ton of acetate rayon produced, 1.35 tons cotton linters are required which are treated with caustic soda and bleached in sodium hypochlorite. For acetation of the cellulose, 3 to 4 tons acetate anhydride, 200 pounds sulphuric acid, and 3 to 4 tons acetic acid are applied. The acetone solvent required totaled 4 to 6 tons per ton of acetate rayon; in actual practice less new acetone is used, as much is recovered from the air of the spinning by refrigeration or by absorption.

278. *Transforming cellulose acetate into plastics.*—Cellulose acetates may be applied to any manufacture for which cellulose nitrate is suitable except, of course, gun cotton. Usually benzol and alcohol are the solvents used to reduce it to a plastic substance. Other chemicals are added to impart specific qualities in the product, while pigments and filling materials may be used to produce the desired products. As it has been more expensive than the nitrate ester it has been substituted only where the explosive quality of the nitrate has proven hazardous. Motion-picture, X-ray and other films are being manufactured by use of acetate sheet as a backing. Its high dielectric quality makes it a valuable coating for electric insulation.

279. *Cupra-ammonium process.*—While cotton linters are most frequently employed in this process, wood pulp and cotton waste have been used successfully. The linters or pulp are purified and bleached in the same manner as for other processes. The solution to be used on the purified cellulose is made up of metallic copper or copper sulphate, caustic soda or soda ash, and ammonia.

280. *Preparation of the solution.*—When metallic copper is employed the solution is made by the action of ammonia on the metal in the presence of air. The copper hydroxide formed is dissolved by the ammonia. When copper sulphate is the basic constituent, it is precipitated by caustic soda or soda ash, washed free of salts and then dissolved in ammonia. The cupra-ammonium solution together with a small amount of caustic soda and the cellulose is agitated in a mixer until all cellulose is dissolved. The mixture is forced, by means of compressed air, through a filter press provided with very fine screening, in order to free it of all foreign matter.

281. *Spinning the solution.*—In this process, coagulation of the filament takes place in a caustic soda or a sulphuric acid bath. The alkali bath produces a stronger and less brittle liquid. Because this process is usually employed to produce very fine filaments, the 2-bath formation with a gradual stretching of the thread is employed. (See p. 367.) After winding on a bobbin or reel, the copper is removed from the rayon by a bath in dilute sulphuric or hydrochloric acid. Washing and drying follow as in the viscose process. The textile operations are the same.

282. *Recovery of metal.*—Efforts are made to recover the copper and the ammonia employed in this process. If caustic soda has been used in the coagulating bath, ammonia may be evaporated from the spinning waste and copper recovered by electrolysis. When sulphuric acid is employed in the bath, bars of iron suspended in the bath will recover the copper.

283. *Zinc-chloride process.*—This process is quite distinct from the four other methods of treating cellulose and its finished cellulose product does not compete with them in their respective markets. The cellulose so treated is used in the electrical field for spacing blocks

and radial segments, slat wedges, fuses, bases, tubes, and other mechanical purposes. It is called "vulcanized fiber" and finds competition chiefly from bakelite, a phenol-plastic.

284. The raw material employed is rags. These are cut up, boiled, washed, and beaten into pulp. The pulp passes through paper machines which form it into sheets, dry and roll it. These sheets are soaked in solutions of zinc chloride for extended periods. After this process is complete, sheets are air dried, flattened in steam-heated hydraulic presses, and hung for seasoning. They are cut up into rods and tubes.

285. *Other processes.*—Firms, both in this country and abroad, maintain research staffs which are engaged in perfecting present processes and in pure scientific research on cellulose. It is reported that the Franco-German Co. of France is treating cellulose with butyric acid but commercial production has not been announced as yet.[8]

Power Requirements in Rayon Manufacture and in Manufacturing Raw Materials for Rayon

POWER USED IN RAYON MANUFACTURE

286. The power requirements for rayon manufacture itself are entirely for mechanical operation of the machinery although process and conditioning steam is also necessary. Consequently, plants supplying their own power have usually installed steam turbines, in the past. These generate all electric power and are bled for necessary steam. But a number of plants find it convenient to purchase current where a 24-hour supply is available at a reasonable rate. The following table shows the power equipment in mills operating in 1927:

TABLE XX.—*Source of power supply in rayon industry* [1]

Equipment	Number	Capacity
		Horsepower
Total		155, 803
Steam engines	66	7, 228
Steam turbines	47	68, 749
Internal-combustion engines	1	10
Electric motors driven by purchased current	6, 251	46, 419
Electric motors driven by current generated in plant	4, 149	33, 397
		Kilowatts
Electric generators	26	49, 825

[1] U.S. Bureau of the Census, Census of Manufactures, 1927.

POWER REQUIREMENTS FOR CHEMICALS ENTERING INTO RAYON MANUFACTURE

287. Only when rayon is considered in terms of the chemicals entering into its manufacture does it become an industry of interest in power development.

288. *Caustic soda and chlorine.*—All pulp, whether made from wood or cotton linters, must be bleached for rayon manufacture regardless of process. This is usually done in chlorine or in sodium

[8] 1930 Rayon Year Book.

hypochlorite made by passing liquid chlorine through caustic soda. In the viscose process 2 tons of high quality caustic soda are used in the production of 1 ton rayon solution, while an additional amount is used in the sodium hypochlorite bleach of the final skeins. In the cupra-ammonium process a caustic soda bath may be used to coagulate the spinning solution. It is estimated that 115,000 tons of high-quality caustic soda were consumed in production of rayon in 1929. The manufacture of this caustic required approximately 287,500,000 kilowatt-hours of energy. While chlorine consumption in the rayon industry was much less than the consumption of caustic soda, this textile offers an outlet for a part at least of the chlorine manufactured in the process of caustic soda production.

289. *Sulphuric acid and carbon disulphide.*—The other chemicals essential to the manufacture of viscose rayon, namely, sulphuric acid and carbon disulphide, may be gotten from sulphur fumes produced in electrolytic zinc or copper plants. Carbon disulphide is manufactured by electrical heating of charcoal or other carbonaceous product in the presence of sulphur-dioxide gas. Although sulphuric acid is now used for the coagulating bath, a cheaper price on phosphoric acid might lead to a substitution of this electric furnace product. It is estimated that 145,000 tons of sulphuric acid and 33,000 tons of carbon disulphide were consumed in rayon manufacture in 1929.

290. *Nitric acid.*—Rayon made from cellulose nitrate consumed approximately one half ton nitric acid, nine tenths ton sulphuric acid, 1,080 pounds ethyl alcohol, and 1,680 pounds ether. Nitric acid is now made by the oxidation of ammonia. (See p. 149, Power in Fertilizer Material Production.)

The total nitric acid consumed was 2,700 pounds, ethyl alcohol 2,800 and ether 4,300 tons.

291. *Acetic chemicals.*—The acetate process is of importance because of its recent rapid growth and because of its possibilities in plastic manufacture. Each ton of rayon manufactured by this process required from 3 to 4 tons acetic anhydride, and the same amount of acetic acid. Estimates of the acetone requirements range upwards from 1.6 tons per ton rayon as acetone is recovered in the course of the process. In addition, about one tenth ton of phosphoric acid or sulphuric acid is required.

292. Until recently, the source of all acetic chemicals was pyroligneous acid, a byproduct of hardwood distillation, methanol being the principal product obtained. While acetic acid is gotten by treating the pyroligneous acid with milk of lime and then with sulphuric acid, when acetic anhydride is desired, it is treated with soda ash and the sodium acetate produced is acted upon by sulphur chloride. The hardwood-distillation plants ship out the sodium or calcium acetate to such chemical establishments as the Dow Chemical Co. who manufacture it into acetic anhydride and other chemicals.

293. Acetone was obtained from calcium acetate, but only 36 pounds is secured from 180 pounds of the acetate. Consequently, when Great Britain required acetone for the manufacture of her official smokeless powder, cordite, and acetone was also necessary for airplane-wing dope, efforts were made to obtain a cheaper source than the hardwood distillation product. While several plants were opened, operations ceased with the war and resumption of newer methods of manufacturing acetic chemicals have only come about

by the demands for acetates as solvents in the lacquer, rayon, and plastic industries.

294. In 1920 the Commercial Solvents Corporation at Terre Haute and later at Peoria, began the manufacture of acetone, butyl alcohol, and ethyl alcohol from low-grade corn. From 1 bushel of corn 10 to 11 pounds of mixed solvents are obtained, in the proportion of 30 percent acetone, 60 percent butyl alcohol, and 10 percent ethyl alcohol. The company is erecting a unit for the manufacture of acetic acid by the Langwell process. Farm waste of various kinds will be fermented and while butanol and acetone will be gotten first, the residue will be used for acetic acid. Waste hydrogen and waste carbon dioxide gases from the fermentation process yield methanol.

295. The Niacet Chemical Corporation, in 1928, began the manufacture of acetic acid from acetylene at Niagara Falls. Acetylene is obtained by placing calcium carbide in water, 1 ton of calcium carbide requiring over 3,000 kilowatt-hours of energy. As off-grade carbide can be used for acetic-acid manufacture, this is a valuable product from the viewpoint of the calcium-carbide manufacturer. (See p. 432 of The Original and Sane New Electric Furnace Products.) Research has been under way to produce acetylene from methané of natural gas but as yet efforts are still in the experimental stage. It is also reported that an electro-deposition of petroleum oils is being attempted.

296. Germany is stated to digest wood much in the same way as it is done for pulp manufacture to produce her acetic acid.

COST OF RAYON PRODUCTION

297. *Labor costs.*—Large American rayon factories not only produce rayon skeins by a chemical process, but carry on such textile operations as will render the threads in condition for the knit-goods manufacturer or the weaver. European firms usually ship rayon to this country in skeins, which must be dyed, twisted, and wound on cones, quills, cops, or spools by "converters" or rayon throwsters before reaching the knitting or weaving mill.

298. It is these textile operations that make labor costs such a large item in rayon production. The textile operations and inspection are done chiefly by women. The number employed varies with the fineness of the thread produced and is variously given as 350 women and 500 men in a 5-ton-a-day rayon mill to 1,000 employees in a 3-ton-a-day mill. This labor is, however, semiskilled. Rayon mills built in Tennessee and Virginia chose sections near small towns where there was no industry competing for semiskilled labor. They drew in mountain people from the mountains and the small towns and trained them to the industry.

299. The prevailing hours for men are 51, for women 49 per week; the prevailing wage scale is $0.50 an hour for men and $0.35 an hour for women. This data was procured by the United States Bureau of Labor Statistics from 21 rayon mills in 1930.

300. Even at these rates, it is estimated labor costs form from 40 to 50 percent of total costs; and engineering and administrative forces add another 10 percent to the salaries and wages roll.

301. *Raw materials.*—Raw materials represent the second item of cost, figured roughly at 25 percent of the total cost. Sulphite pulp and caustic soda are, of course, the chief items entering into this cost. Power, water, and coal are figured at 6 percent of total cost.

302. *Capital costs.*—Estimates vary greatly as to capital costs of a rayon plant. One engineer places the figure at $3,000,000 for a 3-ton-a-day plant; another places it at about the same figure for a 5-ton-a-day plant. The investment in equipment is heavy, although only the spinning machine represents a departure from regular chemical or textile equipment. Rayon machinery is usually charged off at 15 percent; engines, boilers, etc., at 10 percent.

303. The cost of manufacture of rayon in 1928 in a small plant of 1,000-ton yearly capacity was $0.894. This included selling cost. The average selling price during the same period was $1.15 a pound.

Development and Control of Industries

304. The cellulose-nitrate or pyroxylin plastic industry began in the United States with the establishment of a factory at Newark, N.J., in 1872. The rayon industry was first established in France in 1884, in Germany in 1890, and in England about 1900. The first rayon plant in the United States was established in 1910 at Marcus Hook, Pa., by an English company. As a consequence, while the cellulose plastic industry has developed as an American industry, the rayon industry has been built up in the United States largely by foreign companies operating under foreign patents. Cellulose lacquer had been used prior to the World War but the industry developed only after the close of the war when lacquers of low viscosity and high nitrocellulose content made possible their extended application.

CELLULOSE PLASTICS

305. *Pyroxylin.*—From its inception, pyroxylin, or cellulose nitrate, easily molded and shaped, has found extensive use. Today, there are only four firms manufacturing the basis material—that is, cellulose nitrate or "pyroxylin" as it is known in the trade. This is made up into sheets, rods, and tubes, part of which are fabricated into final marketed form in the original plant and part offered for sale to other manufacturers. In 1929 the total production of these four firms was 25,283,235 pounds, of which 4,856,625 pounds were consumed in the same establishment and 20,426,610 pounds, having a value of $18,063,154, offered for sale to manufacturers of toys, dolls, tooth brushes, fountain pens, combs, hairpins, brushes, and numerous other articles. Safety glass is the latest use of cellulose nitrate. A thin sheet of this material is placed between two sheets of glass and pressed together. This may be built up until bullet-proof glass is attained. In 1929, about 1,250 tons of pyroxylin sheeting was consumed in laminated-safety-glass production. The du Pont de Nemours Co. is the largest manufacturer of cellulose nitrate.

306. *Competitive products.*—Cellulose nitrate for plastic uses has been in competition with phenolic plastics, such as bakelite, for a number of years. Until recently, these phenolic plastics could only be manufactured in tones of amber, brown, and black, and were used chiefly for industrial purposes in telephone sets, radio tubes, and caps, and in other electric switches and plates. In 1931, however, comes the announcement that these synthetic plastics are to be produced in pastel shades and may, therefore, enter a number of fields now held by pyroxylin or cellulose-nitrate plastic. Urea formaldehyde plastics are

entering into table and household ware. Casein formaldehyde compounds have also reached the stage of active competitors in the plastic field.

307. *Cellulose nitrate.*—But cellulose nitrate plastics are threatened from another cellulose plastic—that is, cellulose-acetate plastic. The acetate plastic is nonexplosive and, therefore, possesses a great advantage over the nitrate. It was first made in this country in 1909 by the Eastman Kodak Co. for use as a film base. This firm is the largest producer of cellulose-acetate plastic today, the product being made at its plant in Kingsport, Tenn. But it has only been within the last 3 years that the cellulose acetate has been produced at a price to make it available in a larger market. In 1929, molded production from cellulose acetate totaled between 750,000 and 1,000,000 pounds.

The Rayon Industry

EUROPEAN CONTROL OF AMERICAN RAYON PLANTS

308. It is stated that 80 to 85 percent of the world's rayon production is controlled directly or indirectly by three companies: Courtaulds, Ltd., of England; Snia Viscosia, of Italy; and Vereinigte Glanzstoff-Fabriken, of Germany.

309. Samuel Courtaulds, Ltd., became interested in the development of the viscose process of rayon manufacture. While development started in the Courtauld factories in England in the early part of the twentieth century, the company established a branch in the United States in 1910, the Viscose Co., by far the largest producer of rayon in the United States.

310. The dominant firm in the German rayon industry is the Vereinigte Glanzstoff-Fabriken. While this company uses the viscose process, it controls the J. P. Bemberg A.G., leading producers of cupra-ammonium rayon, and is also interested in a plant producing acetate rayon. This company has built two plants in the United States. The American Glanzstoff Corporation began operation in 1928 at Elizabethton, Tenn., producing viscose rayon, while the American Bemberg Corporation produces cupra-ammonium rayon at Johnson City, Tenn.

311. The leading French producer of rayon is the Comptoir des Textiles Artificiels which, with E. I. du Pont de Nemours & Co., formed the Du Pont Fibersilk Co. in 1920. Later, this became the Du Pont Rayon Co. with present plants at Buffalo, N.Y.; Old Hickory, Tenn.; and Richmond and Waynesboro, Va. Cellulose-acetate yarn, to be produced at the last-named plant, will be made according to patents controlled by the Soie Rhodiaseta, a French company. The Du Pont Rayon Co. is considered a 100 percent American firm.

312. The Tubize Artificial Silk Co., with plant at Hopewell, Va., was organized by the Fabrique de Soie Artificielle de Tubize of Belgium to manufacture cellulose-nitrate rayon. All patent rights were purchased, however, by the American company and it now operates as an independent plant.

313. The Snia Viscosia of Italy was in part responsible for the establishment of the Industrial Rayon Corporation, of Cleveland, Ohio, and Covington, Va., but this company is now operating as an American factory under American control.

314. Other United States plants sponsored by European rayon manufacturers are:

American Chatillon Corporation, representing the Soie de Chatellon, of Italy; American Enka Corporation, representing the N. V. Nederlandsche Kunstzijdefabrick, of Holland; Celanese Corporation of America, subsidiary of British Celanese, Ltd., England.

AMERICAN RAYON COMPANIES

315. The basic patents for viscose rayon, cellulose nitrate, and cupra-ammonium rayon have expired, while some patents concerning these processes and the acetate process are made accessible to all by the Chemical Foundation. Many new patents have been taken out covering all phases of manufacture and new processes are being investigated by all large companies, so that European producers still own patent rights controlling many phases of various processes and American firms must pay royalties for the privilege of using them. However, the firm hold rayon has taken in the American market has led a number of new producers to enter the field in the last few years. While production was less in 1930 than in 1929, the manufacture of rayon in this year is listed by firms in order that new plants may be included.

Rayon manufacturers in United States in 1930

Firm name	Plant location	Process used	Estimated production, 1930 [1]
			Tons
Viscose Co.	Marcus Hook, Pa.	Viscose	22,500
	Lewistown, Pa.	do	
	Roanoke, Va.	do	
	Parkersburg, W.Va.	do	
	Meadville, Pa.	Acetate	
	Nitro, W.Va.	Cotton linters treatment plant.	
Du Pont Rayon Co.	Buffalo, N.Y.	Viscose	9,250
	Old Hickory, Tenn.	do	
	Richmond, Va. (new)	do	
	Waynesboro, Va.	Acetate	
Industrial Rayon Corporation	Cleveland, Ohio	Viscose	5,000
	Covington, Va. (new)	do	
Celanese Corporation of America	Amcelle, Md.	Acetate	5,000
Tubize Artificial Silk Co.	Hopewell, Va.	Nitrocellulose	4,925
American Glanzstoff Corporation	Elizabethton, Tenn.	Viscose	3,500
American Enka Corporation	Asheville, N.C.	do	3,000
Tennessee Eastman Corporation	Kingsport, Tenn.	Acetate	[2] 1,250
American Bemberg Corporation	Johnson City, Tenn.	Cupra-ammonium	1,000
Skenandoa Rayon Corporation	Utica, N.Y.	Viscose	1,000
Delaware Rayon Corporation	New Castle, Del.	do	875
Belamose Corporation	Rocky Hill, Conn.	do	800
Amoskeag Manufacturing Co.	Manchester, N.H.	do	750
New Bedford Rayon Co.[3]	New Bedford, Mass.	do	700
Woonsocket Rayon Co.	Woonsocket, R.I.	do	643
Acme Rayon Corporation	Cleveland, Ohio	do	483
American Chatillon Corporation	Rome, Ga.	Nitrocellulose; viscose	[4]
A. M. Johnson Rayon Mills, Inc. (new).	Burlington, N.C.	Viscose	500
The Rosland Corporation	Paterson, N.J.	Cupra-ammonium	[5]
The Furness Corporation	Gloucester, N.J.	do	[5]
Napon Rayon Corporation	Clifton, N.J.	do	[5]

[1] "Textile World", Feb. 7, 1931.
[2] Started operations October 1930. Capacity, when completed, will be 1,250 tons.
[3] Owned by Delaware Rayon Corporation.
[4] Included in Tubize Artificial Silk Co.'s figures.
[5] Production only beginning or plant still operating on laboratory scale.

316. The production of principal companies is given in the following table for the last 6 years.

TABLE XXI.—*United States rayon production, by companies, from 1924 to 1929* [1] [2]

[Short tons of rayon]

Company	1929	1928	1927	1926	1925	1924
Totals	61,565	48,851	37,525	31,288	26,105	19,425
The Viscose Co	31,000	27,000	20,500	18,500	17,500	14,000
Du Pont Rayon Co	12,250	9,116	7,550	5,450	3,381	2,000
Tubize Artificial Silk Co	4,375	4,250	3,750	3,500	2,600	2,125
Industrial Rayon Corporation	2,688	2,125	1,725	1,700	1,125	1,000
Celanese Corporation of America	3,500	2,500	1,750	1,250	750	
American Glanzstoff Corporation	1,925	175				
American Bemberg Corporation	1,150	1,050	175			
Delaware Rayon Co	1,000	750	250			
Belamose Corporation	750	690	700	438	338	
American Enka Corporation	312					
Skenandoa Rayon Corporation	665	575	500			
Acme Rayon Corporation	450	370	250	200	161	
New Bedford Rayon Co	250					
American Chatillon Corporation	750					
Other companies	500	250	375	250	250	300

[1] Compiled from The Rayon Industry, by Mois H. Avram, 1929; Rayon Year Book, by Textile World, 1930; Textile World, Feb. 7, 1931.

[2] Total United States production for prior years were: 1923, 17,700 tons; 1922, 12,200 tons; 1913, 800 tons. Estimated production for 1930 is 59,500 tons.

317. *Rayon production compared with consumption.*—In 1914, we produced 1,200 tons of rayon and consumed twice as much. At the close of the World War, or in 1919, consumption had almost doubled while production increased two and a half times. From 1919 on, both production and consumption of rayon in the United States have increased steadily through 1929. But in each year consumption has exceeded production in the United States. In the latter year, we consumed 72,443 tons of the fiber, of which we manufactured 61,565 tons. While 1930 production is estimated to be less than 1929, this is to be expected in view of the lessened production in all consuming textile industries.

318. The United States consumed about 38 percent of the world's rayon and manufactured 32 percent. Its imports, therefore, amounted to over 10,000 tons. The table following lists the countries of export. It is amazing to see the number of countries prepared to supply this market with this relatively new textile material. The United States exports little rayon, although it does export some finished rayon articles.

TABLE XXII.—*United States imports of rayon in 1929 by country of origin* [1]

Imported from—	Tons [2]	Imported from—	Tons [2]
Total	10,878	Austria	200
		Belgium	185
Germany	3,227	Australia	46
Italy	2,038	British India	26
France	1,889	Hungary	21
Netherlands	1,227	Sweden	19
Switzerland	1,087	Czechoslovakia	17
Great Britain	427	Brazil	16
Japan	236	Others	12
Canada	203		

[1] Compiled from U.S. Department of Commerce, Foreign Commerce and Navigation, 1928, 1929.

[2] Includes waste, and yarns made from waste.

319. The reason for this is made obvious by a study of table XXII. In all large rayon producing European countries the production of rayon exceeds its consumption. While Italy, the world's second largest manufacturer of rayon, produces approximately 25,000 tons, she consumes but 9,500 tons. Although France manufactures 19,000 tons of rayon, she consumes but 13,600 tons; Great Britain produces 24,000 tons and consumes 21,000 tons; Germany, 22,000 tons produced and 21,000 tons consumed with exports of 9,500 tons and imports of 8,500 tons. Italy, Germany, Holland, and France are the chief exporting countries contributing about three fourths of the world's total exports. The only countries that consume noticeably more rayon than they manufacture, other than the United States, are Canada, South America, Australia, India, China, Spain, Sweden, Hungary, and Czechoslovakia.

TABLE XXIII.—*World production and consumption of rayon in 1929* [1] [2]

[In short tons]

Country	Production	Consumption	Imports	Exports
Total	194, 465	189, 768	50, 353	55, 050
United States	61, 565	72, 443	[3] 10, 878	
Great Britain	24, 250	21, 375	1, 125	4, 000
Germany	22, 000	21, 000	8, 500	9, 500
France	19, 000	13, 625	625	6, 000
Italy	25, 000	9, 500	500	16, 000
Japan	7, 000	7, 000		
China		6, 500	6, 500	
Belgium	8, 000	5, 450	450	3, 000
Spain	1, 500	3, 750	2, 250	
India		3, 750	3, 750	
Switzerland	6, 000	3, 600	1, 600	4, 000
Canada	1, 875	2, 625	750	
South America	500	3, 500	3, 000	
Czechoslovakia	2, 000	3, 500	2, 250	750
Holland	10, 000	2, 000	1, 000	9, 000
Poland	2, 750	2, 500	750	1, 000
Australia		1, 500	1, 500	
Austria	2, 000	1, 500	1, 000	1, 500
Sweden	175	1, 050	875	
Hungary	350	750	700	300
Others	500	2, 850	2, 350	

[1] Compiled from Rayon Year Book, Textile World, Feb. 7, 1930, and U.S. Bureau of Foreign and Domestic Commerce, Foreign and Domestic Commerce.
[2] Including estimate of 1928 excess production absorbed in 1929.
[3] Includes waste and yarn made from waste.

320. *The rayon market.*—The first quantitative use of rayon in the hosiery industry occurred in 1912. In the first years of the industry's expansion, hosiery took the major part of the production while plushes and cotton goods consumed about 15 percent each. Gradually its use in knit underwear expanded until latest figures indicate that about 29 percent of all rayon consumed in the United States enters into knit underwear, while 21 percent is manufactured into hosiery. Other knit goods, such as sweaters and ties, take 4 percent. The cotton industry weaves rayon into tablecloths, bedspreads, and numerous other cloths, so that it takes about 22.5 percent of our rayon, while the silk manufacturers consume 14 percent in the manufacture of silk goods, and the wool weavers 1 percent. Or, over three fourths of all rayon is consumed by knit-goods and cotton-goods manufacturers.

321. While viscose yarns have a wide market, some of the larger producers of other types of rayon have endeavored to meet specialized

demands. The first acetate rayon firm has featured fine dress materials, a nitrocelulose company has supplied the outer knit-goods market, and a cupra-ammonium rayon firm is centering on hosiery.

322. The following table indicates the consumption of rayon in the several States in the knit-goods and cotton-goods industries, as compiled from United States Census Reports. While this table accounts for only two thirds of the rayon produced, the complete figures would not change the relative importance of consuming centers. There has been a marked tendency for hosiery mills to locate near rayon-producing plants. This accounts for the growth in knit-goods manufacturing in North Carolina, Tennessee, and Virginia.

TABLE XXIV.—*Consumption of rayon by States* [1]

[Based on two thirds of the total consumption for 1927]

State	Total		Rayon used in knit-goods industry (short tons)[2]	Rayon used in cotton-goods industry (short tons)[3]
	Short tons	Percent		
Total [4]	30,741	100.0	17,339	13,403
New York	6,696	21.8	6,696	----------
Pennsylvania	5,712	18.6	2,944	2,768
Massachusetts	5,204	16.9	983	4,221
North Carolina	3,979	13.0	2,111	1,868
Rhode Island	1,914	6.2	340	1,574
Tennessee	1,086	3.5	1,086	----------
Connecticut	827	2.7	----------	827
South Carolina	798	2.6	----------	798
New Jersey	780	2.5	661	119
Virginia	753	2.5	697	56
Other States	2,992	9.7	1,821	1,172

[1] Compiled from U.S. Bureau of the Census, Census of 1927.
[2] Includes hosiery, underwear, and sweaters.
[3] Approximate.
[4] This total represents over four fifths of the total United States production for 1927, and about two thirds the total consumption for that year.

EXPORTS

323. Very little rayon yarn and thread is exported. In 1929 the total was 120 tons valued at $340,109. This was shipped principally to Mexico, Germany, and Canada, with smaller amounts to Venezuela, Cuba, and Peru. About $7,000,000 worth of rayon manufactures was exported in 1929. These consisted of dress and piece goods, hosiery, underwear, ribbons, braids, and trimmings, tapestry and drapery fabrics, etc., and went chiefly to Cuba, Canada, Mexico, Colombia, Philippines, and South Africa.

324. The table following shows the exports in detail:

TABLE XXV.—*Exports of rayon yarn and manufactures in 1929* [1]

Exported to—	Total value	Yarn and thread		Dress and piece goods, value	Hosiery, value	Underwear, value	Ribbons, braids, and trimmings, value	Tapestry and drapery fabrics, value	Other rayon manufactures, value
		Pounds	Value						
Total	$7, 222, 686	120	$340, 109	$2, 295, 355	$3, 200, 488	$407, 678	$106, 518	$81, 398	$791, 140
Canada	1, 521, 934	15	57, 199	514, 961	441, 684	48, 303	49, 089	47, 996	362, 702
Cuba	1, 135, 520	6	15, 027	480, 863	482, 142	98, 804	13, 853	5, 327	39, 504
Mexico	678, 587	42	130, 128	372, 334	34, 298	7, 761	1, 854	8, 232	123, 980
Philippines	450, 343	3	10, 518	123, 859	210, 868	2, 399	26, 221	192	76, 286
Columbia	425, 734	3	8, 981	115, 209	262, 261	25, 285	----------	1, 474	12, 524
South Africa	322, 425	(2)	69	3, 265	246, 031	70, 203	1, 368	----------	1, 489
United Kingdom	172, 601	(2)	3, 024	76, 978	66, 341	1, 054	1, 628	----------	23, 576
Australia	163, 090	1	10, 667	56, 189	70. 074	423	5, 997	5, 377	14, 363
Panama	161, 049	(2)	359	34, 958	80, 299	22, 972	108	752	21, 601
Guatemala	125, 925	1	3, 575	62, 437	46, 045	3, 288	----------	913	9, 667
Netherlands	100, 253	(2)	125	3, 119	95, 835	955	----------	196	23
Egypt	99, 582	----------	----------	215	98, 417	112	----------	----------	838
Argentina	94, 262	(2)	2, 894	9, 918	51, 737	24, 760	----------	1, 028	3, 925
Veneztuela	93, 539	8	19, 893	29, 615	36, 741	1, 498	----------	----------	5, 792
Peru	55, 142	6	20, 643	2, 386	27, 203	921	25	1, 705	2, 259
Germany	54, 596	28	42, 087	1, 411	2, 405	42	2, 317	320	6, 014
China	32, 767	(2)	1, 750	1, 610	21, 364	6, 411	108	----------	1, 524
Other countries [3]	1, 535, 337	3	13, 170	406, 028	926, 743	92, 487	3, 950	7, 886	85, 073

[1] Compiled from U.S. Department of Commerce, Foreign Commerce and Navigation.
[2] Less than 1 ton.
[3] Principally to Central America, West Indies, and Jamaica, Java, and New Zealand, British India, and Syria.

THE CELLULOSE LACQUER INDUSTRY

325. *Production.*—Nitrocellulose lacquer production has increased over 400 percent since 1914. The growth of this industry is shown by the following data taken from the United States Census of Manufactures and from estimates of Chemical and Metallurgical Engineering:

Total production

Year	Gallons	Value	Year	Gallons	Value
1914	852, 571	$1, 308, 796	1925	12, 265, 206	$27, 254, 796
1919	500, 061	923, 464	1927	30, 836, 168	60, 269, 673
1921 [1]	1, 409, 280	3, 093, 862	1929 [2]	41, 000, 000	----------
1923 [1]	3, 255, 857	6, 944, 366			

[1] Not strictly comparable with figures for 1925 and 1927. Does not include data for "thinners."
[2] Estimated.

326. Unlike the plastic industry, cellulose lacquers are manufactured by a number of firms. These firms buy the nitrocellulose and mix it with camphor and various solvents and pigments to produce quick-drying nitrocellulose lacquers. As these lacquers replaced the oleoresinous varnish and varnish enamels for automobiles and other finishes, their manufacture has been largely taken up by paint and varnish manufacturers since 1921, following upon the initial success of firms manufacturing the nitrocellulose and the lacquers.

327. The principal nitrocellulose lacquer producing States are New Jersey, Michigan, Ohio, and Illinois, although substantial production occurs in all sections of the country.

TABLE XXVI.—*United States production of cellulose lacquers in 1927 by States* [1]

State	Total		Lacquer enamels		Clear lacquers		Lacquer thinners	
	Gallons	Value	Gallons	Value	Gallons	Value	Gallons	Value
Total	30, 836, 168	$60, 269, 673	10, 757, 852	$30, 187, 332	7, 738, 079	$15, 721, 249	12, 340, 237	$14, 361, 092
New Jersey	8, 962, 312	18, 436, 769	2, 825, 324	9, 197, 745	1, 943, 997	4, 382, 154	4, 192, 991	4, 856, 870
Michigan	5, 626, 573	10, 339, 650	2, 392, 794	6, 308, 494	348, 914	847, 592	2, 884, 865	3, 183, 564
Ohio	3, 674, 958	7, 043, 907	1, 409, 527	3, 302, 450	1, 070, 504	2, 326, 945	1, 194, 927	1, 414, 512
Illinois	3, 590, 000	7, 130, 965	1, 149, 252	3, 195, 974	1, 308, 920	2, 334, 039	1, 131, 828	1, 600, 952
New York	1, 791, 961	3, 738, 327	586, 456	1, 650, 482	745, 018	1, 439, 855	460, 487	647, 990
Massachusetts	1, 076, 317	1, 882, 184	120, 738	398, 575	511, 963	914, 116	443, 616	569, 493
Kentucky	913, 169	1, 455, 808			913, 169	1, 455, 808		
California	778, 706	1, 305, 072	287, 639	699, 901	160, 604	260, 671	330, 463	344, 500
Pennsylvania	767, 329	1, 523, 173	530, 351	1, 094, 445	108, 691	235, 538	128, 287	193, 190
Indiana	511, 707	1, 101, 847	121, 410	302, 060	390, 297	799, 787		
Wisconsin	298, 772	890, 543	298, 772	890, 543				
Maryland and Missouri	1, 476, 069	2, 020, 100	[2] 158, 962	538, 046	[2] 149, 527	514, 615	1, 167, 580	967, 439
Others	1, 368, 295	3, 401, 328	876, 627	2, 608, 617	86, 475	210, 129	405, 193	582, 582

[1] Compiled from: U.S. Bureau of the Census, Census of Manufactures, 1927.
[2] Missouri only.

328. *Markets.*—Nitrocellulose lacquers found a ready market in the automobile industry, where quantitative production demanded a quick-drying finish. It is estimated that the consumption of cellulose lacquer in this industry in 1929 amounted to approximately 26,000,000 gallons. Their use has been extended to rolling stock of railroads, to finishing machinery, to such household articles as refrigerators, bathroom fixtures, porch furniture, and other furniture exposed to hard wear. The expansion and contraction of wood, however, has limited its extensive use in wood finishing. Consequently, nitrocellulose lacquer is sometimes mixed with synthetic resin lacquers.

329. Competition is also growing through the development of quick-drying synthetic resin varnishes and through the electroplating of metals and coating of other materials with plastics, so that lacquers, paints, or varnishes are no longer employed on a number of articles of commerce.

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